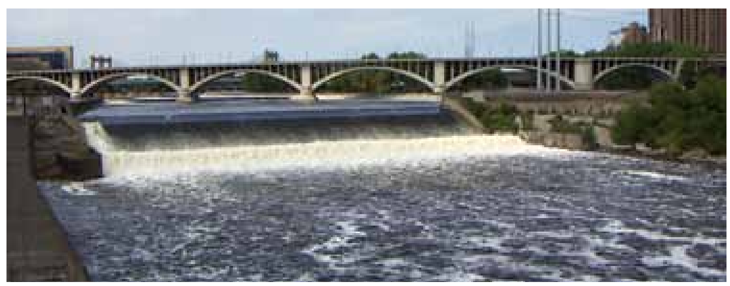
Xcel Energy
Renewable Development Fund (RDF)

Biennium Report to the Minnesota State Legislature and the Minnesota Public Utilities Commission

January 1, 2011 – December 31, 2012



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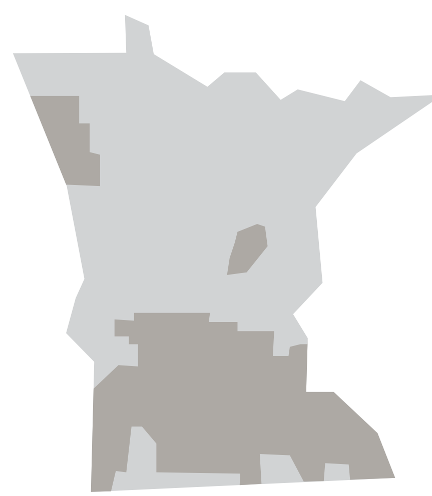
Funding for the Renewable Development Fund provided by the customers of Xcel Energy.

Xcel Energy is a U.S. investor-owned electricity and natural gas company with regulated operations in eight Midwestern and Western states. Based in Minneapolis, we are one of the largest utility companies in the nation, serving approximately 3.4 million electricity customers and 1.9 million natural gas customers through our four wholly-owned operating companies. In Minnesota, Northern States Power Company, a Minnesota corporation (NSP-Minnesota), and an Xcel Energy company, provides electricity to 1.2 million customers and natural gas to about 437,000 customers.



The Renewable Development Fund (RDF) is an NSP-Minnesota administered program mandated by the Minnesota State Legislature with oversight by the Minnesota Public Utilities Commission. The RDF's mission is to increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology.

I. Executive Summary

This 2011 – 2012 Renewable Development Fund (RDF) Biennium Report documents Xcel Energy's efforts to support the development of emerging renewable electric energy technology and reduce customer costs in the process.

Some of the most significant energy production projects during the biennium were the installation of a 9.176 MW hydroelectric facility adjacent to the St. Anthony Falls lower lock and dam along the Mississippi River in downtown Minneapolis and 87 kW of installed photovoltaic capacity at six Minnesota state parks. In total, the RDF has funded more than 21 MW of generation capacity at renewable energy facilities which has generated nearly 100 megawatt hours (MWh) of electricity during the biennium. Research activities ranged from demonstrating battery technology as a viable storage method for renewable energy, using torrefaction as a method to blend biomass with coal, and the cultivation of algae to feed on carbon dioxide (CO_2) emissions from the flue gas of coal-fired power plants. RDF funded research has expanded the knowledge base for renewable energy technologies by having eleven articles published in scientific journals and the delivery of 30 presentations before peers and industry officials during the past two years. A complete list of RDF projects that were active during the biennium is included in the appendix of this report.

Renewable power sources play an important role on Xcel Energy's electric system in Minnesota. The RDF has funded new electric power supply from wind, solar, and hydro resources. These resources work to meet customers' energy needs by:

- Diversifying our energy portfolio so we are not overly dependent on any one power source;
- Providing energy at a fixed cost without being subject to changes in fuel prices, which can be the case with power from coal and natural gas; and
- Producing clean power that helps us meet new, tougher environmental requirements, as well as renewable energy standards.

In 2012, the Minnesota Legislature amended Minn. Stat. §116C.779 affecting administration of the RDF program. These changes continued to recognize that the Commission is the appropriate entity to exercise oversight of the RDF program, given that it is funded entirely by Xcel Energy ratepayers. Highlights of the 2012 legislation are as follows:

Fund Expenditure and Minnesota Preference—Specific language was added to focus funding only for development of renewable energy sources and that a preference must be given to projects located in Minnesota.

Commission Approval of RDF Expenditures—2012 legislation provided more flexibility for the Minnesota Public Utilities Commission (Commission) to disapprove or modify proposed RDF expenditures that it finds to be non-compliant with prior orders or otherwise not in the public interest.

Advisory Group—Definition was given to the consulting role that an advisory group provides and clarified that Xcel Energy has full and sole authority to determine which expenditures shall be submitted to the Commission for approval.

Higher Education Institutions—RDF funds may be directed to higher education institutions located in Minnesota for multiple research projects.

Annual Reporting—Xcel Energy must submit an annual report to the chair and ranking minority member of the legislative committees with jurisdiction over energy policy about projects funded by the RDF account for the prior year and all previous years.

Project Reporting—Several RDF administrative requirements that were in effect due to Commission orders were incorporated into statute. These reporting requirements included the following:

- Reports must include sufficient detail for technical readers as well as a clearly written summary for non-technical readers;
- Reports must be posted online on a public website; and
- Reports must acknowledge that the project was made possible in whole or part by Xcel Energy's Minnesota electric ratepayers.

Minnesota Department of Natural Resources photovoltaic installation—Afton State Park

Through the course of administrating three RDF grant cycles, Xcel Energy has learned many lessons regarding the role that a dedicated fund may serve in providing resources for the development of renewable electric energy. In addition, feedback from organizations that have an interest in renewable energy issues and recommendations from the Office of Legislative Auditors (OLA) have provided the opportunity for the RDF fund to adapt to the current needs and trends in Minnesota. Some of the lessons involve the logistics to administer the fund to allow for project flexibility while still protecting the electric ratepayers' investment into the fund. Other modifications have been made to clarify and define how the RDF mission can be put to practice. In general, the RDF provides resources for three programs:

1) Grant funds to reduce capital cost of renewable electric generation facilities that demonstrate Minnesota's renewable resources;
2) Grant funds for renewable electric research that is relevant within Minnesota; and
3) Incentive funding to narrow the competitive price gap between renewable electric generation and conventional electric generation.

At the end of the 2011 – 2012 biennium period, it is anticipated that $20 million to $30 million will be available for Cycle 4. On Nov. 29, 2012, Xcel Energy filed with the Commission a notice of intent to proceed with our fourth cycle of the RDF. The overall goal for the fourth cycle will be to encourage the development of renewable energy projects that are otherwise unable to secure public and private financing sufficient to proceed with development, and to advance new cost-effective technology. In addition, a new RDF research program is being initiated which will provide block grants for Minnesota higher education institutions to utilize for electric research initiatives.

Energy Performance Systems tree harvester demonstration

II. RDF Program Background

The RDF program was mandated by the Minnesota Legislature in 1994 in conjunction with legislation regarding the Prairie Island nuclear generating plant in Red Wing, Minn. As a condition of storing spent nuclear fuel in dry casks at Prairie Island, Minn. Stat. § 116C.779 initially required NSP-Minnesota, as the public utility owner of the plant, to transfer $500,000 for each dry cask containing spent fuel to a renewable energy fund after Jan. 1, 1999, amounting to $9 million annually. In 2003, this statute was amended to extend the life of the nuclear-waste storage at Xcel Energy's Prairie Island plant and increased the amount Xcel Energy must pay to $16 million annually, of which $10.9 million annually shall be used to fund renewable small-wind, hydro and biogas incentives via the renewable energy production incentive (REPI) program administrated by the Department of Commerce. (See Section V for further discussion of REPI.)

In 2007, the statute was further amended to add an additional assessment of $350,000 for each dry cask stored at Xcel Energy's Monticello nuclear generating plant. Ten casks were filled in 2008 and continue to be stored at our Monticello plant. Since 2008, $19.5 million has been set-aside annually for the RDF program.

The cost of Commission-approved program expenses allocated to Minnesota is recovered through an adjustable surcharge on Xcel Energy's customer bill statements as part of their monthly charges for electricity. This surcharge mechanism is known as a "rate rider." On Oct. 1 each year, Xcel Energy submits an RDF summary report to the Commission. This summary report contains a proposed RDF rate rider charge for the upcoming year and an annual financial report which summarizes the RDF program's past expenses and a two-year expense forecast. In 2011, the RDF charge was $0.000401 per kWh and in 2012 the RDF charge was $0.000479 per kWh. In 2013, Xcel Energy was able to reduce the RDF charge to $0.000402 per kWh. For a typical residential customer using 750 kWh per month, the RDF cost per month is $0.30.

The RDF advisory group was established by Xcel Energy, and serves as a voluntary and independent entity to assist Xcel Energy in evaluating and selecting grant project proposals for recommendation to Xcel Energy and the Commission. Xcel Energy uses technical and professional consulting resources, as needed, to carry out its duties. The advisory group makes recommendations regarding the selection of projects and has seven members consisting of representatives from the following organizations:

- Environmental interests (two)
- Prairie Island Indian community (one)
- Residential customers (one)
- Commercial and Industrial customers (one)
- Xcel Energy (two)

The RDF advisory group is further detailed in the Appendix.

Xcel Energy program staff has responsibility for the practical day-to-day administration of the RDF grant contracts and resources.

University of North Dakota—mobile liquefaction facility to process biomass

III. RDF Program Mission and Performance Metric Evaluation

The RDF's mission was established on Oct. 5, 2006 through a Commission Order as an operational guideline for the fund.

> *The overall purpose (mission) of the fund is to increase the market penetration of renewable energy resources at reasonable costs in the Xcel Energy service territory, promote the start-up, expansion and attraction of renewable energy projects and companies in the Xcel Energy service territory and stimulate research and development into renewable energy technologies that support this mission.*

In 2012, the RDF mission was further clarified and supported through Minn. Stat., § 116C.779 which prescribes the following types of expenditures for which RDF funds may be used to:

- Increase the market penetration within the state of renewable electric energy resources at reasonable costs;
- Promote the start-up, expansion, and attraction of renewable electric energy projects and companies within the state;
- Stimulate research and development within the state into renewable electric energy technologies; and
- Develop near-commercial and demonstration scale renewable electric projects or near-commercial and demonstration scale electric infrastructure delivery projects if those delivery projects enhance the delivery of renewable electric energy.

The RDF program established the following performance metrics for evaluating program effectiveness:

- Expansion of knowledge base;
- Environmental benefits; and
- Economic benefits.

These performance metrics, detailed below, are revisited after the completion of each project to determine whether the project:

- Remained on course with its stated goals;
- Furthered RDF program objectives; and
- Was a prudent and beneficial grant award on behalf of our customers.

Sartec researched how algae can feed on the CO_2 emissions from a coal-fired power plant to then be harvested and have the lipids converted into bio-diesel. The biofuel can then be sold to offset emission reduction costs.

