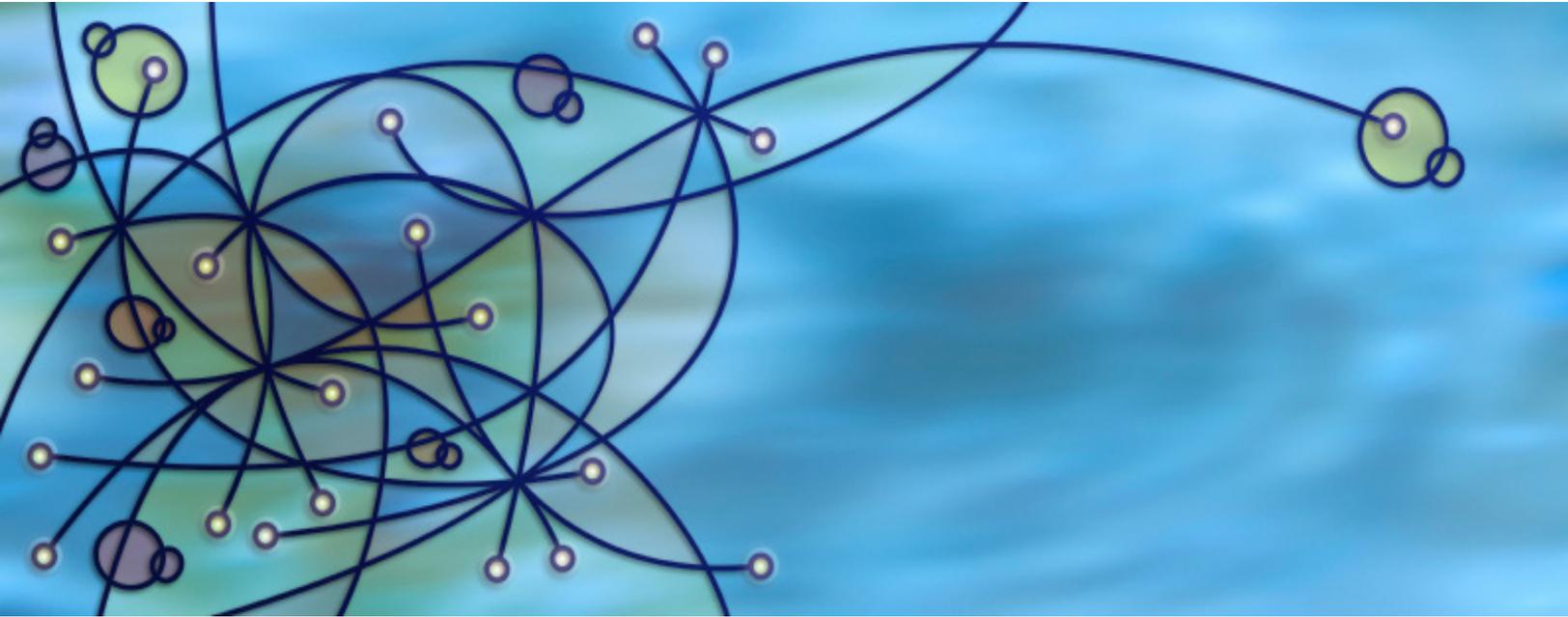


CONVERGENCE COLLOQUIA

Cultivating Serendipity for Action



Renewable Energy

October 9, 2015



Office of the Vice President for Research

UNIVERSITY OF MINNESOTA

Driven to DiscoverSM

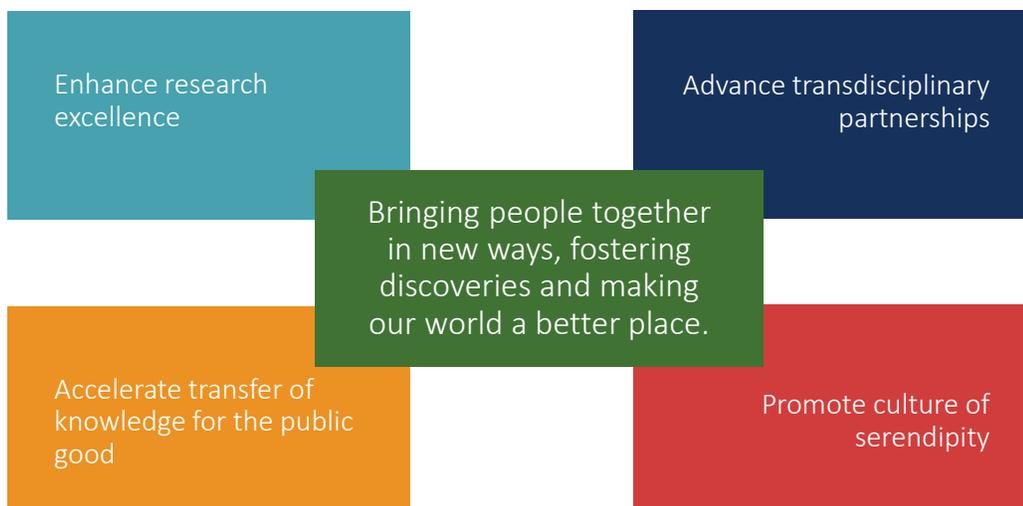
Convergence Colloquia: Cultivating Serendipity for Action

The Convergence Colloquia are a series of multi-disciplinary gatherings that advance cutting-edge research to develop innovative solutions and build long-term partnerships that improve our world. The University of Minnesota's Office of the Vice President for Research (OVP) selected the topic of renewable energy for its fourth colloquium, held on Oct. 9, 2015.

The colloquia serve as action-oriented think tanks focusing on critical issues for our communities, from building smarter cities to exploring sustainable food systems to addressing water scarcity to advancing health equity, that bring together U of M researchers with private, public and nonprofit stakeholders to identify strategic collaboration opportunities that can lead to significant impacts at the local, state, national and global scales.

The colloquia grew out of recommendations from the U of M's research strategic plan, Five Years Forward, to promote a culture of serendipity that advances scientific discovery through collaborative thinking and action. Embedded in a strategic vision and action plan, the colloquia are grounded in a results-oriented approach that includes ongoing evaluation and reflection to ensure accountability and outcomes.

FIVE YEARS FORWARD - Vision and Cornerstones



Each workshop is intended to engage approximately 75-100 participants from a variety of disciplines and fields. Through facilitated sessions and focused dialogue, participants work to identify a set of strategic research priorities and explore opportunities for collaboration. Serendipity Grants are available to support follow-on collaborative research efforts that engage U of M researchers, along with public, private and nonprofit participants.

The renewable energy colloquium engaged nearly 100 participants from the U of M and public, private and nonprofit organizations. Participants represented six colleges, the University of Minnesota Duluth and the University of Minnesota Morris, as well as university-wide and college-based centers such as the Clean Energy Resource Teams, Energy Transition Lab, the Institute on the Environment, the Natural Resources Research Institute and the Center for Sustainable Building Research. Experts from outside of the U of M included staff from numerous nonprofit organizations, more than a dozen private companies and public sector participants representing local, regional and state agencies, including the Minnesota Department of Commerce, Minnesota Department of Transportation and Minnesota Pollution Control Agency. A list of participants is included in Appendix A.

