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HEARING ON EXAMINING STRATEGIES TO REDUCE GREENHOUSE GAS EMISSIONS AT U.S. COLLEGES AND UNIVERSITIES

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

APRIL 3, 2008

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ONE HUNDRED TENTH CONGRESS
SECOND SESSION

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C O N T E N T S

Page

THURSDAY, APRIL 3, 2008

OPENING STATEMENTS

Klobuchar, Hon. Amy, U.S. Senator from the State of Minnesota 1
Craig, Hon. Larry E., U.S. Senator from the State of Idaho 3
Sanders, Hon. Bernard, U.S. Senator from the State of Vermont 4
Whitehouse, Hon. Sheldon, U.S. Senator from the State of Rhode Island 5

WITNESSES

Birgeneau, Robert, Chancellor, University of California, Berkeley 7
Prepared statement 10
Johnson, Jacqueline, Chancellor, University of Minnesota, Morris 31
Prepared statement 34
Levin, Richard C., President, Yale University 75
Prepared statement 78

HEARING ON EXAMINING STRATEGIES TO REDUCE GREENHOUSE GAS EMISSIONS AT U.S. COLLEGES AND UNIVERSITIES

THURSDAY, APRIL 3, 2008

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

The full committee met, pursuant to notice, at 10 a.m. in room 406, Dirksen Senate Office Building, Hon. Amy Klobuchar (member of the full committee) presiding.

Present: Senators Klobuchar, Craig, Sanders and Whitehouse.

OPENING STATEMENT OF HON. AMY KLOBUCHAR, U.S. SENATOR FROM THE STATE OF MINNESOTA

Senator KLOBUCHAR. The hearing will come to order.

Senator Boxer is going to be joining us soon, and she asked me to sit in and begin this important hearing, which is entitled Examining Strategies to Reduce Greenhouse Gas Emissions at U.S. Colleges and Universities.

We are very pleased that we have our guests here today. We have Robert Birgeneau, who is the Chancellor of the University of California at Berkeley. I will say, Dr. Birgeneau, that I saw the other day Mark Yudof, who is going to be heading up the University of California system, who previously left the University of Minnesota where he was much loved, and then went to Texas. So you are very lucky to have him there. He also would host pancake breakfasts every so often. Maybe that was more of a Minnesota thing. I don't know what he will do in California, maybe granola. I don't know.

We also have Dr. Jacqueline Johnson with us. She is the Chancellor at the University of Minnesota at Morris. We are pleased to have her here. I visited the campus on my tour of all 87 counties in Minnesota, and was so impressed by the work that they are doing with the wind turbine and everything else, and really the whole university community is a part of it. I think it will give us a different perspective, more of a rural perspective of what colleges and universities are doing.

And then we also have Dr. Richard Levin here from Yale University. I was honored to speak on climate change in front of the Yale trustees about a month ago. I know that Yale has been doing great work in this area as well.

I thank each of you for being here today. I believe each of you has recognized the challenges of climate change, and have taken

steps toward reducing the universities' carbon footprint, doing something about it, working with not just faculty, but also students and alumni to make sure that they understand that this is so important to our entire world going forward.

I know that all of you have had unique initiatives. President Levin, I have gotten the information on what you have done, and Yale has been committed to reducing greenhouse gas emissions on campus to 10 percent below 1990 levels by the year 2020. What interests me most, and I know interests some of my colleagues who are going to be coming shortly, is the fact that Yale plans on expanding its 13.5 million square foot campus by nearly 20 percent during the same time. I think this underscores this idea that you can expand economically and still be able to reduce carbon dioxide. In fact, with new buildings it is probably easier to do.

Chancellor Birgeneau, I understand that you have made a similar commitment, and we look forward to hearing about some of the climate research programs at Berkeley.

As I mentioned, Chancellor Johnson, you have been doing great work there, and the fact is that by 2010, your campus will be carbon-neutral. But what is even more impressive is that the University of Minnesota at Morris has achieved this carbon neutrality completely through onsite generation.

Today's hearing is about more than specific greenhouse gas reduction strategies. It is also about how colleges and universities can have a unique role to play in this important work. I truly believe that we have to act quickly to develop the technologies and strategies to address climate change before other nations do. Not only is it an environmental necessity and obligation, but it is also an economic necessity. We have seen first-hand in our State the wind turbines all over. We just went to No. 3 in the Country with wind energy, and it has really been a boon to our rural economies in Minnesota.

By eliminating our own greenhouse gases and conducting vital climate researches, colleges and universities across the Country are leading the fight against global warming. They are educating and training the next generation of engineers, architects, business leaders and scientists to build and compete in a low-carbon economy.

I often use the example of the space race and Sputnik and all of the great technology that came out of our colleges and universities and those devoted to this research just because we wanted to put a man on the moon. We can do the same thing here with this challenge that we are faced with. We did everything from developing CAT scans to space sticks, which my family used on hiking trips in Wyoming, Senator Craig, in the western part of our State.

Senator CRAIG.

[Remarks made off microphone.]

Senator KLOBUCHAR. What?

Senator CRAIG.

[Remarks made off microphone.]

Senator KLOBUCHAR. Yes. Well, of course.

This all came out of, again, the Nation's commitment to doing something to move our Country ahead.

The National Renewable Energy Labs have identified a shortage of skilled workers as one of the leading barriers to deployment of clean energy technologies. High schools, vocational schools, junior colleges, labor management apprenticeship programs and, yes, colleges and universities like yours will be all called on to prepare our young people to fill the gap.

So I look forward to hearing about the ways in which colleges and universities are incorporating climate matters into their curriculum and what more can be done. I also look forward to learning more about how successes achieved on campuses are being scaled up to the community and State level and what more can be done to accelerate that process.

So I thank each of you for being here.

Senator KLOBUCHAR. I know my colleagues would like to make brief opening remarks.

Senator Craig.

OPENING STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM THE STATE OF IDAHO

Senator CRAIG. Madam Chairman, thank you very much.

And to all of you chancellors who have joined us today, thank you for being here and participating in this hearing.

I must say at the outset, Madam Chair, that the hearing came as a bit of a surprise in relation to its timing. I say that because it was very difficult for all of our staffs on this side to properly scope and get ready for it. So it has reduced me to suggesting and this is to you, Dr. Levin that this is an alumni gathering for Yale, and probably that in itself makes it worth turning on the lights and assembling the staff, because we have obviously the Chair as an alum as well as committee members Senator Lieberman, Senator Clinton and Senator Whitehouse. So congratulations. That in itself is worth the gathering.

But I must say, Madam Chair, that in looking at the totality of what universities are doing today, it is important that we get it right. Again, I look at the timeliness of the meeting and the proper preparedness that went into it. I am looking at a memo that suggests four universities tied to the Chicago Climate Exchange, and they missed four for some reason. They missed my University of Idaho. They missed Tufts. They missed Hadlow College, and they missed the University of California at Irvine.

So let's get it right as we talk about these critical and important issues, and that in no way belittles the universities that are before us today. Michigan State, they said it was the University of Michigan.