Expansion of Knowledge Base

Project milestone reports and final reports submitted by grant recipients provide a public venue for the disclosure of new research breakthroughs that can stimulate the further development of new renewable technologies. These reports are available on the RDF web page at **www.xcelenergy.com/rdf**. In addition, the publication of project results in scientific journals and the presentation of research activities at conferences and other forums provide another avenue to expand the academic and practical knowledge base of renewable energy technologies. During this biennium, 11 articles were published in scientific journals. Thirty papers were presented at a variety of regional, national, and international conferences and workshops. (See Appendix C) These publications and venues provide a critical scientific peer review of project research findings and are a basis for additional research activities or commercial efforts.

In addition, during the previous biennium there were four RDF research projects that were actively seeking patents. Northern Plains Power Technologies has submitted a patent application for their Cycle 3 project (RD3-21). The project's goal is to develop islanding detection methods. The University of Florida also stated its intent to file a patent for findings developed during their Cycle 2 project, (RD-34) which demonstrated a system for anaerobic digestion of solid and soluble organic wastes from sugar beet processing, a Cycle 1 project (CW-06) has received a patent for a pulse-width modulation controller that can be used for matrix converters used in the wind industry. Two provisional patents received in 2008 were abandoned during this biennium, a provisional patent by Russell Forrest (RD-68) for a rhizome processor to plant miscanthus and a provisional patent to Phil Hutton with the University of North Dakota (CB-08) for a thermal stabilizer to be used within a gasification system.

Lower St. Anthony Falls Hydroelectric Facility —Minneapolis, Minn.

Environmental Benefits

The RDF's environmental contribution is the avoidance of both air pollutant and greenhouse gas emissions when compared with alternative methods of generating electricity. Installed RDF energy production projects generated 91,173 MWh of electricity during the 2011 – 2012 biennium. Overall, RDF projects have generated a total of 195,013 MWh of electricity produced from a renewable energy resource. (See Table 1). Since solar electricity is only generated during peak daytime periods, it can also help meet demand energy requirements.

Table 1 —Electrical Generation (MWh)

Type	Prior Bienniums	Current Biennium	Total Generation
Hydro	0	27,061	27,061
Solar	7,431	5,591	13,022
Wind	96,409	58,521	154,930
Total	**103,840**	**91,173**	**195,013**

Hydro, solar and wind resources, which create no air emissions, have provided all RDF project power generation to date. When compared to electric energy produced by coal, the RDF generation has provided environmental benefits through the reduction in several primary air emission categories (See Table 2). Solar and wind-sourced electric generation offsets the release of particulate matter resulting from conventional electric power generation. RDF electric generation projects are helping Xcel Energy meet a goal to reduce CO_2 emissions by 20 percent from 2005 levels by 2020.

Table 2 —Air Emission Reductions (Compared to Coal)

Emission	Prior to 2011 (pounds)	Biennium (2011 – 2012) (pounds)	Total (pounds)
CO_2	146,956	127,460	274,416
SO_2	307	209	516
NO_X	234	155	389
VOCs	5.24	4.61	9.85
Hg	2.60	1.82	4.42
Pb	1.37	1.20	2.57

Emissions data is based on Xcel Energy's 2011 Corporate Responsibility Report

RDF projects have also generated Renewable Energy Credits (RECs) which are tradable, non-tangible energy commodities. These credits represent the environmental attributes of the power produced from renewable energy projects. RDF projects have generated 146,059 RECs which can be used to meet Xcel Energy's renewable energy goals and requirements (See Table 3).

Table 3 —Renewable Energy Credits (RECs)

Emission	Prior to 2011	Biennium (2011 – 2012)	Total
kWh	103,850	91,163	**195,013**
Credits	66,227	79,832	**146,059**

Economic Benefits

RDF grants for renewable energy research and energy production initiatives generate significant economic benefits. During the biennium RDF expenditures included more than $9.3 million in RDF project grant reimbursements, about $18.0 million in REPI payments, nearly $1.8 million for solar rebates, and $7.8 million in funding for special legislative projects. RDF expenditures promote and expand economic activity on both a local and regional scale through the purchase of goods and services, expansion of employment opportunities, and in some cases, the fostering of new or expanded business opportunities. In cases where permanent energy production facilities are constructed, RDF investments can also expand the property tax base for a community through land improvements. RDF grant funds support supply-side economic growth by providing an incentive for people to produce goods and services which allow consumers to benefit from a greater supply of those goods and services at lower prices.

Leveraged Funds

RDF grant awards have leveraged other funds to expand and/or enhance project activity. Since the RDF program inception in 2002, RDF grant awards have stimulated the investment of more then $152 million in renewable energy. This includes more than $110 million in construction activity, goods and services as a result of the start-up, expansion and attraction of renewable energy projects and companies in the NSP-Minnesota service territory and nearly $42 million in research. Energy production projects that have been active during the past biennium, have leveraged more than $64 million, which is equivalent to $5.25 for each RDF dollar spent. (See Table 4).

Table 4 —Energy Production Funds Leveraged

(Active Projects in 2011 – 2012 Biennium)

Technology	Grant	Cost Share	Total Costs	Leverage
Biomass	$400,000	$17,940,712	$18,340,712	4,485%
Hydro	$5,561,409	$40,279,126	$45,840,535	724%
Solar	$6,249,479	$6,018,385	$12,267,864	96%
Total	**$12,210,888**	**$64,238,223**	**$76,449,111**	**526%**

An additional $6.9 million has been leveraged during the past biennium for research and development which includes $4.7 million in Minnesota. Research and development projects typically do not have the extensive leverage capacity as compared to energy production because the funding is predominately applied to personnel rather than construction and material costs (See Table 5). RDF grant dollars leverage $0.56 for each grant dollar invested.

Table 5 —Research and Development Funds Leveraged
(Active Projects in 2011 – 2012 Biennium)

Technology	Minnesota			Outstate			Total Leverage
	RDF Grant	Cost Share	Leverage	RDF Grant	Cost Share	Leverage	
Biomass	$4,438,325	$1,513,174	34%	$3,818,614	$1,270,311	33%	34%
Solar	$732,032	$0	0%	$1,493,608	$906,686	61%	41%
Wind	$1,999,999	$3,247,181	162%	$0	$0	0%	162%
Total	**$7,170,356**	**$4,760,355**	**66%**	**$5,312,222**	**$2,176,997**	**41%**	**56%**

Job Creation

Money invested into an area's economy for the material delivery of goods and services results in the need to hire additional or retain existing employees to meet the business needs. Therefore, money spent on energy production projects, as well as research and development projects, provides real economic benefits through the promotion of commerce and additional work hours. Organizations such as the National Renewable Energy Laboratory, the U.S. Department of Energy, and the American Council for an Energy Efficient Economy have developed job calculator models to evaluate the impact of dollars spent on renewable energy and energy efficiency projects. On average, these tools indicate that 10 to 11 jobs are created and/or retained (permanent and temporary) for each $1 million invested. Of the nearly $9.3 million in RDF project grant funds disbursed in 2011 and 2012, RDF project activity leveraged an additional $43.0 million for an investment of $52.5 million in renewable energy projects. This resulted in $46.0 million for construction projects to produce more renewable energy generation capacity and $6.5 million to fund renewable energy research. This investment resulted in 350 to 500 construction related jobs and about 70 research jobs that were either created or retained during 2011-2012.

Outland Renewable Energy —When finished, this 2 MW photovoltaic installation near Slayton, Minn. will be the largest solar facility in Minnesota.

It should be noted that several out-of-state projects used Minnesota contractors or project hosts located in the NSP-Minnesota service area and are not included in the previous numbers. This project association keeps the research relevant to Minnesota and directs additional RDF funds to businesses and organizations in the state. These projects include:

- Grid and delivery system data from NSP-Minnesota is being analyzed for anti-islanding and loss-of-mains by Northern Plains Power Technologies (RD3-21)
- Haubenschild Farms, Princeton, Minn. provides feedstock and a testing site for University of North Dakota (RD3-68)
- P & J Farms, Northfield, Minn. is host to the gasification demonstration for Coaltec USA (RD3-77)

IV. RDF Lessons Learned

The RDF has been recognized by many as an important source of funding for renewable electric energy research and renewable electric energy production projects. Just as renewable energy technologies are continuously developing and responding to market conditions, it is necessary for the RDF to respond to the resource requirements and deficiencies generated by this evolving technology group. In 2009, the Minnesota Legislature directed the Office of the Legislative Auditor (OLA) to conduct an RDF program evaluation. The review was to focus on:

- The process for determining which projects receive RDF support;
- Whether RDF projects have met statutory goals and provided Minnesota-specific benefits; and
- Whether project outcomes have been effectively communicated to the public and policy makers.

The OLA's evaluation and report was issued in the fall of 2010 and aspects of the report recommendations were incorporated into Minn. Stat. §116C.779 in the spring of 2012 and put into practice during this biennium.

The OLA recognized that the administrative responsibility for RDF projects has grown more diffuse and that there was a need to refocus the RDF on renewable electric energy initiatives. The legislative auditor also offered a number of key recommendations including:

Clarify RDF structure and purpose
The RDF mission which was adopted by Commission order on Oct. 5, 2006 was reaffirmed by 2012 legislature and memorialized in Minn. Stat. §116C.779. The legislature consolidated the project approval process by directing Xcel Energy to select funding initiatives under the regulator oversight of the Commission. Consolidation of project approval provides the ability to adopt uniform project eligibility criteria amongst all RDF funding initiatives.

Clarify RDF Board Structure and purpose
The composition of a seven member advisory group with the responsibility to oversee and provide recommendations on project selection was also reaffirmed by the 2012 legislature.

Reporting requirements

Project reporting requirements that were adopted by Commission order in Oct. 5, 2006 were reaffirmed by the 2012 legislature and memorialized in Minn. Stat. §116C.779. These requirements include the following details: all projects must produce a final written report that includes sufficient detail for technical readers and a clearly written summary for non-technical readers; RDF financial reports should include more useful information, and reports should be posted online. Similar reporting requirements were incorporated into Cycle 3 grant contracts and will be further adapted in Cycle 4 projects.

Funding Acknowledgement

The requirement that all final reports are to acknowledge that the work was funded by the RDF was incorporated into statute. This requirement was already in practice for Cycle 3 grant recipients.

Minnesota Preference

2012 legislation directed that project preference selection should be give to Minnesota applicants and projects that foster Minnesota-specific benefits (i.e. working with Minnesota companies or using Minnesota products). The upcoming Cycle 4 project selection criterion includes this preference by either requiring certain types of projects to be based in Minnesota or providing scoring and selection preferences to proposals that demonstrate a Minnesota-specific benefit.

RDF Project Administrative Cost Caps

The auditor recommended that certain RDF project administrative costs be limited to direct more grant funding to project activity. Administrative costs caps have been proposed for Cycle 4 grants—a 25 percent cap for project grants and 35 percent cap for higher education block grants. Currently Xcel Energy's average cost to administer the RDF program from 2004 – 2012 is 3.8 percent of RDF grant funds disbursed.