Colloquium attendees explored opportunities for collaborative research around the production, distribution and consumption of renewable energy sources, considering issues such as technology, policy, design, governance and finance. The event offered an opportunity to explore renewable energy issues at the household, neighborhood, city, industrial and agricultural scales. The event convened experts from across a variety of topic areas to explore new research collaborations that can offer insights for policy and practice.

Converging on Renewable Energy

From the international to the city scale, we are seeing increased attention to the role of governmental institutions and policy in advancing renewable forms of energy that reduce environmental and climate change impacts. Further, we are seeing increasing innovation in the renewable energy sector that is advancing the production and use of renewables from cities and homes, to industry, agriculture and transportation. New technologies are also emerging that allow us to harness renewable energy from a greater variety of sources, including but not limited to solar, wind and biomass, for a more diverse set of uses. In addition, thermal energy is receiving increasing attention in Minnesota, as communities and neighborhoods explore opportunities for new and expanded district energy systems, such as those already in place in communities like

St. Paul, Minneapolis and Duluth. As our production, distribution and consumption of energy evolves to include an even greater share of renewable sources, we have an opportunity to shape that future by addressing key issues such as access, equity, efficiency, economics and sustainability.

Based on trends in energy production, it is clear that there is transition to renewable sources in the U.S. and Minnesota. According to the U.S. Energy Information Service, about 13 percent of current U.S. electricity generation comes from renewable sources, compared with 18 percent for Minnesota.¹ One of the key drivers of Minnesota's increasing renewable energy production and consumption rates is the state's Renewable Portfolio Standard, which requires that utilities provide at least one quarter of their total electrical sales from renewable sources. Xcel Energy must provide 31.5% of their electricity sales from renewable sources.

The future of Minnesota's energy policy is also a focus of the Legislative Energy Commission's 2025 Energy Action Plan process. The planning process, funded by a grant from the U.S. Department of Energy, will be complete in late spring 2016 and is intended to "develop indicators and action plans to significantly advance a number of strategies and technologies for clean, efficient energy in Minnesota between now and 2025."² The process has included multiple stakeholder meetings to gather feedback, as well as the engagement of a stakeholder advisory committee that includes participants from the public, private and nonprofit sectors, as well as from the U of M.

Additional innovations at the forefront of renewable energy in Minnesota include efforts to engage energy utilities. The Minneapolis Clean Energy Partnership is a first of its kind agreement in the U.S. to engage a city and its electricity and natural gas utility in planning, implementing, marketing and tracking new approaches around renewable energy, as well as energy efficiency and energy choices. The Partnership, through broad stakeholder engagement and shared leadership among the three partners facilitates implementation of Minneapolis' Climate Action Plan and its 2040 Energy Vision.³ The e21 Initiative, led by the Great Plains Institute, is also engaging utilities including Xcel Energy, Centerpoint Energy and Minnesota Power, as well as other stakeholders to map the transition to new utility business models. The Initiative seeks to move utilities from revenue based on sales to compensation based on their performance in achieving goals such as increasing distributed generation, reducing carbon emissions and providing expanded options for customers.⁴

¹U.S. Energy Information Service. 2015. What is renewable energy? www.eia.gov/energyexplained/index.cfm?page=renewable_home.

²Legislative Energy Commission. 2015. Minnesota's 2025 Energy Action Plan. www.leg.mn/projects/2025.html.

³Minneapolis Clean Energy Partnership. 2015. <http://mplscleanenergypartnership.org/>.

⁴Great Plains Institute. 2015. www.betterenergy.org/projects/e21-initiative.

Community solar gardens are now also available to many utility customers in Minnesota. This option was enabled by state legislation passed in 2013. Solar gardens allow customers who cannot or choose not to install solar on their property to participate in the ownership and financial benefits of a solar installation. There is currently one active garden in Minnesota and over 40 approved applications, as well over 750 more in the application review process, totaling more than 1,400 megawatts.¹



Participants highlighted research needs and opportunities in small groups.

¹Xcel Energy. 2015. Solar*Rewards community. www.xcelenergy.com/Energy_Solutions/Residential_Solutions/Renewable_Energy_Solutions/SolarRewards_Community-MN.

Directions in Renewable Energy Research

Research funding for renewable energy has been available for many years, with federal agencies focusing on a variety of energy-related topics including energy technology, energy storage and transmission, policy, economics and environmental impacts. Climate change is increasingly connected to energy-related research. The U.S. Department of Energy's Office of Science manages multiple energy research laboratories across the U.S. and also administers research programs that align with DOE's missions around energy, environment and national security. The Basic Energy Sciences program advances discovery around new materials and new chemical processes that advance a "secure and sustainable energy future."¹ In addition to its programs on fusion energy, high energy physics and nuclear physics, DOE's Biological and Environmental Research program advances research that brings in chemistry, ecology, biology, and biogeochemistry knowledge to understand issues such as climate change impacts, advance carbon storage, and contaminant bioremediation.²

The DOE's Office of Energy Efficiency and Renewable Energy leads efforts to develop and facilitate deployment of energy efficiency and renewable energy technologies. The Office's 2016-2020 Strategic Plan and Implementing Framework outlines multiple strategic goals including:

- Accelerate the development and adoption of sustainable transportation technologies
- Increase the generation of electric power from renewable sources
- Improve the energy efficiency of our homes, buildings and industries
- Stimulate the growth of a thriving domestic clean energy manufacturing industry
- Enable the integration of clean energy into a reliable, resilient and efficient electricity grid
- Lead efforts to improve federal sustainability and implementation of clean energy solutions
- Enable a high-performing, results-driven culture through effective management approaches and processes

At the core of achieving these goals is a focus on a three-phase process of (1) applied research, (2) development and demonstration and (3) focusing on market barriers that strategically targets investments in university research, national laboratories, as well as industry.³ This phased approach suggests a consciousness of the challenges inherent in taking renewable energy innovations from research to adoption. DOE's SunShot program, started in 2011, targets funding for cooperative research, development,

¹U.S. Department of Energy. 2015. Basic Energy Sciences. <http://science.energy.gov/bes/>.

²U.S. Department of Energy. 2015. Biological and Environmental Research. <http://science.energy.gov/ber/>.