I happen to watch these things very closely, as does my staff. Timeliness and preparedness are critical to good scoping in the preparation of a hearing. The President of my alma mater at the University of Idaho brags that the University of Idaho has the lowest carbon footprint per student of any school in the Exchange. We are very proud of that because Idaho itself has the lowest carbon footprint of any State on a per capita basis. Idaho will further reduce its emissions by 6 percent, not by 2020, but by 2010, on the guidelines of the membership of the CCX in Chicago.

With that said, I will yield my time, because as we get to the testimony and the questions, the role that universities play in educating and training the work force that the Chairman has spoken to is critical. We know right now that we are stressed out as we try to bring clean energy online from the nuclear side of the equation, that we simply don't have the talent that we need and the skills necessary, and that is going to take time to make sure that can come online appropriately and safely, so those roles are played dramatically and very importantly by our universities.

I look forward to your testimony.

Thank you, Madam Chair.

Senator KLOBUCHAR. Thank you, Senator Craig.

Just to clarify, we did try to have a geographic representation with the East, the Midwest, and the West, with a private and a public school. I talked to Chairman Boxer about having an additional hearing. I understand that we did offer your side to provide a witness, and we can do it again with more timing.

Senator CRAIG. Timing is important for preparedness and accuracy. You are absolutely right.

Senator KLOBUCHAR. OK. I would also note for the record that President Bush also went to Yale.

Senator CRAIG. Oh, dear.

[Laughter.]

Senator KLOBUCHAR. We have Senator Sanders here.

Senator SANDERS. I did not go to Yale.

[Laughter.]

OPENING STATEMENT OF HON. BERNARD SANDERS, U.S. SENATOR FROM THE STATE OF VERMONT

Senator SANDERS. Thank you very much for being here. This is in fact an important hearing. The reason that it is an important hearing is not just that colleges and universities all over this Country, some are smaller, some are larger, consume a lot of energy, and like every other entity, we want to see them become more energy efficient. But there is something obviously unique about colleges and universities, and that is they are educating the future of this Country.

So to the degree to which you can involve your student body in greening your campuses, developing sustainable energy, moving toward energy efficiency, what you are doing is you are educating an entire new generation who will leave your schools, go out into the world, and take the lessons that were learned on your campuses.

That, if I may mention, Madam Chairman, is one of the reasons why I, in the recently passed energy bill, introduced a provision which will provide financial support to institutions of higher education as they look to increase more onsite renewable energy and to become more energy efficient. So we now have within the energy bill a provision that should help potentially over a period of time every campus in this Country.

This program supports institutions of higher education through multiple grant opportunities. Taken together, the projects to be funded through the program must develop renewable energy facilities, improve the energy efficiency of buildings, or promote innovative energy sustainable projects.

One of the most exciting parts of this new program is that the colleges and universities must involve their students and local communities in their efforts. That is when you apply for a grant, that is one of the components of the grant. So you work with your students in greening up your campuses.

The other part of the provision is that then you have to tell your communities, your cities, your States what you are doing because colleges and universities virtually all over this Country play a unique role. People look to you, and it is not only the football game or the basketball game. You develop an energy-efficient project all over the State, you will get the publicity, and people will say, wow, Yale did something really extraordinary, what can we learn from that? Or we have something in Minnesota or wherever.

As I mentioned, we have that provision in law, and right now, along with Senator Kerry, we are requesting support from our colleagues to fully fund that provision. I want to thank one of our witnesses, Jacqueline Johnson, the Chancellor of the University of Minnesota at Morris, for signing a letter which has dozens and dozens of signatures on it, seeking full funding of this legislation. And I want to thank my colleague, Senator Warner, for supporting the efforts to get full funding as well.

I want to also thank all of our witnesses for being here and for the good work that you are doing.

So we see that the passage of this provision and the funding of this provision could provide the kind of funds that will really increase the efforts that many campuses are making in America and put you in the forefront of moving this Country away from fossil fuels to energy efficiency and to sustainable energy.

Madam Chair, thank you.

Senator KLOBUCHAR. Thank you very much, Senator Sanders.

Senator Whitehouse has joined us.

OPENING STATEMENT OF HON. SHELDON WHITEHOUSE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator WHITEHOUSE. I am delighted that we varied from the Yale alumni program briefly to have Senator Sanders say a few words, but I want to welcome the panel and particularly express my appreciation to President Levin. Not only am I an alum, but I am a parent at the moment. I am very pleased to see you here.

My daughter reports about how energetically her sustainability class is working with the university on issues that actually pertain to the university's policies. So the manner in which the university has combined its educational and management roles around this I think is very helpful and I appreciate it very much.

I hope we all recognize how quickly Yale graduates can move up in the Senate. We have a brand new freshman Senator, senior to me, but still a freshman Senator who is chairing the hearing. So it is a great thing.

I wanted to just add to the record. I will ask unanimous consent that my full statement be made a part of the record. But I would like to note that Ruth Simmons, the President of Brown University, was in Washington yesterday giving a speech to the Economic Club of Washington. I went to hear her remarks. She said this: "Who would have predicted a century ago the environmental deg-

radation that has led to climate change? Yet, science stands ready to identify problems, raise awareness, change behavior, and bring solutions to bear. This is the miracle of what the modern university and its research capacity offers the world today. What an evolution from the narrow missions of colonial universities."

So I couldn't agree more. I am delighted that you all are here. I want to take a moment to brag on the work that Brown University is doing and the University of Rhode Island. They are both heavily engaged in this. Brown has been at work on green initiatives I believe since 1991, and has been a real leader in this area. All of our colleges participate. Even one of our smaller colleges, Roger Williams, is now running its shuttle bus service on the recycled canola oil from its fryers in the dining halls.

So Rhode Island is keenly interested, and I appreciate very much the role of universities, and I thank all of you for being here.

Thank you, Madam Chair.

[The prepared statement of Senator Whitehouse follows:]

STATEMENT OF HON. SHELDON WHITEHOUSE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Thank you Madam Chairman, and thank you to all of the members of the panel for being here today. I'd like to extend a special hello and thank you to President Levin of my alma mater, Yale University. I recall my undergraduate career there very fondly and I am proud that my daughter Molly is a freshman at Yale today. I am also greatly pleased to see this great institution at work to combat global climate change. The universities represented here today are educating the next generation of leaders who will help reverse the tide of global warming, and at the same time are leading by example by minimizing their own carbon footprints. I know these efforts required difficult choices, and I commend all the panelists for their institutions? commitment to their students and our environment.

America's universities are uniquely positioned to lead the fight against climate change. Yesterday, I attended a speech by Dr. Ruth Simmons, the President of Rhode Island's own Brown University, in which Dr. Simmons spoke eloquently on the very issue that brings us here today. She stated:

"Who would have predicted a century ago the environmental degradation that has led to climate change? Yet, science stands ready to identify problems, raise awareness, change behavior, and bring solutions to bear. This is the miracle of what the modern university and its research capacity offers the world today. What an evolution from the narrow missions of colonial universities!"