Project Impedances

The auditor recommended that the project selection process should explicitly consider issues that are likely to affect project implementation that may prevent the project from proceeding (i.e. authorizations, leases, permits, etc). For Cycle 4 funding, Xcel Energy has proposed grant contract language that would benefit proposals that are more thoroughly vetted by the applicant for potential problems that would create delays.

Xcel Energy Wind to Battery demonstration —Beaver Creek, Minn.

Part of the process to prepare for Cycle 4 funding entailed the assessment of what administrative processes have been working well and what processes could be improved. In particular, Xcel Energy identified the following:

Project Completion Schedules

The RDF program has generally given project sponsors every opportunity to be successful, and we have approved contract extension amendments providing additional time to achieve specific milestones such as securing a site, obtaining project financing, negotiating a power purchase agreement, and making various technical changes in research projects. However, in some cases, this has added a year or more to project completion. For Cycle 4, Xcel Energy proposed a provision that provides an explicit option of terminating a contract if within a specified period of time (e.g. 12 months) a contractor has not secured a site lease, negotiated a power purchase agreement (PPA), secured project financing, or otherwise initiated project activity. Waiting indefinitely can have negative effects on Xcel Energy's ratepayers by tying up funds that could be used for other projects, and putting already expended RDF dollars at risk due to the inability of a project sponsor to timely complete the project. Currently, any RDF disbursements are tied to the completion of a specific milestone and deliverable. This practice motivates grantees to stay on schedule and complete projects in a timely manner.

Co-Applicant Conflicts

It is difficult for two separate entities to share liabilities and cash flow obligations included in the RDF grant contract because of the potential risk to each co-applicant. This situation is resolved by identifying only one applicant to be the grantee and legally obligated for completion of the project.

Power Purchase Agreements

Sponsors of energy production projects provide non-binding pricing information which is also a factor in determining the total resource score of the proposal and is also a component of the proposal score. However, after the approval of a grant award a much higher PPA energy price may be negotiated for a power purchase agreement group and proposed. While there may have been valid reasons for the pricing change, this resulted in difficult negotiations and added at least a year to the project development process. There are a number of lessons learned from this experience including:

1) It may be administratively more expedient to entertain energy production proposals designed only for self-use;
2) RDF grant contracts should include language that holds Xcel Energy harmless if parties are not able to agree upon a PPA price; and
3) It may be prudent to offer a larger grant award sufficient to cover project costs based on a PPA energy price set at the current average retail rate for Xcel Energy.

Reserve Projects

During Cycle 3, Xcel Energy had some reserve projects to substitute for any potential approved projects that withdrew. Xcel Energy will continue this reserve list for the Cycle 4 funding.

Project Sponsor Capabilities

The involvement of key personnel with the proper skills, training and experience to keep the project on schedule and within budget is critical to ensure project success. During the Cycle 4, greater value will be placed on organizational capability.

Standard Grant Contract Approval

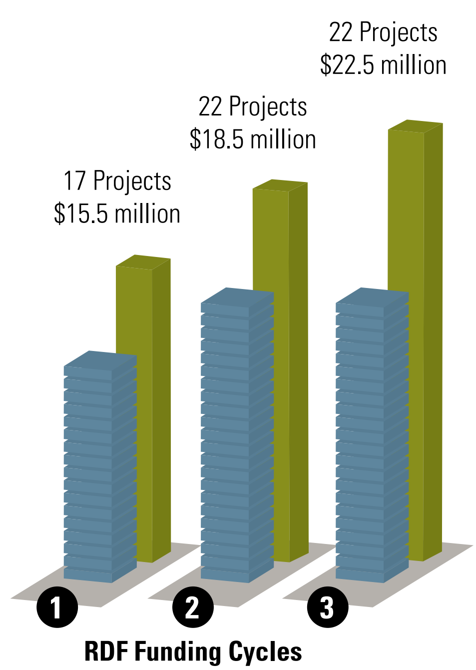
Once an RDF grant contract is negotiated with a project sponsor, Xcel Energy submits the final executed agreement to the Department of Commerce (Department) and Commission for final compliance review. If the Department recommends approval, no further action is required by the Commission. Xcel Energy has proposed elimination of the review period if no changes are made to the grant contract making the grant contract affective after it has been signed by both parties. If any material changes are made to the standard RDF contract, Xcel Energy will continue to submit the modified contract to the Department and Commission for final compliance review.

Contracting Entity

Once a project is selected, the applicant for the grant may prefer to manage the project through a wholly-owned subsidiary formed for the purpose of constructing and owning the project. This is especially common for energy production projects where a specific generating facility is being constructed. It is prudent to allow Xcel Energy to enter into a grant contract with an applicant's project management with a guarantee that the grant applicant will also be contractually liable for the completion of the project.

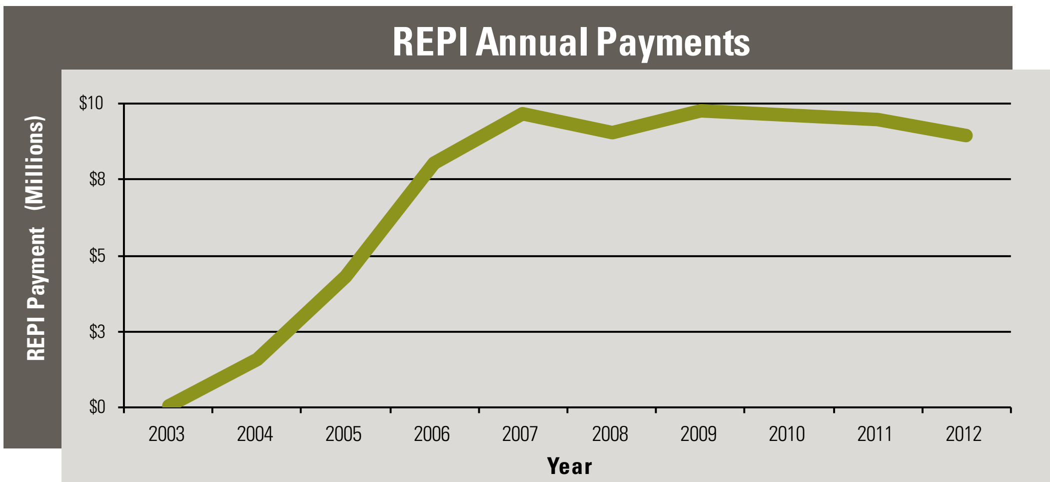
V. RDF Funding Activity

Since 2001, the RDF program has provided $169.2 million for renewable energy initiatives including $70.0 million for REPI payments, $40.7 million for legislatively mandated projects and programs, and $2.0 million for general program support. These mandated programs included the appropriation of $25 million to the University of Minnesota for the Initiative for Renewable Energy and Environment (IREE). The balance of $56.5 million has been awarded over three grant cycles to 61 projects as shown in the following graph:



Renewable Energy Production Incentives (REPI)

As specified by Minn. Stat. §116C.779, Subd. 2., the RDF program provides REPI payments up to $10.9 million for qualifying, including up to $9.4 million annually for electricity generated by wind energy conversion systems and up to $1.5 million annually for on-farm biogas recovery facilities and hydroelectric facilities. Minn. Stat. §216C.41 authorizes an incentive payment of 1.5 cents per kWh for qualified wind projects through 2018, biogas projects through 2015, and hydro projects through 2021. Approximately 225 MW of small wind facilities are subscribed in the program. REPI payments since program inception have totaled about $70.1 million.

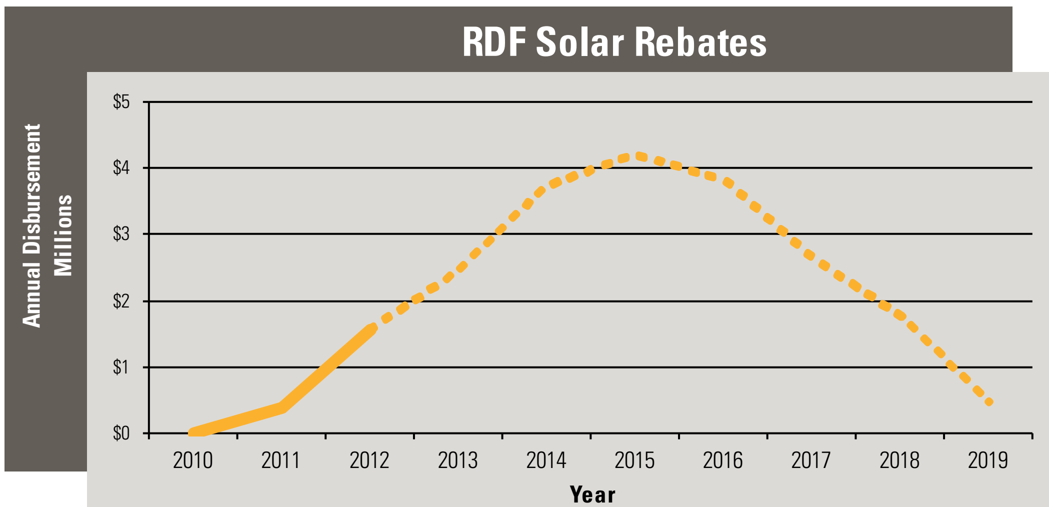


Initiative for Renewable Energy and the Environment (IREE)

In 2009, the Legislature appropriated $2.2875 million from the RDF to support renewable energy projects and programs administered by the Office of Energy Security and $15 million from the RDF to support the University of Minnesota's Initiative for Renewable Energy and the Environment (IREE). As an outcome from legislative modifications in 2012 that affect the allowance or RDF resources, research for institutions of higher education will be awarded through competitive block grants. This funding concept will be initiated as part of Cycle 4.

RDF Solar Rebates

In 2010, the Legislature approved a measure to utilize $21 million from the RDF program for solar rebates over the next five years ($2 million in state fiscal year 2011, $4 million in state fiscal year 2012, and $5 million per year in state fiscal years 2013 – 2015). The legislation specifies that Xcel Energy shall administer the RDF rebates for solar photovoltaic (PV) systems less than 40 kW installed by customers in the NSP-Minnesota service territory. The RDF solar rebates are only available for systems that use solar modules manufactured or assembled in Minnesota. The amount of the RDF solar rebate shall be the difference between the sum of all rebates awarded to the applicant and $5 per watt of installed generating capacity. Further, the amount of all rebates or other forms of financial assistance awarded to an applicant by a utility and the state, including the RDF solar rebate must not exceed 60 percent of the total installed cost of the solar PV installation net of federal income taxes at the highest applicable income tax rates.



Solar rebates were first disbursed in 2011 for the installation of 383 kW photovoltaic and totaled $382,541. In 2012, solar rebate disbursements totaled $1,564,124, which included an additional 1,182 kW of installed photovoltaic capacity. Since the inception of the program, 1,564 kW of photovoltaic capacity has been installed in Minnesota and have all used Minnesota-made modules. Response to the program has been strong and funds have been allocated through 2013.

VI. Overall RDF Project Status

In order to maintain program transparency, the RDF administration files quarterly progress reports with the Commission (available at **www.puc.state.mn.us**) summarizing project activity. In addition, RDF grant recipients submit project milestone reports to Xcel Energy providing a description of activities and findings. Milestone reports are posted on the RDF web page at **www.xcelenergy.com/rdf**.