³U.S. Department of Energy. 2015. 2016-2020 Strategic Plan and Implementing Framework. <http://energy.gov/eere/downloads/eere-strategic-plan>.

demonstration and deployment projects that make solar energy cost-competitive with other forms of electricity. The SunShot program supports industry, universities, state and local governments, nonprofits and national laboratories.¹

The National Science Foundation has also been a source for research funding on renewable energy. NSF's current Energy for Sustainability program is focused on engineering research to advance sustainable electricity and fuel production. Current topics of interest in this program include: (1) biomass conversion, biofuels and bioenergy; (2) photovoltaic (PV) solar energy; and (3) advanced batteries for transportation and renewable energy.² NSF's Energy, Power, Control and Networks Program offers additional targeted funds for the design of cyber-physical systems, including in the emphasis areas of electric power systems, power electronics, battery management systems, the intersection of energy systems and other critical infrastructures, hybrid and electric vehicles and understanding the interplay of power systems with regulatory and economic structures and consumer behavior.³ NSF's recent focus on the interactions of food, energy and water systems provides a further opportunity for research on renewable energy. Emerging and future anticipated funding opportunities will focus on food, energy and water systems-based approaches that enhance our understanding, ability to predict and capacity to react to stress in the linked natural, social and built environments.⁴

Other federal agencies including, but not limited to, the U.S. Department of Transportation, the U.S. Department of Agriculture, and the U.S. Environment Protection Agency have funded renewable energy related research. Examples include recent transportation-related renewable energy research projects focused on kinetic to electric energy conversion via roadways and renewable energy production in road rights-of-way.⁵ USDA has supported renewable energy research in collaboration with the National Institute of Food and Agriculture and DOE around biomass and bioenergy, among other topics.⁶ EPA's Air, Climate and Energy Research Program has a focus on number issues at the intersection air pollution, climate change and the energy sector, including Sustainable Energy and Mitigation.⁷

¹U.S. Department of Energy. 2015. About the SunShot Initiative. <http://energy.gov/eere/sunshot/about-sunshot-initiative>

²National Science Foundation. 2015. Energy for Sustainability. http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=501026.

³National Science Foundation. 2015. Energy, Power, Control and Networks. https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13380.

⁴National Science Foundation. 2015. Dear Colleague Letter: SEES: Interactions of Food Systems with Water and Energy Systems. <http://www.nsf.gov/pubs/2015/nsf15040/nsf15040.jsp>.

⁵Federal Highway Administration. 2015. Renewable Energy in Highway Right-of-Way. http://www.fhwa.dot.gov/real_estate/right-of-way/corridor_management/alternative_uses.cfm.

⁶U.S. Department of Agriculture. 2010. Advancing Renewable Energy. [http://www.usda.gov/energy/maps/resources/brochure/\\$file/renewable_energy_brochure.pdf](http://www.usda.gov/energy/maps/resources/brochure/$file/renewable_energy_brochure.pdf).

⁷U.S. Environmental Protection Agency. 2015. Air, Climate, and Energy Strategic Research Action Plan 2016-2019. http://www.epa.gov/sites/production/files/2015-10/documents/strap_2016_ace_508.pdf.

In Minnesota, some funding for renewable energy related research has come from the Environment and Natural Resources Trust fund, administered by the Legislative-Citizen Commission on Minnesota Resources (LCCMR), with recently funded projects related to renewable and sustainable fertilizers and biomass gasification.



Rolf Nordstrom, President and CEO of Great Plains Institute, highlights the prospect of aligning utility business models with customer and public policy expectations.

¹Legislative-Citizen Commission on Minnesota Resources. 2015. <http://www.lccmr.leg.mn/>.

Exploring Opportunities for Collaborative Research

The primary focus in organizing the colloquium was to advance dialogue and networking among attendees. The discussion was informed by a series of “catalyst presentations” that highlighted big ideas and innovations related to renewable energy. Presenters explored a range of renewable energy topics, including integrating renewable energy sources into a reliable and flexible electricity grid, shaping the way renewable energy is used to meet changing customer expectations and emerging regulations, and reimagining the energy utility business model and the regulatory framework surrounding it. The presenters shared information on these and other topics and explored the preliminary research and potential collaborators needed to move the work forward. The presentations are briefly summarized on this page and the next. Presenter bios are included in Appendix C.

Catalyst Presentations

Can Renewable Energy Power Minnesota – and the World?

Ellen Anderson, Executive Director, Energy Transition Lab, University of Minnesota

The answer is found at the intersection of markets, policy, and technology, but it can only come to fruition through the engagement of leaders at all scales and across sectors. The technical and economic potential for renewable energy to meet all of our energy needs is clear, but what about the challenges? How do we integrate variable resources like wind and solar into our energy systems and electricity grid? And aren't renewable energy resources more expensive? Can renewable energy address the urgent need for equitable climate change solutions? How can a renewable energy transition happen in Minnesota and beyond?

Leveraging Opportunities: A Utility Perspective on Renewable Energy in an Evolving Industry

Amy Fredregill, Manager of Resource Planning and Strategy, Xcel Energy

Xcel Energy is projecting exponential renewable energy growth in the next 15 years- proposing over 4,000 MW of renewable energy additions across our Upper Midwest system. This poses a number of opportunities and challenges for the state's largest utility, in a time of unprecedented change in the industry at large. The future of renewable energy development in the Midwest will be shaped by the evolving policy landscape and market dynamics in the region, and will require continuing collaboration between stakeholders with a diversity of core interests. The presentation touched on the considerations in Xcel Energy's long-term regulatory strategy for renewable energy- including emerging environmental regulations such as the Clean Power Plan, changing customer expectations, emerging technologies, and the transforming utility business model- that will support over 40 percent carbon emissions reductions, while maintaining a diverse fuel portfolio, ensuring system and customer reliability, and keeping customer rates competitive.

Promoting Renewable Energy Options that are Truly Sustainable Using a Life Cycle Approach

Jason Hill, Associate Professor, Department of Bioproducts and Biosystems Engineering, University of Minnesota

Sometimes when we look at the full life cycle of an energy source commonly thought of as “renewable”, we find that it is actually neither “green” nor “sustainable.” To promote those renewable energy options that truly have environmental benefits, decision makers need information about not only supply chains but also about any market-mediated effects that may result. This requires active dialogue among stakeholders, accessible and reliable data, and the employment of analytical methods for understanding the consequences of industrial buildout. The presentation described some of the unintended consequences of prior and current pursuits to develop renewable energy and then discuss strategies for avoiding them in the future.

Catalyst Presentations (continued)

Aligning Utility Financial Incentives with Customer and Public Policy Expectations

Rolf Nordstrom, President and Chief Executive Officer, Great Plains Institute

What if utilities achieved their earnings not by selling more electricity or building capital-intensive facilities (e.g., power plants), but instead by helping society achieve an agreed-upon set of performance outcomes (energy efficiency, affordability, reliability, reduced emissions, more customer choice, etc.). Mr. Nordstrom talked about Minnesota's e21 Initiative and its broader implications and research needs. e21 has brought together the state's utilities and other key interests to re-imagine the utility business model and regulatory framework—already placing Minnesota among the top 5 states in the country examining how the electric system will need to evolve to accommodate dramatic changes in technology, customer expectations, new regulation and public policy.

Communities: Part and Parcel of Our Energy Future

Lissa Pawlisch, Director, Clean Energy Resource Teams, Regional Sustainable Development Partnerships and Extension, University of Minnesota

Energy isn't just a technical issue. It's a community issue and communities need to engage, shape and own that future. We, collectively, need to engage them in this conversation and decision making in meaningful ways. We, collectively, need to point to examples that allow individuals and communities of all backgrounds and perspectives to see themselves in this future. When we can all see energy efficiency and renewable energy projects as part of our daily lives, they feel less foreign, less "alternative," less other. We start to see ourselves as part of that future – a common future. How can we, collectively, make this happen?