I couldn't agree more. I'm especially proud that colleges and universities in Rhode Island have taken critical steps to transform their campuses into models of energy efficiency and carbon neutrality. We in the "Ocean State" regard our environment and our responsibility to protect and preserve it as a nearly sacred cause. So it makes sense that our institutions of higher learning should be models for the way we think and act about climate change. They make me and all Rhode Islanders extremely proud.

Brown University innovated the "green campus' revolution, starting in 1991 with its "Green Initiative" Seventeen years later, Brown has achieved one of the lowest energy densities and carbon footprints among universities of its size. With its recently inaugurated Community Carbon Use Reduction Program, Brown plans to do even more: reduce its greenhouse gas emissions to 42 percent below 2007 levels by 2020, and up to 50 percent below that threshold for all new construction on campus.

Similarly, the University of Rhode Island, in Kingston, has also taken significant steps to reduce its carbon footprint and become more energy-efficient. This winter, URI announced that it would undertake a massive upgrade of its operational systems, from lighting to heating to water management. These upgrades will save the university seven million kilowatt hours of electricity and forty-two millions of pounds of steam per year. Meanwhile, the college's Renewable Energy Club has been studying the feasibility of wind turbines and other alternative energy generation that could make the campus even more sustainable and further reduce its footprint. It's a great example of a university attacking the problem at many different levels, the administration and students matching each other's commitment to change.

Our smaller institutions are also busy creating innovative solutions that will help better meet the needs of the planet.

Roger Williams University, in the town of Bristol on the shores of Narragansett Bay, now runs it shuttle bus on 100 percent recycled canola oil taken from its cafeteria's fryers. This alone will keep 2300 gallons of diesel fuel from being burned, and cut the shuttle's CO_2 emissions by 75 percent. It's a small step, but one that shows the innovative and creative thinking that have become the hallmarks of Rhode Island's college and universities in this area.

America's universities give our young people the tools and the opportunities to live happy, healthy, and productive lives. It makes sense, then, that while these institutions are preparing their students for the future, they should also do everything they themselves can do to make sure that our planet will be in a condition to be enjoyed and enriched by these students. Brown, URI, Roger Williams, and other Rhode Island institutions have all made that commitment, and it is essential that more and more colleges take up this cause and begin to look for ways in which they can contribute to our fight against global climate change.

I thank the Chairman again for bringing this excellent panel together today and I look forward to hearing the testimony from our witnesses.

Senator KLOBUCHAR. Thank you very much.

I think each witness has 5 minutes. We will start with Dr. Birgeneau.

STATEMENT OF ROBERT BIRGENEAU, CHANCELLOR, UNIVERSITY OF CALIFORNIA, BERKELEY

Mr. BIRGENEAU. I hate to admit it, but both I and two of my daughters are Yale graduates also.

[Laughter.]

Senator CRAIG. Oops. Now, this is taking it much too far.

[Laughter.]

Senator KLOBUCHAR. OK, look what you started, Senator Craig. My husband went to the University of Minnesota.

Senator CRAIG. Oh, come on now. You trumped me with George W.

[Laughter.]

Mr. BIRGENEAU. I might also point out, having had to finance my two daughters through Yale, that fees at Berkeley are $7,200 a year.

[Laughter.]

Mr. BIRGENEAU. Senator Boxer, Senator Klobuchar, and other Senators and members of the Committee, thank you for giving me the opportunity to speak to you today on one of the most urgent issues facing our State, our Nation and our globe.

Climate change caused by our use of carbon fuels is one of the most significant and pressing challenges of our time. At UC Berkeley, which is one of the Nation's preeminent teaching and research universities, we are aggressively addressing climate change through our teaching and research, as well as through policy and collective and individual actions on our campus.

The State of California has demonstrated national and international leadership in committing to reduce its greenhouse gas emissions. It has legislated that the State's global warming emissions be reduced to 1990 levels by 2020, which is a 25 percent cut in greenhouse gases, and 80 percent below 1990 levels by 2050. UC Berkeley is at the forefront of energy research and specifically any energy research and implementation to make these goals viable.

We received an important grant from the United States Department of Energy Office of Science to create the Joint BioEnergy In-

stitute through a 5-year, $125 million grant. Another important effort is the creation of the Energy Biosciences Institute, a collaboration between ourselves, the Lawrence Berkeley National Laboratory, the University of Illinois at Urbana-Champaign, and the global energy corporation, BP.

The institute is funded by—and this is unprecedented—a $500 million 10-year grant to UC Berkeley and our partners by BP, awarded in 2007. The purpose is primarily to explore and develop biofuels beyond the corn to ethanol paradigm.

Additionally, scientists from UC Berkeley and the Lawrence Berkeley National Laboratory has been developing a bold research agenda called Helios, exploring solar energy devices from photovoltaics to microorganisms, including nanotechnologies to produce cheaper and more efficient solar cells.

Today, Berkeley has emerged as a leading world center on energy research and education with an annual research budget of about $100 million per year through unprecedented public-private partnerships.

We have also been aggressive with measures to reduce greenhouse gas emissions on campus. Under the Cal Climate Action Partnership, which is a coalition of students, faculty and staff of the administration, we have undertaken a feasibility study, and based on sound analysis and actual policy, have committed to a target of reducing greenhouse gas emissions on campus to 1990 levels by 2014. This is 6 years ahead of the State's mandated reduction. Our strategies for achieving this ambitious target include increasing the efficiency of our energy usage, greening our electricity supply, and promoting sustainable transportation.

Buildings account for over 70 percent of campus emissions. Projects to reduce emissions include large scale lighting retrofits, building recommissioning, making our heating, ventilation and air conditioning systems more efficient, and deploying additional onsite renewable energy production.

Our plan also contains efforts that are indirectly related to energy usage, and also have enormous impact on resource conservation such as water conservation, minimizing waste, and purchasing greener products.

These actions are supported by a formal campus policy entitled the Statement of Commitment to the Environment, and the recent appointment of a Director of Sustainability. Many of these efforts to mitigate UC Berkeley's climate footprint have been led by our students, who are a new generation passionately committed to solving the world's energy needs in both a clean and socially responsible way.

Berkeley students recently voted a $5 add-on student fee increase to fund sustainability projects on campus. The Berkeley Energy and Resources Collaborative is a unique student community that brings together hundreds of students, professors and industry and government leaders on issues of energy and resources at Berkeley.

Our students are acutely aware that one billion people on this planet have no access to modern forms of energy and they live on 50 cents per day or less. These populations will suffer devastating effects if global climate change continues to progress at its current

rate. Our students understand that how we deal with these challenges will transform humankind's relationship with the environment and change the way that we drive the global economy. Universities must lead this transformation.

[The prepared statement of Mr. Birgeneau follows:]

TESTIMONY OF

ROBERT J. BIRGENEAU

CHANCELLOR

UNIVERSITY OF CALIFORNIA, BERKELEY

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

UNITED STATES SENATE

"EXAMINING STRATEGIES TO REDUCE GREENHOUSE GAS EMISSIONS AT U.S. COLLEGES AND UNIVERSITIES"

APRIL 3, 2008

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Additionally, scientists from UC Berkeley and the LBNL have been developing a bold research agenda called "Helios" exploring solar energy devices from photovoltaics to microorganisms, including nanotechnologies to produce cheaper solar cells and improve their efficiency. Today, Berkeley has emerged as a leading world center on energy research and education, with an annual budget of $100 million through unprecedented public-private partnerships.