A. Current Contracts

RDF projects have contract periods of varying lengths and start dates based upon the specific variables and time requirements inherent to the project. Project duration has ranged from two months to 129 months, but the typical project length is just more than three years at 37 months. Some projects are dependent upon seasonal factors (i.e. wind patterns, weather, crop growth, winter construction restrictions, etc.), which require project tasks to be synchronized with calendar dates. The ability for the RDF to allow multi-year projects has been advantageous to biomass research projects that track impact parameters over the course of several growing seasons.

Of the 62 projects that have entered into RDF grant contracts since the RDF's inception, two projects were initiated during the biennial period (See Table 6).

Table 6 —Summary of Projects Initiated
(1/1/2011 – 12/31/2012)

	Prior to 12/31/2010	1/1/2011 - 12/31/2012
Cycle 1	17	0
Cycle 2	23	0
Cycle 3	20	2
Total	**60**	**2**

Thirty-eight projects were completed prior to the biennial period, 14 projects were completed during the biennial period and 10 remain active (See Table 7).

Table 7 —Summary of Completed Projects
(1/1/2011 – 12/31/2012)

	Prior to 12/31/2010	1/1/2011 - 12/31/2012	Active as of 1/1/2013
Cycle 1	16	0	1
Cycle 2	19	2	2
Cycle 3	3	12	7
Total	**38**	**14**	**10**

B. Energy Production Project Status

Eight energy production projects were active during the biennial period of which four were completed and installed, which added additional capacity of 9.903 MW (See Table 8). Annual electrical production from this added generation capacity is projected to be 58,479 MWh. More than $16.4 million of RDF funding has been awarded and obligated to these eight RDF energy production projects. This investment has leveraged an additional $46.0 million for project design, planning and materials for construction projects in Minnesota during this 2011 – 2012 biennium period.

Table 8 —Summary Energy Production Projects
(1/1/2011 – 12/31/2012)

Technology	Total Projects	Completed Projects	Installed Capacity (MW)	Funds Leveraged
Biomass	2	1	0	$1,478,240
Hydro	2	1	9.176	$36,469,287
Solar	4	2	.727	$3,642,564
Totals	**8**	**4**	**9.903**	**$41,509,091**

C. Research and Development Project Status

Sixteen research and development (R&D) production projects were active during the biennial period with 10 completing their proposal activity during that period. (See Table 9). More than $12 million of RDF funding has also been awarded and these R&D projects of which $4.9 million was disbursed during the biennium. This investment has leveraged an additional $1.6 million from other sources for renewable energy research for a total of $6.5 million during this biennium period. More than $3.2 million of these research funds were utilized for research and development projects in Minnesota.

Table 9 —Summary Research Development Projects
(1/1/2011 – 12/31/2012)

Technology	Total Projects	Completed Projects	Published Articles	Scientific Papers	Funds Leveraged
Biomass	11	6	2	4	$1,009,981
Solar	3	3	2	12	$430,370
Wind	2	1	7	14	$165,567
Totals	**16**	**10**	**11**	**30**	**$1,605,918**

D. Reimbursement of Project Costs

Grant funds are disbursed on a reimbursement basis according to project progress and milestones stipulated in each RDF grant contract. More than $9.3 million was dispersed in the biennium to reimburse project costs (See Table 10). Some projects were completed under budget, and $2,478,732 in savings was credited to the RDF program for future RDF grant awards.

Table 10 —Use of Funds Under RDF Contract
(1/1/2011 – 12/31/2012)

Cycle	Contracted RDF Funds	RDF Funds Dispersed			Funds not utilized
		Prior to 12/31/2010	1/1/2011 - 12/31/2012	Balance after 1/1/2013	
Cycle 1	$15,550,401	$11,671,876	$0	$3,561,409	$317,116
Cycle 2	$29,440,996	$24,703,669	$1,697,741	$968,149	$2,071,437
Cycle 3	$22,510,293	$11,321,787	$7,658,471	$3,949,463	$90,179
Total	**$67,501,690**	**$47,187,726**	**$9,356,212**	**$8,479,021**	**$2,478,732**

E. Project Benefits to NSP-Minnesota Customers

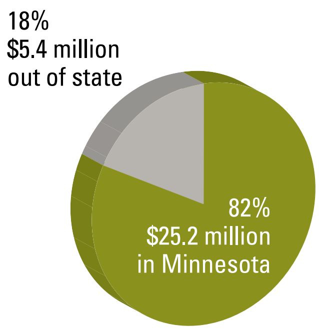
The majority of RDF projects are based in Minnesota. As a result, the majority of RDF dollars are also spent in the NSP-Minnesota service area. One of the selection criteria for RDF grant projects relates to the benefits a project will bring to NSP-Minnesota customers. Therefore, research activity conducted by an entity that is not located in Minnesota needs to be applicable and transferable to Minnesota. This is often accomplished through the use of a Minnesota site serving as a host for the development and demonstration of an RDF project. (See Table 11)

Table 11 —Minnesota Hosts Activities
(1/1/2011 – 12/31/2012)

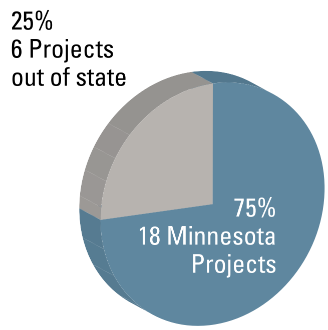
Project	Grantee	Minnesota Host	Host Location	Host Activity
RD3-21	Northern Plains Power Technology	Xcel Energy	Minneapolis, Minn.	Provided data to test model
RD3-68	University of North Dakota	Haubenschild Farms Dairy	Princeton, Minn.	Pilot demonstration of digester
RD3-77	Coaltec Energy USA	P & K Farms	Northfield, Minn.	Pilot demonstration of gasifier

Appendix D details the Minnesota congressional districts that have either hosted project activity or have had a project sponsor located within their boundaries.

The following charts depict the number of RDF projects that have been located, and the funding for such projects, in and outside of Minnesota:



RDF Funding



RDF Projects

VII. Conclusion

The RDF program continues to be a source of funding for renewable electric energy research, development and demonstration projects in Minnesota. Throughout the past 10 years and three grant award cycles, the RDF program has supported projects of state, regional and national significance. Yet, not all projects unfold as planned, and it often takes years for the results from research projects to bear fruit. There have been many lessons learned in conjunction with past RDF projects and these lessons will be applied to future efforts.

We look forward to working with the Legislature and the Commission on possible revisions to the RDF program. Further, we remain committed to making certain the RDF program provides maximum benefits for those who most directly make it possible—our customers.

Appendix A —Active RDF Projects During Biennium (1/1/2011 – 12/31/2012)

	Contract	Project Name	Grant	Type	Cycle	Category	Status	Project End Date
1	AH-01	Crown Hydro	$5,100,000	EP	1	Hydro	Active	1/20/2015*
2	EP-34	Lower St. Anthony Falls	$2,000,000	EP	2	Hydro	Completed	12/26/2011
3	EP-44	CMEC	$2,000,000	EP	2	Biomass	Completed	3/12/2011
4	EP-51	RCM Digesters/Diamond K Dairy	$936,530	EP	2	Biomass	Active	11/1/2013*
5	RD-50	Energy Performance Systems	$957,929	RD	2	Biomass	Active	1/16/2013
6	EP3 - 10	Outland Renewable	$2,000,000	EP	3	Solar	Active	3/14/2013
7	EP3 - 11	City of Minneapolis	$2,000,000	EP	3	Solar	Completed	7/19/2012
8	EP3 - 12	freEner-g	$1,488,922	EP	3	Solar	Completed	2/17/2011
9	EP3 - 13	Minnesota Dept. of Natural Resources	$894,000	EP	3	Solar	Active	3/12/2013
10	RD3 - 1	University of Minnesota	$992,989	RD	3	Biomass	Active	10/22/2013
11	RD3 – 2	Sartec	$350,000	RD	3	Biomass	Completed	7/11/2011
12	RD3 - 4	Bepex International	$924,671	RD	3	Biomass	Completed	7/28/2011
13	RD3 - 12	NSP-Minnesota	$1,000,000	RD	3	Wind	Completed	12/19/2011
14	RD3 - 21	Northern Plains Power Technologies	$493,608	RD	3	Solar	Completed	12/17/2012
15	RD3 - 23	University of Minnesota	$819,159	RD	3	Biomass	Completed	8/1/2011
16	RD3 - 25	University of Minnesota	$732,032	RD	3	Solar	Completed	12/26/2011
17	RD3 - 28	University of Minnesota	$979,082	RD	3	Biomass	Active	6/22/2013
18	RD3 – 42	University of Minnesota	$999,999	RD	3	Wind	Active	8/7/2013
19	RD3 - 53	Interphases Solar	$1,000,000	RD	3	Solar	Completed	7/20/2012
20	RD3 - 66	University of North Dakota	$999,065	RD	3	Biomass	Completed	4/10/2012
21	RD3 - 68	University of North Dakota	$970,558	RD	3	Biomass	Completed	4/30/2012
22	RD3-69	Minnesota Valley Alfalfa Producers	$1,000,000	RD	3	Biomass	Active	8/23/2014
23	RD3 - 71	University of North Dakota	$999,728	RD	3	Biomass	Completed	3/23/2012
24	RD3 - 77	Coaltec Energy USA	$1,000,000	RD	3	Biomass	Active	4/22/2014*
		Total RDF Projects	**$30,638,272**					

*Project end date dependent upon anticipated completion of project activity.