Grid Modernization with a Focus on Distribution Systems – Building a Minnesota Conversation

Matt Schuerger, President, Energy Systems Consulting Services, LLC

Today's interconnected electric grid is reliable, affordable, and increasingly clean. In recent decades, much progress has followed the development, through federal actions, of wholesale markets and regional transmission systems. Evolving public policy, changing consumer demands, and new distributed energy technologies (both supply and demand side) are driving further modernization of the grid. Focus is shifting to develop and incorporate progress in local distribution systems at the retail level through state activities and actions. This presentation described the transition to tomorrow's integrated electric grid that will be more distributed and flexible; will optimize and extract value throughout the grid; will operate resiliently against natural disaster and attacks; will be cleaner, reliable, and affordable.

Unlocking the Potential of Efficiency and Renewable Energy through System Integration

Ken Smith, President and CEO, Ever-Green Energy and District Energy St. Paul

According to the UN, cities account for over 70 percent of global energy use and 40 to 50 percent of greenhouse gas emissions worldwide. In many cities, the heating and cooling of buildings accounts for up to 50 percent of local energy consumption. Often times the conversation and efforts to expand the use of renewable energy focuses on the electricity and transportation sectors. The presentation described how using a holistic approach to planning and design of infrastructure and buildings in cities unlocks the potential of efficiency and renewable energy.

Implementing Renewables in Practice: Re-inventing Tools, Rules and Joules

Elizabeth Wilson, Professor, Humphrey School of Public Affairs, University of Minnesota

Creating a low-carbon and sustainable electric system to respond to climate change and meet societal energy needs requires different technologies and changes in supporting policies and institutions. Many new low-carbon energy technologies like wind and solar are variable and integrating them into the electric grid requires new technologies, policies, and changes in how the grid operates. But changing the rules underpinning how the electricity system works requires coordinated interaction across many different stakeholder groups and multiple levels of governance. This presentation outlined different processes of policy implementation and examined the ways in which renewable energy resources are changing the operation and markets of the electric grid. Renewable resources and policy implementation decisions are shaping the use and value of new and existing energy technologies and, in doing so, transforming the energy system.

Key Questions and Potential Collaborations

Informed by the catalyst presentations, participants were invited to participate in small group discussions. The discussions focused on a set of questions about renewable energy that participants identified and expressed interest in exploring with others. A portion of the questions were identified at the meeting and others were identified from responses to a brief pre-survey completed when registering for the event.

Participants had the opportunity to self-select to table discussions that interested them and could participate in two rounds of discussion. For their table question, participants were asked to explore three issues: (1) new insights or information needed to answer the question; (2) key assets (e.g. data, technology, expertise) that can be drawn upon to answer the question; and (3) new or existing collaborations that could be tapped to advance research on the question, including specific recommendations of stakeholders who should be involved. The table discussions were engaging and free-flowing. Key insights from the table discussions are highlighted below.

1 *How can business model innovation be applied to accelerate development and deployment of renewables?*

Participants noted a need to understand and catalog the barriers hampering energy innovation, the sources of capital that can fund development and where the opportunities are for Minnesota to become a renewable energy leader. Businesses and innovators must come together to pool existing data sets and forecast what will be needed in the future, rather than the present. Collaborative groups will be instrumental in this effort, including Minnesota's e21 Initiative and the Minnesota Public Utilities Commission.

2 *As renewable energy projects are increasingly located in and near urban/suburban areas, how can communities adapt to them?*

The discussion revolved around the need for tracking the age and replacement needs of energy infrastructure. Community engagement will be an important part, to educate those affected about renewable energy, explain current energy costs and find out where energy is being wasted. In approaching this issue, participants should reference past examples of communities and building owners adapting to renewable energy, as well as resources like city planning approaches and solar mapping tools. Collaborative opportunities include working with the Metropolitan Council in developing workshops, and the project will require a convening and coordinating entity to gather disciplines together and to pursue work with communities.

3 *What is the role of biomass in renewable energy technology and economies?*

In addressing this question, participants noted a need to define what forms biomass takes and the various economic and emissions qualities of each. Better understanding the role of biomass would require a deep understanding of the effects of using biomass instead of coal, including the costs that are required for production and cleanup. Opportunities for collaborations include energy corporations and manufacturing industry leaders.

4 *How can we best leverage renewables for heating at the site, community, district or utility scales?*

Participants noted a need to discover local opportunities for redevelopment and to model the economic value of implementation through demonstration projects. To move forward on the project, collaborators must find out the age of infrastructure across the state, share case studies from other states and countries to understand what is possible and target existing district heat systems that could be improved. Catalyst projects can help drive engagement surrounding opportunities to develop thermal networks. A program is needed to facilitate these collaborations and raise awareness of available resources.



Lissa Pawlisch, Director of the Clean Energy Research Teams, highlighted the role of communities in advancing renewable energy.

5 ***How can we better integrate energy efficiency and renewable energy?***

In this discussion, participants indicated a need to estimate communities' energy needs, assess how these needs vary by building type and persuade consumers to see efficiency as a desirable quality on par with renewables. The group noted a need to help consumers understand the value of energy efficiency and spur behavioral change through education, policies and benchmark measurements. This effort will require the collaboration of energy companies, researchers and consumers.

6 ***How can renewable energy be used to address income disparities?***

In addressing this question, participants noted a need to engage low-income residents in energy programs, as well as to discover what others are doing to address disparities. To proceed, knowledge must be acquired of the ownership structure of buildings and the opportunities for solar thermal heating systems to replace propane in low-income housing. Equity goals must also be included in state energy policy. Potential collaborators for this issue include energy utilities, higher education institutions and the Metropolitan Council through its transit-oriented development funds.

7 ***How do we grow Minnesota's solar market beyond community solar?***

Participants noted a need for greater political support for solar energy, including in the communities that will host solar development. Education efforts are needed as well to explain the benefits to society and how community solar programs work in Minnesota. Models of renewable energy integration projects from other communities, such as those where solar panels are installed on rooftops, can inform future efforts to expand solar in the state. Future efforts will need to take into account what subsidies are available for different energy sources and arrange for incentives to encourage people to use clean, renewable energy.

8 ***How will new portfolios of energy generation place stress on grid functionality and financing the grid, and what are possible mitigation strategies?***

In this discussion, participants identified the need for forward-looking information to aid in forecasting needs, costs and policy changes, which will inform the best methods for transmitting and distributing energy on the grid. Consultants, nonprofits and national laboratories can help forecast future costs and market trends, along with data from consumer electricity meters and state and federal policies. Opportunities for collaboration exist between planners, building associations, the e21 Initiative, the state, academia and independent system operators controlling a region's electricity grid.

9 ***What are the necessary innovations in energy storage that need to be addressed to create a viable renewable energy production and distribution system?***

This discussion highlighted the need to develop technological improvements that modify renewable energy sources to add value and make these systems economically feasible. University researchers can be connected with those who know the marketplace needs to develop incentives for collaboration with industry and trade groups. Texas, Sweden and other markets will serve as case studies for this system.

10 *How do we facilitate community conversations and feedback in a nimble, adaptive manner? What's the energy story? Who gets to tell it?*

Participants discussed the need to broaden the conversation around renewable energy to involve more community members as partners in the effort. Social media and community meetings can help spread the conversation to a greater portion of area residents to find common goals. Additionally, using art, storytelling and other forms of emotional connection can help convey messages and invite further conversation.