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fund sustainability projects on campus. The Berkeley Energy and Resources Collaborative is a unique student community that brings together hundreds of students, professors and industry and government leaders on issues of energy and resources at Berkeley. Our students are acutely aware that over one billion people live on 50 cents per day or less and that these populations will be disadvantaged even further if global climate change continues to progress at its current rate. They understand that how we deal with these challenges will transform humankind's relationship with the environment and change the way that we drive the global economy. Universities must lead this transformation.

Thank you for this opportunity to describe very briefly UC Berkeley's strategies for reducing greenhouse gases both on its campus and even more importantly, its strategies for contributing to greenhouse gas emission reduction world-wide.

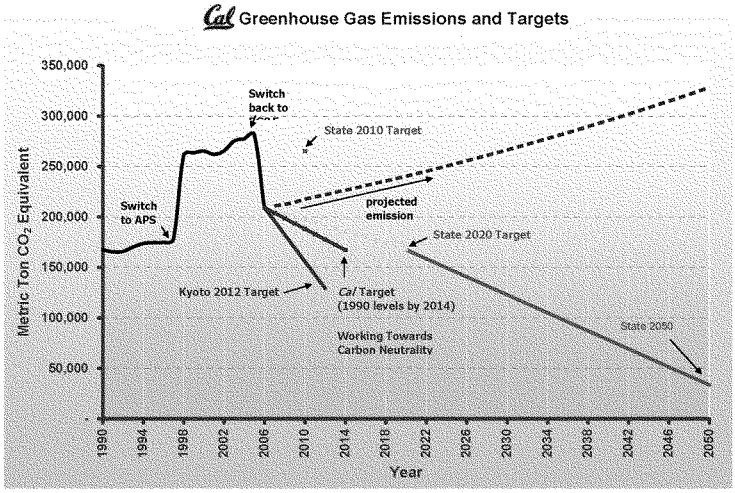
Finally, if you would allow me to comment on national policy, I feel strongly that while there is so much that universities and other local entities can do to reduce their carbon footprints, global warming really must be addressed at the national level if we as a nation are going to have the kind of impact we must have to prevent further destruction of our atmosphere. To that end, passage of the S.2191 or similar legislation to impose strict limits on greenhouse gas emissions, is absolutely critical.

I have submitted a much fuller written submission describing in detail our many initiatives. I would be pleased to answer any questions that you may have.

Campus Activities to Reduce Emissions

The University of California at Berkeley is committed to reducing the greenhouse gas emissions associated with our campus activities. We have inventoried our emissions, set an ambitious target, and begun implementation. Our Cal Climate Action Partnership (CalCAP) program is an interdisciplinary research and implementation program and is the torchbearer of climate action on campus. In April 2007, based on recommendations from the CalCAP study, I committed the campus to reduce its greenhouse gas emissions to 1990 levels by the year 2014, which is equivalent to meeting California's AB-32 (Global Warming Solutions Act) six years early (see Figure 1).

Figure 1: Projected Emissions and Potential Targets



Emissions Sources and Reduction Feasibility

CalCAP started in the fall of 2006 by creating a climate action feasibility study. This study led to the development of a ten source greenhouse gas emissions inventory and the emissions reduction target, which included 14 possible projects as a starting point for implementation. Our target and inventory are based on both our direct emissions – like energy usage in buildings and our fleet vehicles – and optional categories like air travel, staff and student commute to campus, water consumption, and solid waste.

In order to achieve this ambitious emission reduction target, we will:

- Use aggregate emissions targets as a metric in campus communication and planning
- First implement infrastructure-related emissions reduction projects, starting with the most cost-effective (i.e., highest $/MTCO$_2$e) projects, and then use the savings from those projects to invest in additional projects or to purchase Renewable Energy Credits (RECs)
- Focus on identifying additional cost-effective GHG mitigation opportunities on campus, such as energy efficiency.

The campus joined the California Climate Action Registry and has certified its emissions inventory for 2005 and 2006 (see Figure 2). Of the 14 projects that have been initially associated with the CalCAP target, four projects are active and seven projects are in a small pilot phase. Investments of almost $2 million have already yielded an estimated one million KWH energy savings.

Figure 2: UC Berkeley GHG Emissions by Source in Calendar Year 2006

Emissions Sources (required & optional reporting)	CO_2 equivalent (metric tons)	Percentage Contribution
Steam (co-generation)	82,000	38.8%
Purchased Electricity	65,000	30.6%
Air Travel	24,000	11.3%
Faculty and Staff Auto Commute	19,000	8.6%
Natural Gas	13,000	6.1%
Student Commute	4,000	1.8%
Fugitive Emissions- Refrigeration	2,000	1.0%
Water Consumption	2,000	0.9%
Solid Waste	1,000	0.4%
Campus Fleet	1,000	0.4%
Total Emissions	209,000	100.0%
Required reporting emissions sources	160,000	76.5%
Optional Reporting emissions sources	50,000	23.5%

While our 2007 inventory calculations are not certified yet, we expect that our overall emissions will be lower (approximately 207,000 metric tons) than what we had originally projected. The relative percentage contribution by various emissions sources has not shifted by a significant portion.

The reasons for this year's reduction can be attributed to implementation of various energy efficiency projects on campus. Examples of these efficiency measures include lighting retrofits, building re-commissioning, and upgrades to heating and air conditioning systems. An additional factor is the increased use of cleaner electricity, as the campus has purchased more of its power from Pacific Gas and Electric. Other initiatives are discussed below.

Specific Initiatives

1. **Infrastructure projects** – The following types of projects enhance the energy efficiency of campus energy systems. They can have a significant upfront cost, but can also have a quick payback and generate savings that can be further invested.

a. Co-generation plant steam trap survey and repair (saving up over 1,000 tons of carbon a year)
b. Monitoring-based commissioning (all buildings over 50,000 square feet will be re-commissioned; energy savings of up to 15% are expected)
c. Automated lighting controls (for example, use of wireless lighting controls in a pilot study has yielded energy reductions of 65%)
d. Fluorescent lighting retrofits (for example, installation of more than 700 electronic ballasts and photoelectric control in five parking structures)
e. Fleet vehicle replacement plan (questionnaire and plan to convert the single-occupant fleet on campus to electric by 2014)

In addition, the campus is completing a Strategic Energy Plan (SEP) in partnership with PG&E. Consultants have started surveying almost 70 campus building to identify commissioning, retrofit, HVAC upgrade and other energy efficiency projects. Work is expected to begin in 2009. The campus also plans to purchase up to 1MW of solar power Solar through a power purchase agreement.