Appendix B —RDF Advisory Group

- **Eric Jensen**, energy coordinator
  Izaak Walton League
  Representing the environmental community

- **Linda Taylor**, clean energy director
  Fresh Energy
  Representing the environmental community

- **Lise Trudeau**, engineer
  Minnesota Division of Energy Resources
  Representing residential customers

- **Ben Gerber**, manager energy policy
  Minnesota Chamber of Commerce
  Representing commercial and industrial customers

- **Heather Westra**
  Representing Prairie Island Indian community

- **Kevin Schwain**, manager emerging customer program
  NSP-Minnesota
  Representing NSP-Minnesota

- **Mike Bull**, manager public policy and strategy
  NSP-Minnesota
  Representing NSP-Minnesota

RDF Administration

- **Paul Lehman**, program manager
  NSP-Minnesota

- **Mark Ritter**, grant administrator
  NSP-Minnesota

Appendix C —Scientific Articles and Presentations

Scientific Articles

Date	Grant #	Grantee	Article Title	Journal
January 2011	RD3-42	U of M	Large-Eddy Simulation of Wind-Turbine Wakes	Boundary-Layer Meteorology
July 2011	RD3-42	U of M	Turbulent Flow Properties Around a Staggered Wind Farm	Boundary Layer Meteorology
September 2011	RD3-28	U of M	Crop Residues of the Contiguous United States: Balancing Feedstock and Soil Needs	Sustainable Feedstock's for Advanced Biofuels
September 2011	RD3-1	U of M	The Big Picture: Researchers Partner with Farmers and Industry to Build a Biomass Energy System that Works	Solutions
September 2011	RD3-42	U of M	Reynolds Number Dependence of Turbulence Statistics in the Wake of Wind Turbines	Wind Energy
September 2011	RD3-42	U of M	On the Evolution of Turbulent Scales in the Wake of a Wind Turbine Model	Journal of Turbulence
November 2012	RD3-42	U of M	Computational Study and Modeling of Turbine Spacing Effects in Infinite Aligned Wind Farms	Physics of Fluids
March 2012	RD3-42	U of M	Non-uniform Velocity Distribution Effect on the Betz Limit	Wind Energy
May 2012	RD3-25	U of M	Moving Void Enhanced Crystallization of Amorphous Silicon	Nature Materials
August 2012	RD3-53	Inter-phases	Film Growth Mechanism for Electrodeposited Copper Indium Selenide Compounds	Thin Solid Films
January 2013	RD3-42	U of M	Drag Reduction in Large Wind Turbines Through Riblets: Evaluation of Riblet Geometry and Application Strategies	Renewable Energy

Appendix C (continued) —Scientific Articles and Presentations

Papers/Presentations

Date	Grant #	Grantee	Paper Title	Conference	Location
January 2011	RD3-12	Xcel Energy	Energy Storage for Wind and Solar Integration - Wind-to-Battery Project Preliminary Results	Marcus Evans Electric Energy Storage Conference	Phoenix, AZ
January 2011	RD3-42	U of M	Turbulence Patterns Around a Large Wind Farm	49th AIAA Aerospace Sciences Meeting	Orlando, FL
March 2011	RD3-12	Xcel Energy	Energy Storage for Wind and Solar Integration - Wind-to-Battery Project Preliminary Results	Midwest Rural Energy Council Annual Conference	Bloomington, MN
March 2011	RD3-12	Xcel Energy	Energy Storage for Wind and Solar Integration - Wind-to-Battery Project Preliminary Results	University of Colorado, LEEDS School of Business	Boulder, CO
March 2011	RD3-12	Xcel Energy	Energy Storage for Wind and Solar Integration - Wind-to-Battery Project Preliminary Results	CPUC Energy Storage Workshop	Denver, CO
March 2011	RD3-12	Xcel Energy	Energy Storage for Wind and Solar Integration - Wind-to-Battery Project Preliminary Results	IQPC Energy Storage Summit	San Francisco, CA
March 2011	RD3-12	Xcel Energy	Energy Storage for Wind and Solar Integration - Wind-to-Battery Project Preliminary Results	Minnesota Municipal Utilities Association	Bloomington, MN
March 2011	RD3-21	NPPT	Solar Generation Control With Time-Synchronized Phasors	64th Annual Conference of Protective Relay Engineers	College Station, TX
April 2011	RD3-25	U of M	Hopping Transport in Doped Co-deposited Mixed-phase Hydrogenated Amorphous/Nanocrystalline Silicon Thin Films	2011 Materials Research Society Meeting	San Francisco, CA
April 2011	RD3-25	U of M	Studies of Doped a/nc-Si:H Films	2011 Materials Research Society Meeting	San Francisco, CA
April 2011	RD3-25	U of M	Quantum-confined Silicon Nanocrystals as Candidates for Solar Cell Absorber Material	2011 Materials Research Society Meeting	San Francisco, CA
May 2011	RD3-53	Interphases	Spray Deposited Transparent Conducting ZnO Films	NSF SBIR/STTR Conference	Baltimore, MD
May 2011	RD3-53	Interphases	Next Generation High efficiency Solar Cells	Army Research Laboratory meeting	Adelphi, MD
May 2011	RD3-53	Interphases	Next Generation High efficiency Solar Cells	Defense Advanced Research Projects Agency (DARPA) meeting	Arlington, VA
June 2011	RD3-12	Xcel Energy	Optimal Strategy to Dispatch Storage in Real-Time Markets	World Forum	The Hague, Netherlands
June 2011	RD3-12	Xcel Energy	Energy Storage For Integration of Renewables	Colorado Renewable Energy Conference	Ft. Collins, CO
June 2011	RD3-1	U of M	Using Non-Timber Forest Product Markets to Drive Conservation and Community Development in Minnesota	North American Agroforestry Conference	Athens, Georgia
July 2011	RD3-25	U of M	Novel Crystallization of Silicon for Thin Film Solar Cells	20th International Symposium on Plasma Chemistry,	Philadelphia, PA
July 2011	RD3-1	U of M	Willingness of Agricultural Landowners to Supply Perennial Energy Crops	Agricultural & Applied Economics Association's 2011 Annual Meeting	Pittsburgh, Pennsylvania
August 2011	RD3-28	U of M	Soil Carbon Balance - Residue Removal	USDA-NRCS Soil Quality Training	Brookings, SD
August 2011	RD3-12	Xcel Energy	Electricty at the Crossroads: A Smart Grid for the Midwest Workshop	University of Minnesota School of Law	Minneapolis, MN
October 2011	RD3-28	U of M	Yield Response to Corn Stover Harvest in the Northern Corn Belt	ASA-CSSA-SSSA 2011 International Annual Meeting	San Antonio, TX
November 2011	RD3-42	U of M	Turbine Layout Effects on the Flow Structure Inside an Above Large Wind Farms	American Physical Society Meeting	Baltimore, MD
November 2011	RD3-42	U of M	LES Investigation of Turbine Spacing Effects in Wind Farms	64th annual meeting American Physical Society	Baltimore, MD
December 2011	RD3-12	Xcel Energy	Wind-To-Battery Project Preliminary Results	E3 2010 Conference	Minneapolis, MN
February 2012	RD3-53	Interphases	CIS Thin Film Solar Cells Manufacturing Challenges	International Colloquium on Environmentally Preferred Advanced Power Generation (ICEPAG) Conference	Costa Mesa, CA
February 2012	RD3-42	U of M	Characterization of the Turbulence Structure and transport Aprocesses in the Wake of a Wind Turbine	Euromech Colloquium	Oldenburg, Germany
June 2012	RD3-21	NPPT	Synchrophasors for Island Detection	38th IEEE PV Specialist Conference	Austin, TX
July 2012	RD3-21	NPPT	A Statistically-Based Method of Control of Distributed Photovoltaics Using Synchrophasors	IEEE PES General Meeting	San Diego, CA
November 2013	RD3-21	NPPT	The Future Role of Passive Methods for Detecting Unintentional Island Formation	48th Annual Electrical and Computer Engineering	Brooklyn Center, MN

Appendix D —Location of RDF projects by Congressional Districts

RDF Projects (1/1/2011 – 12/31/2012)

RDF Contract	Grant	Type	Cycle	Renewable Category	Host Site		Project Sponsor	
					District	Location	District	Organization
District 1								
EP-51	$936,530	EP	2	Biomass	MN01	Diamond K Dairy, Altura	CA	RCM Digesters, Berkley
RD3-12	$1,000,000	RD	3	Wind	MN01	Beaver Creek, Rock County	MN05	NSP-Minnesota, Minneapolis
District 2								
EP3-13	$894,000	EP	3	Solar	MN02	Afton State Park	MN04	MN DNR, St. Paul
RD3-1	$992,989	RD	3	Biomass	MN02	Rahr Malting, Shakopee	MN04	U of M, St. Paul
RD3-77	$1,000,000	RD	3	Biomass	MN02	P & J Farms, Northfield	IL	Coaltec Energy USA, Carterville
District 3								
RD-50	$957,929	RD	2	Biomass	MN07	Traverse County area	MN03	EPS, Rogers
District 4								
EP3-12	$1,488,922	EP	3	Solar	MN04	Metro area	MN05	freEner-g, Minneapolis
EP3-13	$894,000	EP	3	Solar	MN04	Afton State Park	MN04	MN DNR, St. Paul
RD3-1	$992,989	RD	3	Biomass	MN02	Rahr Malting	MN04	U of M, St. Paul
District 5								
AH-01	$5,100,000	EP	1	Hydro	MN05	Crown Hydro, Minneapolis	MN05	Crown Hydro, Minneapolis
EP-34	$2,000,000	EP	2	Hydro	MN05	St. Anthony Falls, Minneapolis	MN05	U of M, Minneapolis
EP3-10	$2,000,000	EP	3	Solar	MN07	Outland, Slayton	MN05	Outland, Minneapolis
EP3-11	$2,000,000	EP	3	Solar	MN05	Convention Center	MN05	City of Minneapolis
EP3-12	$1,488,922	EP	3	Solar	MN05	Metro area	MN05	freEner-g, Minneapolis
EP3-13	$894,000	EP	3	Solar	MN05	Ft. Snelling State Park	MN04	MN DNR, St. Paul
RD3-4	$924,671	RD	3	Biomass	MN05	Bepex, Minneapolis	MN05	Bepex, Minneapolis
RD3-12	$1,000,000	RD	3	Wind	MN01	Beaver Creek, Rock County	MN05	Xcel Energy, Minneapolis
RD3-42	$999,999	RD	3	Wind	MN05	St. Anthony Falls Laboratory	MN05	U of M, Minneapolis
District 6								
EP3-13	$894,000	EP	3	Solar	MN06	Wm O'Brien State Park	MN04	MN DNR, St. Paul
RD3-2	$350,000	RD	3	Biomass	MN06	Sartec, Anoka	MN06	Sartec, Anoka
District 7								
RD-50	$957,929	RD	2	Biomass	MN07	Traverse County area	MN03	EPS, Rogers
EP3-10	$2,000,000	EP	3	Solar	MN07	Outland, Slayton	MN05	Outland, Minneapolis
EP3-13	$894,000	EP	3	Solar	MN07	Lake Sheteck & Lac qui Parle	MN04	MN DNR, St. Paul
RD3 28	$979,082	RD	3	Biomass	MN07	U of M, Morris	MN07	U of M, Morris
RD3-69	$1,000,000	RD	3	Biomass	MN07	MnVAP, Priam	MN07	MnVAP, Raymond
District 8								
EP-44	$2,000,000	EP	2	Biomass	MN08	CMEC, Little Falls	MN08	CMEC, Little Falls
RD3-66	$999,065	RD	3	Biomass	MN08	Marcel, MN	ND	UND, Grand Forks
RD3-68	$970,558	RD	3	Biomass	MN08	Haubenschild Farms, Princeton	ND	UND, Grand Forks

INFORMATION SHEET
RENEWABLE DEVELOPMENT FUND

Investing in Renewable Energy

TORREFACTION AND DENSIFICATION OF BIOMASS FUELS FOR GENERATING ELECTRICITY

Project Description

The project researched torrefaction and densification of biomass feedstocks to develop an efficient and economical supply chain for biomass feedstocks. Torrefaction is a process that uses mild heat (200 to 320°C) to remove water and volatiles contained in woody biomass. The process produces a charcoal-like solid containing the cellulose and lignin and is referred to as "bio-coal." The torrefied material is compressed into pellets for easier handling and storage.

Methodology

The project was to develop, optimize and demonstrate a torrefaction and densification process that would produce a biomass product with good storage capabilities, could be handled and transported by conventional methods, and provide uniformity of biomass feedstocks for the production of renewable base load electricity, heat or syngas. Bepex conducted an economic feasibility study and process modeling to determine mass and energy balance data from torrefaction.