11 *What are the best institutional arrangements for delivering district systems that communities need?*

In this discussion, participants noted a need to determine who can best assist with improving infrastructure, which would include considerations on waste heat use. Coordination with transportation, wastewater and water infrastructure systems is useful as well. Applied U of M research, along with policy change, is needed to scale up to a demonstration level. Conveying the benefits of renewable energy through storytelling in video or social media formats can help engage the community.

12 *How can Minnesota be a world leader in renewable energy in 10 to 20 years?*

Participants noted a need to identify Minnesota's assets, including its ample wind, solar and biomass resources, along with its food and agricultural strengths in major industry leaders like Cargill and General Mills. Collaboration may include partnering with industry in the areas of food, energy and water; state agencies like the Department of Commerce; and nonprofit groups like the Great Plains Institute.

13 *What mechanisms do we need to move information/data to support distributed energy systems?*

In addressing this question, participants noted a need to gather data on costs and impacts of renewable energy systems, as well as a heat map of energy use. A centralized energy data repository would allow communities to participate in energy infrastructure and programs. Assets to draw on include utility companies, state programs, the Public Utilities Commission and other organizations.

14 *How does the current natural gas situation impact renewable energy adoption?*

This discussion highlighted the need for forecasting natural gas prices and what taxes may be appropriate for gas going forward. Participants noted the need to understand both the economic and life cycle impacts of using gas-fueled heat versus renewable sources, and to find ways to deter the use of natural gas despite its low cost.

15 *What kinds of policies are needed to advance renewable energy and how can we help policymakers pass them?*

The discussion group indicated a need to communicate the value of renewable energy to policymakers, targeting those who are receptive and will play a key role in moving policy forward. Institutional knowledge and experience, as well as renewable energy forecasting, could help inform decision-makers as the need for and impacts of potential policies.

16 *How do we incorporate more life cycle analysis into renewable energy discussions?*

In addressing this question, participants identified a need to quantify the benefits of a healthy ecosystem, and to educate stakeholders on what renewable energy sources and development can and cannot do related to a life cycle assessment, where complete environmental impacts are taken into account. Tax codes, regulations, carbon pricing and more were among the considerations participants said needed to be taken into account. Facilitators must bring together consumers, producers and manufacturers to inform the life cycle assessment.

17 *How can we more efficiently consider people relative to calculating return on investment?*

In this discussion, participants noted that productivity of human workers is typically not factored into the equation, even though it is a much larger cost than energy production. It is important to engage people and convey the return-on-investment for renewable energy, as people often do not see it. Incentives such as cost savings for tenants can help spur behavioral change. Openly accessible data can assist in conducting comparative studies at the neighborhood level, creating more impetus for residents to improve. A coordinating entity will be needed to connect communities to University assets.

18 *How do we fix the disconnects between water and energy?*

Participants noted a need to correct the conventional wisdom that water is abundant, and to identify the water footprint involved in generating energy. Opportunities and barriers related to nonconventional practices must be considered, along with technologies that can reduce energy and water use. To move forward, policy discussions must include water and energy concerns to help reach the implementation stage. Potential collaborators include the Metropolitan Council and the Minnesota Department of Natural Resources.



Participants networked across sectors and disciplines.

Research Needs

The discussion summaries above reveal a variety of directions for future research, practice and policy related to renewable energy. With a diversity of renewable energy technologies available, the focus is on implementation and deployment. Research focused on barriers to implementation, such as current policies and public perceptions of renewable energy, is a key priority. Future research might address policy changes and interventions to address perceptions related to renewable energy in our electricity system, as well as at the community, neighborhood and building scales.

Addressing barriers to renewable energy deployment requires research related to energy storage and mechanisms for integrating greater volume and diversity of distributed renewable energy generation into the grid. Intersections with other systems including urban infrastructure offer another area of potential research focus as we consider opportunities around thermal energy and the integration of smaller scale renewable systems in redevelopment projects. Additional information and data are highlighted as key needs as we explore the range of impacts of renewable energy on equity and the environment. New data and better integration of data sets, potentially through a centralized repository, are also needed to forecast future needs, plan the deployment of distributed generation and reveal production potential. Priority research questions that emerged from the discussions and integrate across a number of the topics noted on the previous pages are listed below.

Priority Research Questions:

1. What are the prospects of energy storage that can ensure the further development and viability of a renewable energy production and distribution system?
2. How can we better understand the sustainability of renewable energy systems by more fully assessing the environmental impacts of renewable sources, the viability of economic models for renewable energy production and distribution and the equity of renewable energy access and benefits?
3. How can renewable energy integrate with district energy systems at multiple scales, as well as with urban infrastructure?

Across many of the key questions and priorities noted above, greater collaboration is essential. There are already strong intersections across the public, private and nonprofit sectors. Building on the momentum and capacity gained through recent successes in expanding renewable energy production in Minnesota, research has the potential to evaluate factors that have been critical in making progress and also to reveal the new opportunities. Research that is conducted with close collaboration between academics and practitioners will position Minnesota for further leadership and innovation in renewable energy.

Colloquium Outcomes and Next Steps

The Renewable Energy Convergence Colloquium offered a valuable opportunity to build new networks and enhance existing connections among the range of researchers and practitioners working on renewable energy issues. The event explored environmental, economic and community impacts of integrating renewable energy sources and spurred new collaborations that position Minnesota to become a leader in the transition to renewable energy. The interactions and conversations helped enhance existing networks and expanded the conversation about future priorities in renewable energy research and practice.

A post-event survey, completed by 46 percent of the participants, revealed very favorable reactions to the colloquium. Of those who responded to the survey, 98 percent strongly agreed or agreed that the event provided opportunities to meet people outside of their discipline and more than 98 percent indicated that it allowed them to meet people from both within and outside of the U of M. About 60 percent noted that they met five or more new people at the event, with 38 percent of the remaining respondents indicating they had met three to four new people. Almost 98 percent of the respondents agreed or strongly agreed that the colloquium provided productive opportunities for interaction among participants and 90 percent noted that the event revealed new prospects for engaging U of M and external partners. Over 92 percent expect to collaborate in the future with one or more people that they met at the event. Finally, 80 percent of respondents indicated an interest in participating in a follow-up event.

As noted earlier, attendees of each of the Convergence Colloquia are eligible to apply for Serendipity Grants to support the formation of and capacity building for new collaborative research teams. Qualifying research teams are required to engage diverse disciplinary perspectives and integrate U of M experts with those from the public, private and/or nonprofit sectors. Eleven proposals, engaging more than 60 unique

participants, were submitted following the Renewable Energy Convergence Colloquium. Proposal participants include faculty and researchers from multiple disciplines and from five U of M Twin Cities colleges, plus the U of M Duluth and U of M Morris. Practitioners from 16 private companies, eight nonprofits and a number of public organizations at various governmental levels were included.