2. **Educational and Behavioral Projects** – These campus initiatives will encourage individuals to conserve more energy and educate the campus population to incorporate conservation into their daily activities. They require some capital investment and a significant dedication to coordination and planning. They have a quick payback and also contribute to establishing a culture of environmentally sustainable practices. Not all of these projects are currently funded.

   a. Introduce fleet biking
   b. Expand electric vehicle fleet
   c. Implement high priority bicycle plan projects & programs
   d. Reward department level energy reduction
   e. Increase utilization of videoconference room(s)
   f. Increasing occupant awareness and electricity curtailment
   g. Introduce Campus Composting program

3. **New Buildings** – We are using the Leadership in Energy Efficient Design guidelines for new buildings, supplemented by additional energy efficiency requirement: all new building projects on campus will be designed to exceed the required provisions of the California Energy Code (Title 24) energy-efficiency standards by at least 20 percent. Our first LEED certified building, the Haste Street Early Childcare Development Center, has been awarded Silver. The certification process was funded through a grant from Stopwaste.Org, procured by Capital Projects. Additional projects presently undergoing USGBC LEED certification include University Village Step 2 (housing); Clark Kerr

Renovation (housing); Li Ka Shing Biomedical Building (laboratory); and Durant Hall Renovation (historic/office).

In addition, LEED Equivalence submittal for the Underhill Parking Structure has been received and planning checklists for all major capital projects have been prepared. All projects are tracking at 20% or greater in outperforming the California Energy Code. We have modified its project approvals to assure that all renovation projects include sustainability measures, as required by policy. The Li Ka Shing Biomedical Building, a Labs 21 partner, has been identified as a Best Practice for Energy Efficient Laboratory Design from the PG&E Savings by Design program. The building will outperform energy code requirements by 33%, and is projected to receive almost $500,000 in energy efficiency incentive funding.

The Berkeley campus has incorporated expectations for internal LEED equivalent certification into all design professional agreements and contracting documents for major capital projects. Results thus far indicate that performance objectives are being met.

Started as a grassroots effort by students, CalCAP has since matured into a results-oriented sustainability program. Today, it is a partnership of various research and administrative departments, and it continues to add stakeholders. The culture of collaboration is rooted in its interdisciplinary steering committee with more than 25 active members from faculty, staff, administration, and students. The CalCAP model is now the University of California standard on climate action, and the program was showcased at the University of California-California State University- Community College annual summit in 2007.

Student Leadership and Ingenuity

Our students have pioneered many of our broader sustainability efforts. In addition to being the driving force behind our climate reduction target and the backbone of our implementation of many projects, they are "walking the walk." Last year, students passed a referendum known as The Green Initiative Fund (TGIF) to increase their fees by $5 per student per semester. This fee has raised about $170,000 so far and will be used to fund sustainability projects around campus. These grants are student controlled and have already generated around $1 million in grant proposals.

One successful student programs are the Green Campus Interns. The projects implemented by the Green Campus Interns, in partnership with the Alliance to Save Energy, have saved over 1500 MWh of energy, which equals $150,000 in avoided energy costs or 70,000 pounds of CO_2. Their projects have included dorm energy competitions ("Blackout Battles") and a fume hood campaign ("Shut the Sash").

Another is the Green Living Project, the first project in the nation to demonstrate that a room in a student resident hall can be environmentally friendly without costing huge sums or sacrificing a comfortable lifestyle. The project, organized by Campus Recycling and Refuse Services in close cooperation with Residential and Student Service Programs and Green Campus, is showing the campus community that it is not only possible but also easy to "go green."

There are unique student initiatives related green building. All our major building projects work to engage students during the process, through an eco-charette or having them assist on tracking LEED and green building performance measures. We employed students to assist with documenting LEED performance on the following projects: University Village Housing Step 2, Units 1 and 2 Infill Housing and Durant Hall Renovations, Hearst Memorial Mining Building. With the College of Civil and Environmental Engineering, we had students work on Life Cycle Cost Analysis tools for the design phase, using our CITRIS building as an example. In addition, there are Green Classroom Programs, where students work with the Registrar's Office and the Classroom Renovation Program to develop recycling in classrooms, energy efficiency lighting, and user satisfaction research tools.

Students have played a key role in integrating climate action into curricula to further elevate the campus' climate commitment. In the fall of 2007, the first student-led climate action course trained 14 undergraduate and graduate students on campus decision processes and emissions reduction options - an engagement that has inspired hundreds of students to integrate climate action into their research and activities. This student-led course – with guest lectures from staff, faculty and students – developed recommendations for holistic campus planning. They concluded that the CalCAP reduction target could potentially be achieved just by focusing on energy efficiency alone. Students are also running two additional courses that are producing an educational campaign and multiple building energy audits.

The CalCAP program also supported student projects that produced actionable recommendations on department and building level energy reduction, greening procurement, emissions inventory data gathering, project financing options and a design for sustainability programs on campus.

Broader Context

These actions to reduce our greenhouse gas emissions are grounded in a broader policy on sustainability. I have an Advisory Committee on Sustainability designed to promote environmental management and sustainable development at UC Berkeley. This Committee is charged with advising me on matters pertaining to the environment and sustainability and draws strength from its diverse composition of faculty, staff, students and alumni. Earlier this year, I approved a formal "Statement of Commitment to the Environment," that commits our campus to being "responsible stewards of the physical environment and to using educational and research activities to promote environmental awareness, global thinking, and local action." As part of this commitment, I recently formed an Office of Sustainability, which has been charged to identify and prioritize ways to improve environmental sustainability on campus and generate creative solutions.

We are also reaching out beyond the edges of campus. In a wholly new and innovative collaboration, the mayors of Berkeley, Oakland, Richmond and Emeryville have joined forces with me and LBNL director Steve Chu to form the East Bay Green Corridor Partnership — aimed at "establishing our region as one of the world's leading centers" of environmental innovation, alternative-energy research, and green business, green job development and industry. After several months of negotiations, a formal *Statement of Principles* was developed that outlines the cooperative agreement between the East Bay cities, UC Berkeley and LBNL. This unique partnership brings the expertise of all the entities together to contribute to emerging green and sustainable industries, alternative energy research and green workforce development throughout the region. This new alliance is intended to position the East Bay to become one of the nation's green economic engines that also looks to keep California competitive and the nation energy independent.

The CalCAP program offers many benefits to the local community, including local emissions reductions information, informed participation in the process of climate change mitigation, and a forum for discussion of ideas, strategies, and best practices. The City of Berkeley and community action groups are involved participants in the group's steering committee to jointly work on community based carbon reduction opportunities. In January 2008, our campus observed Focus the Nation – Global Warming Solutions for America, that brought together over 500 students, staff and local community members to jointly discuss solutions for climate change at a regional scale.

Additional information is available at our websites: www.sustainability.berkeley.edu and www.climateaction.berkeley.edu.

Research on Global Climate Change at UC Berkeley

California and its academic institutions have a unique history in addressing climate change, which includes path-breaking scientific and technological research, as well as the development of new economic techniques and assessments of social impacts of changing environmental conditions. Researchers at UC Berkeley have been at the forefront of national and international research efforts that have found there can be significant local benefits to confronting climate change, including energy savings from "greening" buildings and industries, creating job growth, and building export opportunities in some of the fastest growing economic sectors.