A torrefaction and densification system was designed and constructed to produce a biocoal product to be utilized at commercial power plants. Co-firing tests were conducted at District Energy St. Paul.

Executive Summary

The project demonstrated that the torrefaction process is a technically feasible strategy to utilize biomass in pulverized coal power plants. Through torrefaction and densification, biomass can be transported, stored and co-fired with coal. Information generated from this project identifies when it would be economically advantageous to use this technology. Torrefaction upgrades raw biomass into a coal-like substance or biocoal that has an increased energy density and does not absorb moisture or decompose. The project developed a fundamental understanding of the underlying economics of the overall torrefaction process from the field to post-combustion ash analysis.

Grantee: Bepex International LLC
Project Dates: 7/28/2008 – 9/7/2011
RDF Funding Cycle: 3
Project Funding: $924,671 RDF Grant (Total project cost $924,671)
Project ID: RD3-4
RDF Mission: To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

Contact:
Renewable Development Fund
Xcel Energy - GO 7
414 Nicollet Mall
Minneapolis, MN 55401
rdfstaff@xcelenergy.com
www.xcelenergy.com/rdf

TORREFACTION AND DENSIFICATION OF BIOMASS FUELS FOR GENERATING ELECTRICITY

Benefits

Torrefaction and densification alters raw biomass to have characteristics similar to coal. This process produces a biocoal product that can replace coal and reduce fossil fuel emissions.

- A fuel mixture that replaces 10 percent of the coal with biocoal demonstrated an emission reduction of 17 percent for sulfates and 15.6 percent for nitrates
- Increased bulk density allowing more cost effective transportation and storage
- Increased grindability compared to raw biomass allowing cofiring with coal produce steam, heat or electricity
- Lacks ability to absorb water, which reduces rot and waste
- Can use same methods and infrastructure to transport, handle and store coal
- No chemicals or binders required to form briquettes and reduce dust

Lessons Learned

- Torrefaction is a value added process to improve the usability of biomass in an industry based upon coal
- Processing costs to produce biocoal is $17.64 per ton plus the cost of the raw biomass
- The use of corn stover biocoal proved to be technical feasible at existing pulverized coal power plants to produce electricity
- Proved biocoal specifications meet known minimum requirements for use in pulverized coal boilers, stoker grates, and gasification systems
- Proved feasible and statistically relevant reductions in emission profiles compared to coal

RDF Mission:
To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

INFORMATION SHEET
RENEWABLE DEVELOPMENT FUND

A Solar Solution for Residential Markets

Project Description

freEner-g, LLC installed 25 roof-top mounted solar photovoltaic (PV) systems that had an aggregate nameplate capacity rating of 280 kW. Seven systems were installed on commercial buildings and 18 systems were installed on residential homes. The average residential install was 4.07 kW and included a variety of roof pitches and configurations. Commercial systems averaged 33.81 kW and also included a variety of array configurations, racking systems and angle of tilt.

Methodology

- Conducted a web-based pricing sensitivity survey to explore the viability of solar leasing and the pricing sensitivity ('willingness-to-pay') of the Twin Cities market.
- Identified homeowners and business owners who wanted to install solar on their property.
- Designed and installed a solar array based upon the solar power production capacity and roof for selected properties.
- Installed web-monitoring at: **http://enlighten.enphaseenergy.com/installer_systems/590/freEner-g** for real-time and historical performance.

Executive Summary

The project demonstrated the commercial viability of providing solar-generated electricity based on a leasing and service package. There is an apparent need for this financing tool to overcome pricing and capitalization barriers in the solar market, which have been documented to be the primary obstacles to solar expansion.

Grantee: freEner-g, LLC, dba Solarflow Energy
Project Dates: 2/10/2008 – 2/17/2011
RDF Funding Cycle: 3
Project Funding: $1,488,922 RDF Grant (Total project cost $2,189,871)
Project ID: EP3-12
RDF Mission: To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

Contact:
Renewable Development Fund
Xcel Energy - GO 7
414 Nicollet Mall
Minneapolis, MN 55401
rdfstaff@xcelenergy.com
www.xcelenergy.com/rdf

A SOLAR SOLUTION FOR RESIDENTIAL MARKETS

Benefits

- Developed best practices in the area of permitting and inspections of small, solar PV systems
- Renewable Energy Credits generated
- Electricity generation of 355 MWh/year will reduce annual emissions of CO_2 by 428,130 pounds, SO_2 by 959 pounds, and NO_x by 675 pounds

Lessons Learned

- The viability of solar leasing depends on various incentives, such as solar rebates and Investment Tax Credits. Such rebates and tax credits make solar leasing attractive to private capital.
- An initiative to streamline and standardize permitting is very broad in scope and will take years
- The commercial market was more price sensitive and the leasing model had to show savings in relation to electricity costs
- The duration of the lease was a lesser concern for businesses compared to residents. On average, commercial leases were 18 years while residential leases were 15 years.
- For the residential market, solar lease pricing had to be approximately equal to the current cost of electricity
- Demand charges paid by business customers are a major cost and reduce the benefits of the commercialization of solar power

Outcomes

- The average residential installation cost was $6.90/watt and the average commercial installation cost was $5.70/watt
- 79 percent of facilities cited both environmental and pricing as the two basic reasons for their decision to install solar
- 280 kW of generating capacity was installed
- Six full time “green” jobs were created

RDF Mission:
To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

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INFORMATION SHEET
RENEWABLE DEVELOPMENT FUND

Investing in Renewable Energy

LOWER SAINT ANTHONY FALLS HYDROELECTRIC FACILITY PROJECT

Project Description

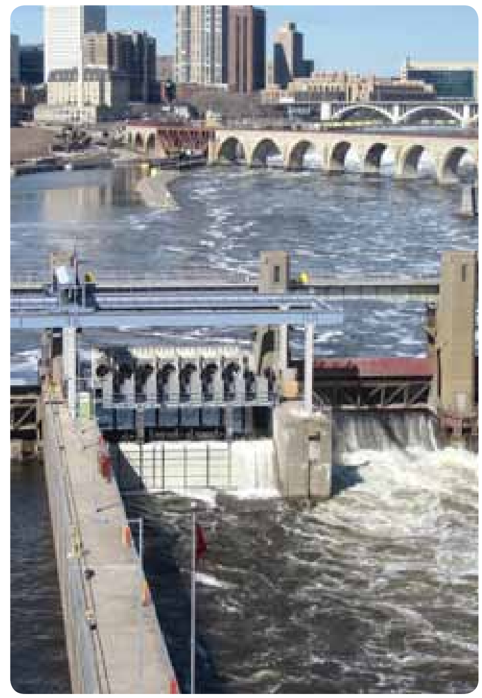
SAF Hydroelectric, LLC (SAF) installed a 9.176 MW run-of-river hydroelectric facility in the auxiliary lock at Lower Saint Anthony Falls that is estimated to generate sufficient electric energy annually to power about 7,500 homes. The facility consists of concrete encased draft tubes that have downstream gates to control water flow and removable turbine modules on the upstream side. A set of four spillway gates were installed to provide additional control of river flow. The facility utilizes an array of 16 submerged matrix turbines, which are unique in the United States. A successful demonstration of this technology may lead to greater use at run-of-the river locations elsewhere in the United States.

Methodology

In 2001, SAF submitted a license application to the Federal Energy Regulatory Commission (FERC). After the evaluation and study of project impacts, FERC license #12451 was issued on February 21, 2006. The license provided the authority to construct and operate a hydropower facility on the Mississippi River at Lower Saint Anthony Falls Lock and Dam in Minneapolis. Throughout the process, SAF worked with the U.S. Army Corps of Engineers (USACE) on design and construction standards. The project can utilize up to 6,201 cubic feet per second of river flow. The tragic collapse of the I-35W Mississippi River bridge in August 2007 delayed the project by approximately two years. Construction began in April 2009 and the facility achieved commercial operation in December 2011.

Executive Summary

Sixteen StrafloMatrix turbines were placed in the auxiliary lock chamber of USACE's Lower Saint Anthony Falls Lock and Dam in Minneapolis. The auxiliary lock chamber had been built to allow for continued navigation growth, but its use for this purpose has become unnecessary. The SAF facility will generate clean, zero emission, renewable power. The new facility restores hydropower production at Lower Saint Anthony Falls with minimal impact on the river, the dam, and the surrounding area.



Grantee: SAF Hydroelectric, LLC
Project Dates: 6/5/2006 – 1/31/2012
RDF Funding Cycle: 2nd
Project Funding: $2,000,000 RDF Grant (Total project cost $39,993,881)
Project ID: EP-34
RDF Mission: To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

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Electricity generated qualifies for the state's renewable energy standard and is sold to Xcel Energy through a 20 year power purchase agreement.

Benefits

- Placement of the facility in the existing USACE dam utilized an existing civil works feature and simplified the construction process
- Construction activities did not interfere with regular lock operations and the completed project allows continued safe use of the lock for commercial and recreational river traffic
- Obermeyer spillway gates help maintain consistent water levels in the pond
- Useful in the re-evaluation of other hydropower project sites that could utilize run-of-river technology

Lessons Learned

- StrafloMatrix turbines well suited for low-head rivers such as the Mississippi
- Power purchase agreement, RDF Grant, Renewable Energy Production Incentives and Federal stimulus funding allowed this project to be economically viable
- Unforseen delays and product challenges lead to a more expensive project than initially projected
- Lessons learned regarding coating and cable enclosures should improve product design and installation for future projects

Outcomes

- Restore electrical generation potential of the Mississippi River to the heart of Minneapolis
- Interpretive display increases awareness of hydropower history at the site
- Demonstrates run-of-the-river turbine technology
- Demonstrate how existing dams can be economically developed for renewable hydroelectric generation

Authority

Licensing of hydropower facilities is governed by Part I of the Federal Power Act, 16 U.S.C. §§ 791(a) – 825(r). Licensing at USACE facilities is also governed by a 1981 Memorandum of Understanding between FERC and the USACE.

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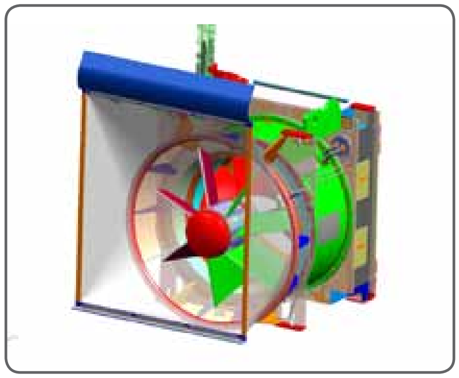

StrafloMatrix turbine

INFORMATION SHEET
RENEWABLE DEVELOPMENT FUND

Investing in Renewable Energy

FLUE GAS CARBON DIOXIDE CAPTURE WITH RAPID GROWTH ALGAE TO PRODUCE BIODIESEL AND RENEWABLE FUELS

Project Description

Algae are plants that feed on Carbon Dioxide (CO_2). Faster growing algae consumes and captures higher amounts of CO_2 to generate more biomass. SarTec selected a fast growing alga that also had high oil content. Alga lipids were extracted from the biomass and converted to biodiesel to produce an easily marketable product. Algae sequestration of CO_2 and the conversion of lipids to biodiesel produce a valuable, renewable, universally consumed fuel while helping to reduce green house gas emissions when fed CO_2 rich flue gas from a coal-burning power plants.