Proposals submitted for Serendipity Grants addressed a range of topics including but not limited to energy efficiency, building-scale energy use, advanced energy grids, energy policy, energy storage, energy data, municipal cooperative utilities, community-based renewable energy, and renewable energy from wastewater systems. Many proposals sought to expand renewable energy to new audiences through education, training, and research. Studies tended to be highly interdisciplinary focused on attending to real world issues that affect policy, technologies, and community access to information, technologies, and services. Funding decisions were announced in early January 2016.



Small group discussions highlighted new opportunities for collaboration.

Appendix A: List of Participants

Last	First	U of M Department/Center/Office	Employer
Becky	Alexander		LHB, Inc.
Ellen	Anderson	Energy Transition Lab, Law School	University of Minnesota
Eray	Aydil	Department of Chemical Engineering and Materials Science	University of Minnesota
Cameran	Bailey	Humphrey School of Public Affairs	University of Minnesota
Nora	Bateman		McKnight Foundation
Stephen	Campbell	Department of Electrical and Computer Engineering	University of Minnesota
James	Carson		RisQuant Energy
Brandon	Charboneau		All Energy Solar
Mary	Christiansen	Department of Civil Engineering	University of Minnesota, Duluth
Sarah	Clarke		Clean Energy Economy MN
Julia	Classen		Aurora Consulting
Jon	Commers		Visible City
Peter	Dahl		HGA Architects and Engineers
Emily	Dehn	U of M Foundation	University of Minnesota
Sairaj	Dhople	Department of Electrical and Computer Engineering	University of Minnesota
Julia	Eagles		Xcel Energy
Frederick	Ebinger	Clean Energy Resource Teams	University of Minnesota
Sabine	Engel	Institute on the Environment	University of Minnesota
Jim	Erkel		MN Center for Environmental Advocacy
Maram	Falk	U of M Facilities Management	University of Minnesota
Abby	Finis		Great Plains institute
Adam	Fischer	U of M Foundation	University of Minnesota
Tom	Fisher	Metropolitan Design Center	University of Minnesota
Donald	Fosnacht	Natural Resources Research Institute	University of Minnesota, Duluth
Amy	Fredregill		Xcel Energy
Lewis	Gilbert	Institute on the Environment	University of Minnesota
Richard	Graves	Center for Sustainable Building Research	University of Minnesota
Joel	Haskard	Clean Energy Resource Teams	University of Minnesota
Josh	Headlee		Accelerated Innovations
Brian	Herman	Office of the Vice President for Research	University of Minnesota
Brian	Herrmann	U of Morris Finance and Facilities	University of Minnesota, Morris
Michelle	Heyn	U of M Foundation	University of Minnesota
Jason	Hill	Department of Bioproducts and Biosystems Engineering	University of Minnesota
Patrick	Holt		MN Solar Sales LLC
Melissa	Hortman		MN House of Representatives
Alison	Hoxie	Department of Mechanical and Industrial Engineering	University of Minnesota, Duluth
Bo	Hu	Department of Bioproducts and Biosystems Engineering	University of Minnesota
Eric	Jensen		Izaak Walton League

Last	First	U of M Department/Center/Office	Employer
Jeremy	Kalin		Eutectics Consulting LLC
Justin	Kaster		2100 Advisors
Phyllis	Kennebeck		GBOC Solar
Richard	Kiesel	Natural Resources Research Institute	University of Minnesota Duluth
Arne	Kildegarde	Department of Economics and Management	University of Minnesota, Morris
Alex	Klass	Law School	University of Minnesota
Rao	Konidena		MISO
Annie	Levenson-Falk		Legislative Energy Commission
Robert	Lund		Thor Sustainability
Michael	Manore		Vispective Management Consulting, LLC
Gregg	Mast		Earthtech Energy
Laurie	McGinnis	Center for Transportation Studies	University of Minnesota
Diana	McKeown		Great Plains Institute
Beth	Mercer-Taylor	Institute on the Environment	University of Minnesota
Stacy	Miller		Minnesota Department of Commerce
Ned	Mohan	Department of Electrical and Computer Engineering	University of Minnesota
Fred	Morris		Northland Securities
Victor	Nemykin	Department of Chemistry and Biochemistry	University of Minnesota, Duluth
Peter	Neumeier		Olson Energy Corporation
Timothy	Nolan		Minnesota Pollution Control Agency
Rolf	Nordstrom		Great Plains institute
Bob	Olson		Olson Energy Corporation
Al	Onkka		Aurora Consulting
Hari	Osofsky	Energy Transition Lab, Law School	University of Minnesota
Hannah	Pallmeyer		MN Senate Energy and Environment Committee
Melissa	Pawlich	Clean Energy Resource Teams	University of Minnesota
Bret	Pence		Ecolibrium3
Shannon	Pinc		City of St. Louis Park
Randall	Porter		Geronimo Energy
David	Quinby		Stoel Rives LLP
Shri	Ramaswamy	Department of Bioproducts and Biosystems Engineering	University of Minnesota
Mike	Reese	West Central Research and Outreach Center	University of Minnesota, Morris
Stephen	Rose	Humphrey School of Public Affairs	University of Minnesota
Roger	Ruan	Department of Bioproducts and Biosystems Engineering	University of Minnesota
Matt	Schuerger		Energy Systems Consulting
Kevin	Schwain		Xcel Energy
Will	Seuffert		MN Environmental Quality Board
Tim	Sexton		MN Department of Transportation
Brendon	Slotterback		City of Minneapolis
Carissa	Slotterback	Office of the Vice President for Research	University of Minnesota
Ken	Smith		Ever-Green Energy

Last	First	U of M Department/Center/Office	Employer
Patrick	Smith		Geronimo Energy
Jamez	Staples		Renewable Energy Partners
Shane	Stennes	U of M Facilities Management	University of Minnesota
Richard	Strong	Center for Sustainable Building Research	University of Minnesota
Matt	Stupnik		Cedar Creek Energy
Doug	Tiffany	Department of Bioproducts and Biosystems Engineering	University of Minnesota
Alexis	Troschinetz	Clean Energy Resource Teams	University of Minnesota
Lise	Trudeau		MN Department of Commerce
James	Van den Ven	Department of Mechanical Engineering	University of Minnesota
Meaghan	Van der Sanden	U of M Foundation	University of Minnesota
Erick	Van Meter	U of M Facilities Management	University of Minnesota
Christopher	Villarreal		MN Public Utilities Commission
Joey	Vossen		Westwood Professional Services
Jason	Willett		Metropolitan Council
Elizabeth	Wilson	Humphrey School of Public Affairs	University of Minnesota
Marcella	Windmuller-Campione	Department of Forest Resources	University of Minnesota
Zhihua	Xu	Department of Chemical Engineering	University of Minnesota, Duluth
Becky	Yust	Department of Design, Housing and Apparel	University of Minnesota
Lisa	Zellmer		Aurora Consulting



Researchers and practitioners shared perspectives on key questions and research needs.

Appendix B: University of Minnesota Resources on Renewable Energy

The list below offers a sampling of U of M programs and centers that have the potential to connect to research on renewable energy. The list is not comprehensive, but offers valuable insights into the range of expertise and capacities for collaboration.