UC Berkeley has a long and rich history of pioneering knowledge and action on the most urgent issues facing our state, our nation, and our globe, and climate change is no exception. A hallmark of our campus is a tradition of not only training the next generation of research and political leaders, but also in engaging in real world mission-oriented projects to meet the needs of the state, nation, and the world. We recognize that as a society, we must discover how and how fast the climate is changing, what degree of climate protection we can implement through low-carbon energy systems, and how can adapt to the climate change we can not prevent. Across the campus, we are deeply engaged in research that focuses not only on the science of climate change, but also on developing new practices to lower energy demand, and the emerging economic and legal frameworks that can help manage our energy demand and impacts that change will have on the planet.

At UC Berkeley more than 300 faculty are already working on issues related to energy, the environment and global warming. We are particularly fortunate in our close association with the Department of Energy funded Lawrence Berkeley National Laboratory. Berkeley Lab is a multidisciplinary scientific research lab that is home to some of the world's best scientific tools and research expertise. Approximately 300 of Berkeley Lab's scientists are also UC professors, and close to 1,000 UC Berkeley students do scientific work and training at Berkeley Lab. It is a remarkable alliance.

Berkeley Lab Director Steve Chu and I have brought together the great resources of our institutions to address the energy and environmental challenges head on. UC Berkeley and Berkeley Lab are pooling our vast experience in energy technology, policy and transportation to help achieve an affordable, sustainable, and clean supply of global energy. From the BP-funded, campus-led Energy Biosciences Institute, to the Berkeley Lab-led, DOE-funded Joint BioEnergy Institute, Berkeley is becoming a world center for sustainable energy research.

These are some of the major research initiatives already underway on our campus:

The **Energy Biosciences Institute (EBI)** is a new research and development organization that brings advanced knowledge in biology, physical sciences, engineering, and environmental and social sciences to bear on problems related to global energy production, particularly the development of next-generation, carbon-neutral transportation fuels.

EBI represents a collaboration between the University of California, Berkeley, Lawrence Berkeley National Laboratory, the University of Illinois at Urbana-Champaign, and BP, which will support the Institute with a 10-year $500 million grant. EBI's multidisciplinary teams will collectively explore total-system approaches to problems that include the sustainable production of cellulosic biofuels, enhanced biological carbon sequestration, bioprocessing of fossil fuels and biologically-enhanced petroleum recovery. A hallmark of EBI will be the attention to the social and environmental impacts of fuel pathways, and the 'life-cycle' impacts of a bio-energy infrastructure.

The Joint Bioenergy Institute (JBEI) is a new organization funded by a $125 million, five-year grant from the US Department of Energy Office of Science to Lawrence Berkeley National Laboratory (LBNL), the University of California, Berkeley, and four other partners to develop better biofuels.

Research at JBEI centers on improvements to current technology for producing ethanol, in particular cellulosic technology for producing ethanol from biomass, and new technologies for producing other biofuels. Research will find out how plant cell walls – the hard lignocelluose that makes plants sturdy – are put together, so that scientists can find a way to take them apart and access the simple sugars they're made from. These sugars could then be fermented along with the simple starches in the plant to produce much more energy than currently possible.

JBEI scientists will also develop the tools and infrastructure to accelerate future biofuel research and production efforts, and help transition new technologies into the commercial sector.

The **Helios** project is a clean energy initiative at LBNL designed to address the challenges of climate change by developing new, clean energy alternatives with low carbon emissions. Its goal is to harness the sun's energy for a secure, sustainable, and prosperous future.

Helios research will concentrate on developing transportation fuel from biomass and from solar energy driven electrochemistry. It will also target solar technologies, including a new generation of solar photovoltaic cells, and the conversion of electricity into chemical storage to meet future energy demands.

The Energy and Resources Group (http://erg.berkeley.edu) is an interdisciplinary academic unit of the University of California, Berkeley whose mission is to develop, transmit and apply critical knowledge to enable a future in which human material needs and a healthy environment are mutually and sustainably satisfied. ERB pursues its mission through education, research, and service. Established in 1973, ERG offers programs of study in Energy and Resources for graduate students leading to MA, MS, and PhD degrees.

The University of California Energy Institute (http://www.ucei.berkeley.edu/), located on the Berkeley campus, is a multi-campus research unit of the University of California system. Since its inception in 1980, UCEI's mission has been to foster research and educate students and policy makers on energy issues that are crucial to the future of California, the nation, and the world.

The **Renewable and Appropriate Energy Laboratory (RAEL)** is a unique research, development, project implementation, and community outreach facility based at UCB. RAEL focuses on designing, testing, and disseminating renewable and appropriate energy systems. The laboratory's mission is to help these technologies realize their full potential to contribute to environmentally sustainable development in both industrialized and developing nations while also addressing the cultural context and range of potential social impacts of any new technology or resource management system. RAEL projects range from theoretical analysis of low-carbon energy futures, to engineering-based efforts to develop new solar, small-scale wind, and biomass gasification technologies, and to work with partner groups in Nicaragua, Kenya, South Africa, Tanzania, China, and elsewhere, to put these projects into operation.

Berkeley Water Center. The nation's water resources are certain to be affected by global climate change. Effective water management is not purely a scientific problem, a political problem, a technological problem, a computer science problem nor a socioeconomic problem; it is a complex, 21st Century problem that demands collaborative coordination between all of these disciplines. The Berkeley Water Center has been developed to integrate expertise across disciplines in support of a new research mode for water investigations.

Center for Fire Research and Outreach. The impact of global warming on our climate is already being felt in our nation's wooded areas. Given the importance of fire in many ecosystems, along with our dependence on and development into inherently fire-prone

landscapes, we need to reach a sustainable coexistence with wildfire. The mission of the Center for Fire Research and Outreach is to develop and disseminate science-based solutions to wildfire-related challenges.

Center for Forestry. The Mission of the Center for Forestry is to sustain forested ecosystems through scientific inquiry. Our approach is comprehensive. We seek to create and disseminate knowledge concerning ecosystem processes, human interactions and value systems, and restoration and operational management practices.

Center for Sustainable Resource Development. The Center for Sustainable Resource Development brings together UC Berkeley's leading environmental and social scientists with other experts and stakeholders from industry, government, and environmental organizations to address complex resource-use issues such as global climate change, sustainable agriculture, water reliability, and population, poverty and the environment.

Center for the Assessment and Monitoring of Forest and Environmental Resources at UC Berkeley (CAMFER). CAMFER is dedicated to providing innovative, state-of-the-art monitoring of environment using geospatial technologies. CAMFER research and outreach staff conduct studies in wetland monitoring and modeling, atmospheric emissions, forest biometrics, and watershed modeling.

CITRIS. The Center for Information Technology Research in the Interest of Society creates information technology solutions for many of our most pressing social, environmental and healthcare problems, including global climate change.

The first public-private partnership created to use IT in this way, CITRIS partners more than 300 faculty and thousands of students from myriad departments at four UC campuses (Berkeley, Davis, Merced and Santa Cruz) with industrial researchers from over 60 corporations. Together they are thinking about IT in ways that have not been thought of before. They see solutions to many of the concerns that face all of us today, including the environment and finding viable sustainable energy alternatives.