Methodology

The alga species *Dunaliella tertiolecta* was selected from several other algae species for a relatively fast growth rate and high lipid content. Algae growth was studied in both outdoor conditions with natural light and controlled indoor conditions with continuous light and temperature controls. Artificial, fluorescent light is less intense than natural sunlight but is consistent from day-to-day. Algae were harvested through centrifugation then dried and pulverized, and the lipids were extracted and converted into biodiesel through the Mcgyan processes developed by SarTec.

Executive Summary

This research investigated a process for using algae to capture CO_2. The basis of this study was to investigate fast growing algae strains for capturing CO_2 and converting the resultant algae into renewable fuels. The biofuel can be sold to produce revenue to partially defray the costs associated with CO_2 capture. It also has the potential to create revenue from carbon credits. Overall, this CO_2 capture/biodiesel process will partially close the carbon cycle at coal-fired plants and reduce fossil carbon emissions.

Grantee: SarTec Corporation
Project Dates: 6/11/2009 – 7/11/2011
RDF Funding Cycle: 3
Project Funding: $350,000 RDF Grant (Total project cost $350,000)
Project ID: RD3-2
RDF Mission: To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

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Benefits

- CO_2 emissions from a coal-fired power plant that are directed into microalgae could be a cost effective method for carbon sequestration
- Algae have a value for making biodiesel fuel or biochemicals
- Algal solids can be burned to help fuel the generation of electricity
- Algal components, such as protein, could potentially be sold as additives for animal feed, fertilizer or other products

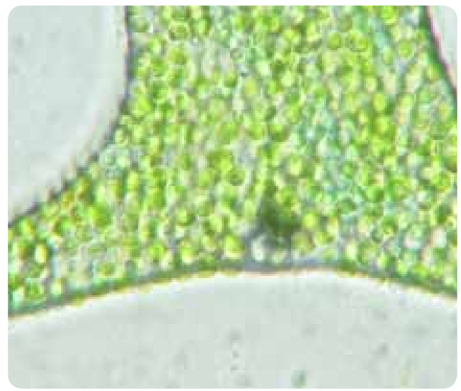
Lessons Learned

- Light penetration, circulation of the algae cultures and an uninterrupted flow of CO_2 are essential to a thriving algae population
- Maintaining a pH that is neutral or somewhat acidic ensures more efficient utilization of CO_2 and higher growth rates
- Outdoor cultures are more likely to have problems with competing organisms that also consume CO_2 or feed upon the algae versus a controlled, indoor environment
- To sustain high growth rates, harvesting at the most appropriate stage of growth helps prevent algal self-shading
- There are limitations on re-using the post-harvest algae growth medium due to build up of metabolites such as glycoproteins, which inhibit algae growth
- Due to competition, *D. tertiolecta* cells decreased in size as their growth rate increased but did not affect biomass production
- Aging algae lose vigor which requires the occasional introduction of new algae organisms to retain rapid growth rates
- Harvesting algae can be time consuming and energy intensive due to the high percentage of water that needs to be removed

Outcomes

- Significant quantities of carbon were captured by the algae in intensive culture environment and shown to be a viable means to capture CO_2 emissions
- Algae can produce feedstock oil for biodiesel fuel at a higher rate than traditional soybean oil productivity
- Revenue generating products can offset sequestration costs
- Utilizing algae as a feedstock will not compete with food crops to produce fuel

RDF Mission:
To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.



INFORMATION SHEET
RENEWABLE DEVELOPMENT FUND

Investing in Renewable Energy

BIOMASS ELECTRICITY GENERATION AT ETHANOL PLANTS - ACHIEVING MAXIMUM IMPACT

Executive Summary

Generating electricity at corn ethanol plants using biomass fuel offers the opportunity to reduce the carbon footprint of the ethanol produced and to send renewable electricity to the grid. The electricity sent to the grid is renewable, dependable (baseload) power that complements power from other renewable sources that are variable such as wind and solar. Generating electricity in a combined heat and power mode works well because the ethanol plant has an almost constant year around need for process heat.

Methodology

A BIGCC system was modeled to maximize the generation of electricity and process heat within an ethanol plant. A BIGCC system gasifies biomass and uses the synthesis gas to fuel a gas turbine to generate electricity. Waste heat from the gas turbine produces superheated steam, which is run through a steam turbine to produce additional electricity. After leaving the steam turbine, the steam is condensed in various parts of the ethanol plant to meet the process heat needs of the facility.

Project Description

The University of Minnesota created the Biomass Integrated Gasification Combined Cycle (BIGCC) model to explore ways to maximize the amount of electricity an ethanol plant could generate while still meeting the process heat needs for the facility. The model evaluated the use of biomass (distillers grain, wood chips and corn stover) as the fuel to replace natural gas for heat needs of the ethanol plant. Also evaluated was the affect of substituting superheated steam drying for steam tube drying.

Benefits

- BIGCC technology could reduce the life-cycle greenhouse gas (GHG) emission for corn ethanol production by 30 percent compared to natural gas
- Investment opportunities and tax advantages for a biomass business entity that would produce electricity and steam which is sold to the ethanol plant and unused electricity is sold via the grid
- Provides baseload electrical energy
- Reduction in GHG emissions of about 12 percent compared to natural gas, and seven percent compared to coal

Grantee: University of Minnesota
Project Dates: 10/22/2008 – 8/1/2011
RDF Funding Cycle: 3
Project Funding: $729,717 RDF Grant (Total project cost $729,717)
Project ID: RD3-23
RDF Mission: To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

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Lessons Learned

- Policies that reward the reduction of greenhouse gas emissions are necessary to support the large capital investment of BIGCC technology
- If widely adopted, Minnesota ethanol plants could increase the baseload renewable generating capacity by up to 500 MW
- Biomass alternatives become economically attractive when the price of natural gas is approximately $10 per million Btu
- Superheated steam drying reduced energy required for ethanol production and saves water through reuse
- Opportunities for adopting BIGCC technology improve with higher prices for fossil energy, particularly natural gas

Outcomes

- Model demonstrated that employing BIGCC power generation offers the potential at corn ethanol plants to produce low carbon fuel and renewable electrical energy
- Implementing natural gas combined cycle systems at ethanol plants may offer a transition strategy for gaining some of the advantages of low carbon fuel and electricity, especially when natural gas prices are low
- Extensive outreach with 47 presentations, seven conference papers and three published articles
- Development of website: biomassCHPethanol.umn.edu

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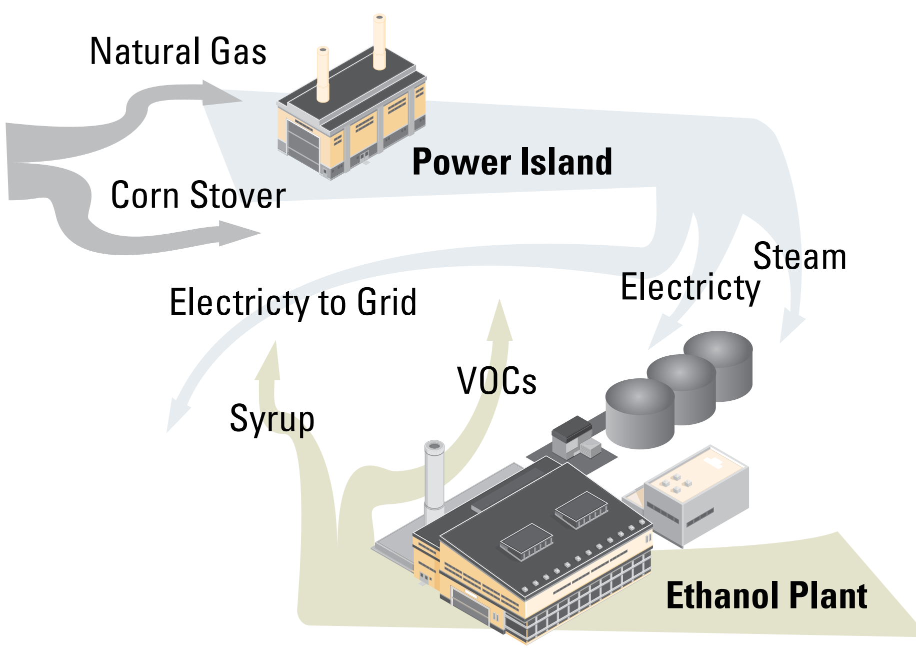
Major Flows of Materials and Energy



INFORMATION SHEET
RENEWABLE DEVELOPMENT FUND

Investing in Renewable Energy

EMBEDDED NANOCRYSTAL SILICON FILMS: A NEW PARADIGM FOR IMPROVING THE STABILITY OF THIN-FILM SILICON

Executive Summary

A new and radically different technique was explored to control the microstructure of hydrogenated amorphous silicon and to improve the grain size of microcrystalline silicon (Si) thin films. Thin-film technology can reduce manufacturing costs of photovoltaic (PV) devices but this saving is negated by the lower efficiencies and poor stability of thin-film Si cells. The University of Minnesota (U of M) studied gains in efficiency and stability for amorphous Si thin-film cells by controlling the micro-structure of the amorphous hydrogenated silicon. In addition the microcrystalline large grain sizes rivaled wafer-based single-crystal silicon produced through conventional manufacturing.

Project Description

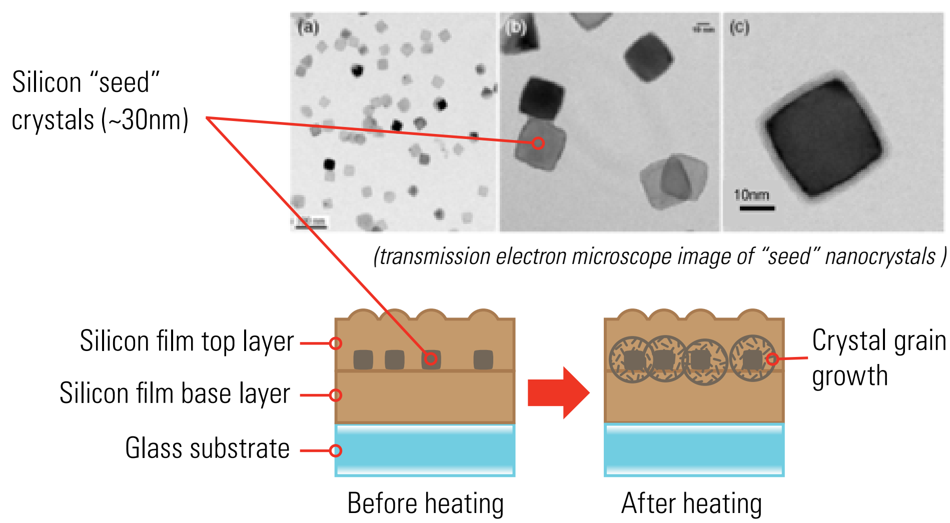
The project researched two methods for increasing the efficiency and lowering the cost of thin film silicon solar cells. The first approach was to produce silicon nanocrystals in a low-pressure plasma-based synthesis reactor and embed nanocrystals in amorphous silicon films. This deposition process provides the ability to independently control properties of the amorphous matrix and crystalline phase, which improves the electronic quality of amorphous silicon. In the second approach the U of M researchers embedded nanocrystals as nuclei for seed-induced re-crystallization of amorphous silicon films.