Center for Biorefining

<http://biorefining.cfans.umn.edu/>

The Center for Biorefining coordinates University efforts and resources to conduct exploratory fundamental and applied research; provide education on bioenergy, biochemicals and biomaterials; stimulate collaboration among University researchers, other public sector investigators, and private investigators involved in bio-based production technology development; promote technology transfer to industries; and foster economic development in rural areas. Economies at the state, national and global level depend on fossil oil, a finite and nonrenewable energy and chemical feedstock source. Finding alternative energy and chemical feedstock sources to supplement the fossil oil supply can maintain sustainable economic growth and reduce dependence on imported fossil oil. A wide range of products that are traditionally derived from fossil oil, such as fuels, materials and chemicals, can also be produced from biological resources. Biorefineries are being widely accepted throughout the world as a means to derive energy, materials and chemicals from biomass — an infinite and renewable source.

Center for Diesel Research

www.me.umn.edu/centers/cdr/

Established by the University of Minnesota Department of Mechanical Engineering in 1996, the Center for Diesel Research serves the diesel engine, automotive and the alternative fuels industries. The center specializes in the physical and chemical characterization of exhaust emissions, evaluation of emission controls, evaluation and demonstration of alternative fuels, certification of on- and off-highway engines, and the evaluation of control technology in the field. The center has unique capabilities to characterize exhaust aerosols. The center staff also has capabilities and experience in conducting and evaluating field demonstrations, conducting surveys within the diesel industry, and preparing economic evaluations/comparisons of alternative fuels and of emissions control devices. In addition to serving commercial clients, the center allows University faculty and students to develop new technology for reducing engine exhaust emissions in both confined and open environments. The center offers research and educational opportunities for engineering students, as well as outreach programs and workshops.

Center for Science, Technology and Environmental Policy

www.hhh.umn.edu/research-centers/center-science-technology-and-environmental-policy

The Center for Science, Technology and Environmental Policy at the Humphrey School of Public Affairs focuses on public issues arising at the intersection of science, technology, environment and society that shape economic development, environmental sustainability, human health and well-being. By integrating science with public policy, community action and multi-sector governance, the center advances the common good in a complex and diverse world. The center recognizes that the complexity of society's grand challenges — infrastructure for future cities, climate change, sustainable energy transitions, governance of emerging and/or disruptive technologies, and food and water security — require innovative leadership and collaboration among academia, communities, government, businesses and nonprofit organizations, anchored upon interdisciplinary and systems thinking rooted in real-world projects. The center's faculty members are widely recognized as leaders in the field and serve on scientific committees that shape environment/sustainability policies locally and globally.

Center for Sustainable Building Research

www.csbr.umn.edu

The Center for Sustainable Building Research's mission is to lead and support — through research, outreach and education — the transformation of the regional built environment to provide for the ecological, economic and social needs of the present without compromising those of the future. The center conducts and shares research, provides assistance and outreach, and educates stakeholders involved in transforming the built environment toward sustainability. The center promotes organizational excellence through effective leadership, management and the establishment of a stable, sustainable base of funding to support its work. The center also organizes and grows the research and outreach missions of the College of Design. Working with other research entities within the University, as well as public and private organizations, is a crucial part of the center, along with serving as a resource for state of Minnesota, design professions, the building industry. Complex environmental challenges can't be solved with business-as-usual thinking. The institute's approach includes discovering solutions to global grand challenges, educating the next generation of environmental leaders and engaging partners to spur collaborative change that shares Minnesota innovation with the world and grows new opportunities at home, regionally and the general public.

Clean Energy Resource Teams

www.cleanenergyresourceteams.org/about-certs

The Clean Energy Resource Teams, or CERTs, are a statewide partnership with a shared mission to connect individuals and their communities to the resources they need to identify and implement community-based clean energy projects. CERTs empowers

communities and their members to adopt energy conservation, energy efficiency and renewable energy technologies and practices for their homes, businesses and local institutions. The public-private partnership is staffed in part by the University of Minnesota Extension, which connects community needs and University resources to address critical issues in Minnesota, and the Regional Sustainable Development Partnerships, citizen-driven university partnerships fostering sustainable development. Other partners include the Great Plains Institute, Southwest Regional Development Commission and the Minnesota Department of Commerce, Division of Energy Resources.

Energy Transition Lab

<http://energytransition.umn.edu>

A strategic initiative of the University's Institute on the Environment with funding from the Office of the Vice President for Research, the Energy Transition Lab (ETL) brings together leaders in government, business and nonprofit organizations to develop new energy policy pathways, institutions and regulations. The lab is builds collaborations with these leaders to create a focal point for innovative solutions. As a land grant university, the University of Minnesota is committed to helping solve local and global "grand challenges." Through the ETL, the University's outstanding researchers and thought leaders will help our energy system transition to meet the challenges of the 21st century. The ETL focuses on energy efficiency, renewable energy, electricity and transportation systems, energy and environmental justice, and responses to climate change. The ETL aims to become the "go-to" place for outside experts and leaders to work with University faculty, students and staff toward solutions to energy challenges.

Institute on the Environment

<http://environment.umn.edu>

The University of Minnesota Institute on the Environment (IonE) envisions a future in which sustainable agriculture feeds the world; renewable energy powers the planet; every person has access to food, clean water and shelter; oceans, lakes and rivers are unimpaired; cities have vibrant economies, neighborhoods and cultures; and thriving ecosystems support thriving economies and societies. IonE's mission is to discover solutions to Earth's most pressing environmental problems by conducting transformative research, developing the next generation of global leaders and building world-changing partnerships. Complex environmental challenges can't be solved with business-as-usual thinking. The institute's approach includes discovering solutions to global grand challenges, educating the next generation of environmental leaders and engaging partners to spur collaborative change that shares Minnesota innovation with the world and grows new opportunities at home.

Natural Resources Research Institute

www.nrri.umn.edu/

The Natural Resources Research Institute (NRRI) fosters the economic development of Minnesota's natural resources in an environmentally sound manner to promote private sector employment. The institute studies the economic impact and sustainability of Minnesota's minerals, forest products, peat, biomass and water-related industries. NRRI collaborates with partners across industry, government, universities, tribes, agencies and communities to foster a sustainable, diversified economy and a healthy environment. The institute uses research to make informed economic and environmental decisions and integrated efforts to provide the range of outreach services necessary for technology development and transfer, business development and experiential learning in the context of informed environmental stewardship. The institute's values are based on the desire and right of all Minnesotans to have a reasonable standard of prosperity, choices in where they live and recreate, and the satisfaction of knowing that the state's natural resources are being well managed and protected.

West Central Research and Outreach Center

<http://wcroc.cfans.umn.edu>

Located in Morris, Minn., the West Central Research and Outreach Center (WCROC) is part of a network of Research and Outreach Centers administered by the University of Minnesota's College of Food, Agricultural and Natural Resource Sciences. For more than 100 years, WCROC has worked with researchers, students, farmers, the rural community and the public to provide applied agricultural research and education for farmers and rural communities in crop production, animal sciences, horticulture, water quality, organic dairy and renewable energy. WCROC also works with farmers, rural leaders, faculty from throughout the University of Minnesota system, other professionals from industry and academia, and citizens to provide research and educational programming to local and global stakeholders. These partnerships keep WCROC connected to the varied and changing needs of the producers and residents of Minnesota.