Energy and the Environment

As climate change continues and the world population expands at a rapid rate, we must find energy solutions that improve the quality of life while not adversely affecting the environment. CITRIS researchers are engaged in a variety of projects in renewable energy; nuclear energy; and carbon capture and storage, to name a few.

- Modeling Electric Usage in Residential Areas. Because electricity cannot be practically or economically stored in large quantities, the electricity generation and distribution system must match supply and demand on a minute-by-minute basis. Delivery of electricity for residential use has traditionally been done by matching the supply to the demand, with little or no control over the demand. This causes severe distortions in the system operation and economics when the demand hits unusually high peak values.
- Energy Efficiency and Reliability in Dense Sensor Networks. This research addresses some important components in the theoretical and algorithmic signal processing machinery needed to make low-power, ubiquitous sensor networks a reality. The physical and hardware attributes as well as the computing and communication capabilities of these low-power, low-cost sensors, particularly those based on high-density low-cost MEMS devices, have the potential to revolutionize next-generation information technology.
- Window Performance for Human Thermal Comfort. Anyone who has ever sat near a cold window on a winter day or in direct sunlight on a hot day recognizes that windows can cause thermal discomfort. In spite of this broad recognition there is no straightforward method to quantify the extent of such discomfort. HVAC designers specify dedicated perimeter heating and cooling systems to mitigate window-related comfort problems, yet they use simplified assumptions that may not solve the comfort problems or that might lead to designs that are energy-inefficient.
- Solar Reflecting Film. The Center for the Built Environment (CBE) at UC Berkeley has developed a sophisticated thermal comfort capable of modeling non-uniform, transient conditions. This model has been used to study occupant comfort in buildings and automobiles. SRF has unique properties that reduce transmitted solar heat gain and lower the glass surface temperature.

Center for the Built Environment. Research is being conducted to improve the design, operation, and environmental quality of buildings by providing timely, unbiased information on building technologies and design techniques.

CBE projects fall into two broad program areas: First, developing ways to "take the pulse" of occupied buildings - looking at how people use space, asking them what they like and don't like about their indoor environment, and linking these responses to physical measurements of indoor

environmental quality. This feedback is highly valuable those who manage, operate, and design buildings.

Secondly, studying technologies that hold promise for making buildings more environmentally friendly, more productive to work in, and more economical to operate. This helps manufacturers target their product offerings, and facility management and design partners to apply these new technologies effectively. Some current research projects include

Indoor Environmental Quality (IEQ). CBE has developed methods to measure the performance of occupied buildings in terms of occupant comfort, workplace efficiency, and building operations.

Building HVAC Systems. Advanced HVAC systems provide opportunities for energy savings and benefits to occupants.

Building Envelope Systems. CBE is developing tools and criteria for evaluating facade performance in terms of occupant comfort and energy efficiency.

Controls and Information Technology. New information technologies provide ways to optimize the performance of building systems.

The Berkeley Institute of the Environment

BIE is a nexus for research on environmental issues that brings together campus teams in a number of thematic areas, that currently include: low-energy buildings; sustainable fuels; environmental history; and life-cycle analyses of materials.

One of the many areas of research related to global warming being conducted at BIE is the Zero Energy Commercial Buildings Initiative. ZECBI will transform the energy use of commercial buildings in the US to routinely achieve carbon-neutral building performance within a generation. The building sector remains responsible for about 40% of energy use and carbon emissions, and over 70% of electricity use. Research at ZECBI will transform the energy use of commercial buildings in the US to routinely achieve carbon-neutral building performance within a generation by addressing industry institutional inertia, fostering technological innovation in equipment, materials, and controls, developing innovative tools and predictive models to support innovative design, enhancing the education of design and engineering professionals, fostering technology transfer from labs to industry, developing innovative processes for delivering and operating high performance buildings, identifying deployment policies that will ensure widespread adoption of high performance buildings, and developing metrics and a framework to track long term progress toward goals.

Environmental Energy Technologies Division (EETD)

UC Berkeley partners closely with the Lawrence Berkeley National Lab on a wide range of research, including research done at the EETD. Together, the LBNL and UC Berkeley

researchers work to find better energy technologies and market mechanisms that reduce adverse energy-related environmental impacts. EETD's work increases the efficiency of energy use, reduces its environmental effects, provides the nation with economic benefits, and helps developing nations achieve similar goals through technical advice. EETD carries out its work through the support of the U.S. Department of Energy other federal entities, state governments, and the private sector. Our staff of 300 represents a diverse cross-section of fields and skills, ranging from architecture, physics, and mechanical engineering to economics and public policy. Many areas of research are directly related to global warming:

Energy efficiency in buildings
• Energy-efficient windows and daylighting systems
• Energy-efficient lighting concepts and systems
• Simulation tools for energy use in buildings
• Information technology for energy efficiency in commercial buildings
• Application of advanced concepts to testbed buildings
Advanced energy technologies
• Electrochemical research on batteries
• Combustion and emissions
• Laser and other spectroscopic tools: development and application
International energy issues
• Energy efficiency in developing countries (special emphasis:China and India)
• Energy efficiency and global climate change
US energy issues
• Appliance and equipment energy-efficiency standards
• Energy efficiency programs to promote market transformation
• Energy utility deregulation
• End-use energy demand forecasting and policy analysis
Indoor environment
• Advanced ventilation, infiltration, and thermal distribution systems
• Sources, emissions, and transport of indoor pollutants
• Air pollutant exposures and health risks
• Control strategies for indoor air quality

Other areas of research and development

- air pollution: from science to public policy
- electricity reliability: distributed energy systems, real-time control, and markets
- industrial energy efficiency: U.S. and international perspectives

BUILDING TECHNOLOGIES

Division researchers work closely with industry to develop efficient technologies for buildings that reduce energy bills while improving the comfort, health, and safety of building occupants.

Technology efforts focus on windows, daylighting, lighting systems, building simulation research, and commercial building systems.

Windows and daylighting

Every year, heat worth billions of dollars flows through windows in American homes and businesses. In hot climates, the heat radiates into homes, requiring expensive air conditioning. In cold climates, it leaks out, requiring more energy to keep the occupants warm. Thermally efficient windows save consumers and businesses energy and money. The Division's researchers develop advanced optical coatings and materials for future windows; study the energy performance of windows and window systems (windows, glazings, and their frames, blinds, louvers, etc.); and create computer tools to improve window energy performance and aid product rating and labeling. In the 1980s, EETD researchers worked with window manufacturers to develop special "low emissivity" window coatings to reduce heat loss through windows. These windows, which reduce energy loss by 20% to 50% depending on the design, now account for 35% of the market and have saved more than $1 billion in energy costs. Current windows research includes developing new tools and measurement techniques to assess energy performance and comfort; advanced electrochromic coatings that automatically change the level of transparency depending on exterior lighting conditions; and technologies and design strategies for commercial buildings that maximize daylighting benefits. In addition, EETD works with industry partners in developing standards for rating windows.