Methodology

Embedded nanocrystals reduce the degradation and efficiency of PV membrane caused by light. Large-grain recyrstalized Si speeds up the growth of crystals.

Embedded nanocrystals were used as nuclei for seed-induced recrystallization of amorphous silicon films. Seed concentrations were controlled to enable faster growth of microcrystalline silicon films with granular sizes larger than produced by other deposition approaches. Amorphous silicon films with embedded nanocrystals were studied to understand whether the inclusion of nanocrystals may improve stability with respect to light-induced degradation, leading to improvements in the conversion efficiency of amorphous silicon PV cells.

"Seeding" films to grow large crystal grains



(transmission electron microscope image of "seed" nanocrystals)

Grantee: University of Minnesota
Project Dates: 10/22/2008 – 12/26/2011
RDF Funding Cycle: 3
Project Funding: $732,032 RDF Grant (Total project cost $732,032)
Project ID: RD3-25
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EMBEDDED NANOCRYSTAL SILICON FILMS: A NEW PARADIGM FOR IMPROVING THE STABILITY OF THIN-FILM SILICON

Benefits

The outcomes of this research project may have significant benefits for the manufacture of thin film silicon solar cells.

- Increased stability may lead to solar cells that can maintain higher efficiency after prolonged solar irradiation
- Good optical absorption allows the films to remain relatively thin
- Reduction of manufacturing cost of amorphous silicon solar cells by about 30 percent
- Elimination of the incubation time by seeding of the films
- Reduced time needed for crystallization during film production and capital

Lessons Learned

- Inclusion of a small fraction of silicon nanocrystals into the amorphous silicon matrix led to films with improved electrical conductivities and reduced susceptibility to light inducted defect creation
- Seeding of amorphous silicon with nanocrystal seeds enabled faster production of microcrystalline silicon through thermal treatment of the seeded amorphous silicon films
- Inclusion of nanocrystal seeds eliminated the incubation time for the seed formation and yielded better control
- Doping by inclusion of Si nanocrystals may yield superior materials for all solar cell applications

Outcomes

This research has shown that the co-deposition of Si nanocrystals into amorphous silicon opens up two attractive routes towards producing more efficient, cost-effective PV cells:

- The inclusion of Si nanocrystals into amorphous silicon leads to a mixed phase material that is more resistive to light-induced defect creation than standard amorphous silicon
- The recrystallization of amorphous silicon seeded with nanocrystal grains enables to control the crystallization kinetics and electronic properties of the microcrystalline Si material produced
- Silicon based technologies face none of the toxicity and limited raw materials associated with conventional PV manufacturing

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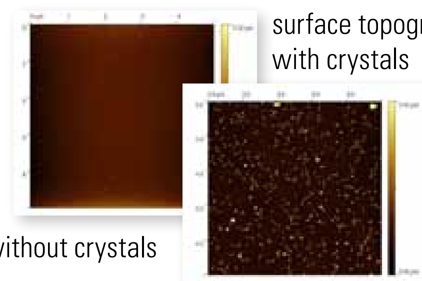
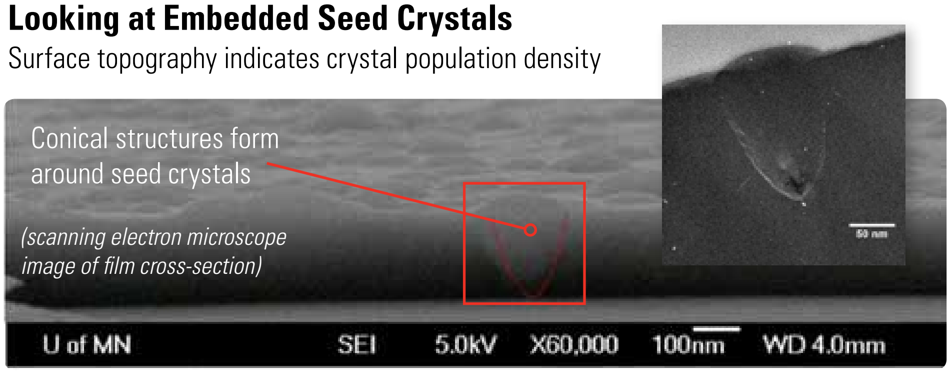


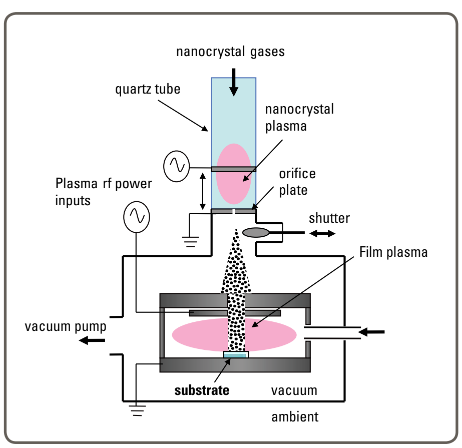
surface topography with crystals

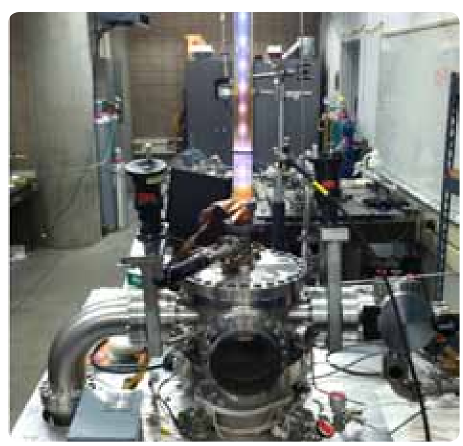
without crystals

Looking at Embedded Seed Crystals

Surface topography indicates crystal population density







INFORMATION SHEET
RENEWABLE DEVELOPMENT FUND

Investing in Renewable Energy

SODIUM SULFUR BATTERY ENERGY STORAGE AND ITS POTENTIAL TO ENABLE FURTHER INTEGRATION OF WIND

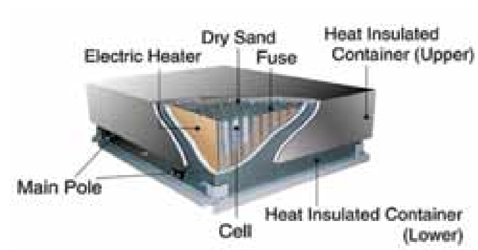
Project Description

Xcel Energy installed a one megawatt (MW) wind energy battery storage system, using sodium sulfur ("NaS") battery technology, to validate the value of energy storage on the Xcel Energy system. NaS technology was selected because it has: high storage capacity; ability to handle numerous charge-recharge cycles from an intermittent wind source; potential for large scalability; a dynamic response to system changes; and was commercially available. The battery system is roughly the size of two semi-trailers stacked one on top of the other and stores about 7.2 megawatt-hours (MWh) of electricity. When fully charged, the battery could power 500 homes for more than seven hours.

Methodology

The project was based near Luverne, Minn. with the battery installation adjacent and connected to an existing 11 MW wind farm. The battery went on-line in October 2008. Testing the battery under five different operating modes commenced at that time and continued throughout the project. Operating modes included: basic storage; economic dispatch of electricity based on market prices to capture arbitrage benefits; frequency regulation; wind smoothing; and wind leveling. Data was collected to evaluate battery impact from different charging and discharging cycles and cell life.

Partners
Minwind Energy LLC – Wind facility
S&C Electric – Project engineer
NGK Insulators- Battery manufacturer
GridPoint- Communication for system integration
University of Minnesota – Cost analysis
Great Plains Institute – Policy analysis
National Renewable Energy Laboratory – Integration analysis



Grantee: Xcel Energy Services, Inc.
Project Dates: 5/8/2009 – 4/15/2012
RDF Funding Cycle: 3
Project Funding: $1,000,000 RDF Grant (Total project cost $4,247,181)
Project ID: RD3-12
RDF Mission: To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

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SODIUM SULFUR BATTERY ENERGY STORAGE AND ITS POTENTIAL TO ENABLE FURTHER INTEGRATION OF WIND

Executive Summary

Integrating a variable wind resource with a power grid that requires a high level of reliability is a challenging issue for the electrical industry. The project tested the hypothesis that effective storage of wind energy enables 'smoothing' of wind energy and reduces the impacts from the variability and limited predictability of wind generation resources. How battery energy storage supports the transmission and distribution grid was also evaluated, which is essential to integrating a much larger percentage of wind resources into the regional energy resource mix.

Benefits

There is a real potential for affordable energy storage systems in the next five years. Because of the knowledge gained, Xcel Energy is better positioned to strategically implement energy storage technology. Xcel Energy's customers have benefited from:

- Increased energy storage flexibility over traditional peaking resources because it is both a dispatchable load and a dispatchable generator
- Understanding how to determine a beneficial price range for energy storage deployment
- The fast-response services that a commercial storage system provides to the transmission system
- Increased company expertise in essential energy storage system functions
- Improved penetration of distributed generation by managing grid issues related to system reliability and performance

Lessons Learned

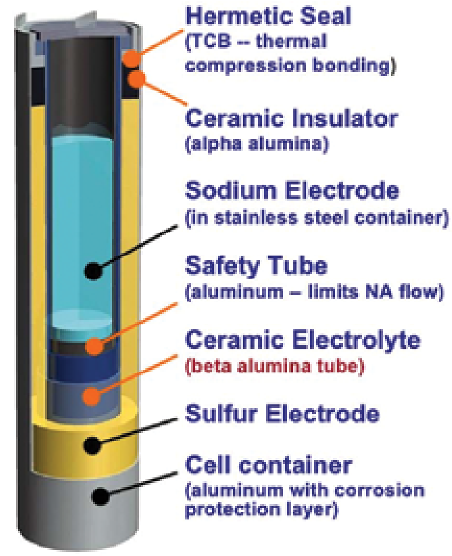
Xcel Energy gained an understanding of how to determine the price range at which energy storage will be cost beneficial.

- Based on arbitrage value, the optimum battery capacity to wind farm capacity appears to be between 20 percent and 40 percent
- Battery storage can smooth a wind resource's output ramp rate and provide a time shift function with the same system during the same time
- Offering the battery system in the MISO ancillary services market for stored energy resources can deliver more revenue than operating the system for arbitrage value
- Bulk energy storage assets must be competitive in price to traditional peaking generation
- A one MW battery effectively levels one MW of installed wind capacity

Outcomes

Test results indicate that the battery has the ability to:

- Effectively shift wind energy from off-peak to on-peak availability
- Reduce the need to compensate for the variability and limited predictability of wind resources
- Support transmission grid reliability by providing voltage support
- Support a regional electricity market by responding to real-time imbalances between generation and load



RDF Mission:
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