Appendix C: Presenter Biographies

Can Renewable Energy Power Minnesota — and the World?

Ellen Anderson, Executive Director, Energy Transition Lab, University of Minnesota
Ellen Anderson is Executive Director of the University of Minnesota’s Energy Transition Lab. The lab leverages University expertise in law, policy and many other disciplines in partnership with the public, private, community and nonprofit sectors to help solve our biggest energy challenges for the future. Anderson is also Adjunct Associate Professor with the U of M Law School and the Sustainability Studies program. From 2012 to 2014, Anderson was Senior Advisor on Energy and Environment to Minnesota Governor Mark Dayton and assisted the state Environmental Quality Board on energy and climate change. From 2011 to 2012, she was Chair of the Minnesota Public Utilities Commission. Anderson served in the Minnesota Senate from 1993 to 2011, representing neighborhoods in St. Paul and the city of Falcon Heights. Her signature legislation includes the Renewable Energy Standard and many other energy laws. Anderson holds a bachelor’s degree from Carleton College and a J.D. cum laude from the U of M Law School. She has received dozens of awards for her leadership.



Informal networking opportunities helped reveal serendipitous connections across people and ideas.

Leveraging Opportunities: A Utility Perspective on Renewable Energy in an Evolving Industry

Amy Fredregill, Manager of Resource Planning and Strategy, Xcel Energy

Amy Fredregill is Xcel Energy's Manager of Resource Planning and Strategy for the Regulatory Affairs department of NSP-MN. She is involved with Xcel's long-term regulatory strategy, including resource planning, acquisitions and utility business model transformation initiatives with stakeholders in the Upper Midwest. Having worked in the public, private and non-profit sectors, Fredregill has nearly 20 years of experience in policy, energy and environmental issues both in the Midwest and nationally. Prior to Xcel, Fredregill had served as Executive Director for the Midwest Renewable Energy Tracking System, as well as Vice President of the Cooperative Network, a business trade association, where she focused on policy issues in the energy and agriculture industries. She has also held positions as a legislative aide for the U.S. Senate and a researcher for the Minnesota Public Utilities Commission. Fredregill has travelled internationally to consult on USAID partnerships, most recently in Mexico to assist with federal energy reform. She currently serves on the board of MAP for Nonprofits and was previously appointed to the board of the Center for Rural Policy and Development. She received a master's degree in public policy and nonprofit management from the George Washington University and a bachelor's in economics from the College of St. Benedict.

Promoting Renewable Energy Options that are Truly Sustainable Using a Life Cycle Approach

Jason Hill, Associate Professor, Department of Bioproducts and Biosystems Engineering, University of Minnesota

Jason Hill is an Associate Professor of bioproducts and biosystems engineering at the University of Minnesota. His research focuses on understanding agricultural, food, energy and natural resource systems from a life cycle perspective, and exploring the environmental and economic effects of the emerging bioeconomy. Hill recently served on the National Research Council's Committee on the Economic and Environmental Impacts of Increasing Biofuels Production and its Committee on Expanding Biofuel Production. He currently serves on the U.S. Environmental Protection Agency Science Advisory Board's Biogenic Carbon Advisory Panel. He received his Ph.D. from the University of Minnesota.

Aligning Utility Financial Incentives with Customer and Public Policy Expectations

Rolf Nordstrom, President and Chief Executive Officer, Great Plains Institute

Rolf Nordstrom is President and CEO of the Great Plains Institute. He has nearly 30 years of experience in energy and sustainable development policy and practice in both governmental and nonprofit settings, including the U.S. Congress, the Executive Branch in Minnesota and non-profit organizations in the U.S. and abroad. For much of his career, Nordstrom has worked to broker agreement among disparate interests on difficult public policy issues. Nordstrom has an undergraduate degree in English literature from Carleton College and a master's degree in international environmental policy from Tufts University.

Communities: Part and Parcel of Our Energy Future

Lissa Pawlisch, Director, Clean Energy Resource Teams, Regional Sustainable Development Partnerships and Extension, University of Minnesota

Lissa Pawlisch is the Clean Energy Resource Teams (CERTs) Director for the University of Minnesota’s Regional Sustainable Development Partnerships and Extension. Over the past 12 years, Pawlisch has guided CERTs, a unique program partnership designed to connect individuals and communities to the resources they need to identify and implement community-scale clean energy projects. Her background is in geology and after an environmental consulting stint, she got her master’s in science, technology and environmental policy. Pawlisch is passionate about working directly with communities to help them understand their energy options and move projects forward. Her current focus areas include community shared solar and local government clean energy adoption.



Small groups had the opportunity to focus on questions about renewable energy production and distribution that interested them.

Grid Modernization with a Focus on Distribution Systems — Building a Minnesota Conversation

Matt Schuerger, President, Energy Systems Consulting Services, LLC

Matt Schuerger, President of Energy Systems Consulting, is an independent consultant working on power system planning and analysis and engaged in the development of new and emerging utility business models and regulatory structures. He has 30 years of experience in the utility industry, including extensive work with the reliable integration of large amounts of variable renewable energy into regional bulk and local distributed power systems. Schuerger is a licensed professional engineer with a master's degree in electrical engineering (power systems) from the University of Minnesota, a bachelor's degree in mechanical engineering from Purdue University, and an MBA from the University of St. Thomas.

Unlocking the Potential of Efficiency and Renewable Energy through System Integration

Ken Smith, President and CEO, Ever-Green Energy and District Energy St. Paul
Kenneth W. (Ken) Smith serves as President and CEO of Ever-Green Energy and District Energy St. Paul. Smith is a regular contributor to conferences, studies, legislative initiatives and task forces, and a frequent speaker nationally and internationally on energy trends, renewable energy, energy efficiency and integrated energy systems. Prior to joining District Energy in 2006, Ken worked for over 20 years consulting, designing and implementing energy projects globally for a variety of industries. Ken has an MBA from the University of St. Thomas and a bachelor's in electrical engineering from North Dakota State University.

Implementing Renewables in Practice: Re-inventing Tools, Rules and Joules

Elizabeth Wilson, Professor, Humphrey School of Public Affairs, University of Minnesota
Professor Wilson is a Professor of Energy and Environmental Policy and Law at the Humphrey School of Public Affairs at the University of Minnesota. She studies how energy systems are changing in the face of new technologies and new societal pressures. Her work focuses on the implementation of energy and environmental policies and laws in practice. Her research has also examined how stakeholders in different U.S. states view emerging energy technologies like wind power and carbon-capture and sequestration and the electric power transmission system. Her recent books include *Energy Law and Policy* (West Academic Publishing) (with Davies, Klass, Tomain and Osofsky) and *Smart Grid (R)evolution: Electric Power Struggles* (Cambridge Press) (with Stephens and Peterson). Wilson's research group is working on an NSF supported grant on decision making in Regional Transmission Organizations. She was selected as a 2015 Andrew Carnegie Fellow.

For more information, visit: research.umn.edu/convergence

Produced by the Office of the Vice President for Research.

© 2016 Regents of the University of Minnesota. All rights reserved.

The University of Minnesota is an equal opportunity educator and employer.