Lighting

Lighting accounts for 25% of all electricity consumed in the United States, at a cost of more than $35 billion per year. Researchers here develop advanced light sources, optimize lighting fixtures and control systems for energy efficiency, design computer tools to quantify the energy performance of lighting systems, and test system performance in the field, including the impacts on human performance and health. The Division's lighting team worked with manufacturers to develop electronic ballasts, a more efficient replacement for the magnetic ballasts used to control the current in fluorescent lamps. Electronic ballasts now account for 32% of the market, saving consumers hundreds of millions of dollars per year. Working with industry, the group developed a torchiere floor fixture based on the compact fluorescent lamp—an energy-efficient, lower-temperature alternative to the hot 300-watt halogen torchieres that are blamed for starting hundreds of fires.

Building simulation

Architecture and engineering firms use DOE-2—a computer program developed by Division researchers that analyzes the energy performance of buildings— to increase the energy efficiency of their designs. According to a DOE-2 user survey, buildings designed with DOE-2 save an average of 20% of building energy use. EnergyPlus, now under development, will replace DOE-2 and offer many new features. Radiance—a computer program for lighting analyses, also developed by Division researchers—allows lighting and daylighting designers to assess the quantitative and qualitative performance of their designs. Desktop Radiance, now under development, will greatly facilitate the use of Radiance and increase its user base. In addition to analytical tools, Division researchers are developing tools, like the Buildng Design Advisor, which change the way architects design buildings, by providing quick and easy access to multiple analysis tools linked to a single building database. In the first-ever such use of the

Internet, a program called Home Energy Saver is available to anyone with Web access (http://HES.lbl.gov). The user inputs information about a home, and HES (using DOE-2) calculates total energy use and cost, and suggests economic ways of reducing the energy bill.

Commercial building systems

The commercial building sector spends $80 billion per year on energy. Maximizing efficiency can cut billions from this cost. Researchers have launched a major effort to address this opportunity, developing tools to benchmark energy performance. Such tools let designers, owners, and operators access data throughout the building lifecycle and ensure that building operations meet performance targets.

The Division's energy analysts gather and interpret information about energy, including supply and consumption, energy technologies, management practices, government policies, and economic and environmental impacts. These studies examine the performance of energy-efficient technology in the marketplace; the impact of various regulatory policies; the feasibility of different approaches to designing energy-efficient standards and building codes; and technology options for reducing the emissions of greenhouse gases. The work provides local, state, and national governments, as well as regulatory agencies and international institutions with information to help them formulate effective energy and environmental policies.

ENERGY ANALYSIS

Standards, codes, and policy analysis

Appliance energy-efficiency standards and provisions in building codes in the United States save consumers billions of dollars a year. Often inspired by the U.S. experience, dozens of nations have adopted or are currently developing appliance standards and building codes. Division research provides impartial technical information on the energy use of appliance technologies to the Department of Energy's standards development process. In addition, studies of building codes help code officials formulate and fine-tune energy-efficiency measures. Division researchers conduct studies of utility-related public policy issues, from transmission pricing and market power to the role of renewables and energy efficiency. As the electric utility industry undergoes restructuring in some states, Division studies provide useful information to the industry and the regulatory community charged with guiding this evolution.

Energy-efficient procurement and labeling

An important approach to improving energy efficiency is to provide large buyers with information about energy-efficient products. The President directed federal agencies—collectively the world's largest customer of most energy-using products—to buy products that are among the top 25% most energy-efficient options on the market. Researchers in Berkeley and the Division's Washington D.C. Office are involved in projects to help federal, state, and local agencies procure energy-efficient products. EETD researchers also provide analytical support for the voluntary ENERGY STAR programs in appliance labeling and new homes, administered jointly by the U.S. Environmental Protection Agency and its partner, the U.S. Department of Energy. The government harnesses market forces to promote energy efficiency and pollution prevention by inducing manufacturers to put ENERGY STAR labels on their products.

Reducing greenhouse gas emissions

EETD's studies of energy use and greenhouse gas (GHG) emissions have made the Division an important source of information on global climate change for policymakers. Researchers have analyzed the potential of energy-efficient technologies to reduce GHG emissions, and have evaluated the emissions of the world's buildings and industrial sectors. Our efforts include co-managing the policy study "Scenarios of U.S. Carbon Reductions," a cooperative effort of five U.S. Department of Energy national laboratories. Internationally, our contributions appear prominently in the United Nations-sponsored Intergovernmental Panel on Climate Change Scientific Assessments. Division researchers also provide technical support to developing nations creating programs, energy codes, and standards to reduce GHG emissions and encourage efficiency. A China energy group works extensively with the Chinese government to exchange information on energy use and energy-efficiency practices.

Urban heat islands

Cities are urban heat islands, zones of higher temperature relative to the surrounding countryside. The heat island effect intensifies the use of expensive air conditioning. Higher outdoor air temperatures also increase smog formation. Division researchers have pioneered an effective, simple approach to keeping cities cooler—the use of shade trees and solar reflective roofing and paving materials. EETD studies have found that the cooling effect from wide application of these measures could save billions of dollars and reduce smog in large cities nationwide.

Indoor Environment

Approximately one-third of the energy consumed in the United States is used in buildings. Energy for ventilation and thermal distribution in buildings accounts for roughly one-sixth of this total (4 to 5 Quadrillion Btu/year) and is valued at about $40 to $50 billion annually. Reducing a building's infiltration and mechanical ventilation can save energy. However, this strategy may produce undesirable side effects, because building energy use, ventilation, indoor environmental quality, and occupant health, comfort, and productivity are interrelated. Buildings can be designed and operated to protect human health and enhance productivity, while using energy as efficiently as possible. EETD researchers have estimated that improvements in U.S. building environments could decrease annual health care costs by $4 to $10 billion and increase worker productivity by $40 to $240 billion.

Ventilation technologies

Division research on air infiltration and ventilation in commercial and residential buildings has led to significant advances in modeling and measuring ventilation and its energy requirements. The work has contributed to the development of many ASHRAE (Association of Heating, Refrigerating and Air-Conditioning Engineers) and state standards, as well as building codes governing ventilation and indoor air quality. EETD research includes developing new methods of measuring ventilation rates and their spatial distribution and evaluating new ventilation technologies with potential to improve indoor air quality and reduce energy use. Sealing leaky, energy-wasting ducts is one way to reduce energy use substantially. An EETD study showed that a typical house with ducts located in the attic or crawlspace wastes approximately 20% to 40% of heating and cooling energy through duct leaks, and draws approximately 0.5 kilowatts more electricity during peak cooling periods. Sealing leaks could save close to 1 Quadrillion Btu of energy per year nationwide. Division research has led to the development of a major new duct sealant technology that uses aerosols to reach and seal areas of ducts inaccessible to humans. Its commercialization is underway

Batteries and fuel cells

A major goal of the Division's electrochemistry research is to develop electrochemical power sources suitable for applications in electric and hybrid electric vehicles. Battery systems are expensive and don't hold enough electric charge to drive a vehicle the same distance as a comparable gasoline-powered automobile. EETD is undertaking research that will lead to the development of low-cost, rechargeable, advanced electrochemical batteries with the high-performance potential to compete with the combustion engine. Current work focuses on lithium-polymer and lithium-ion batteries.

Cleaner combustion

Combustion research generates the fundamental physical and chemical knowledge necessary to reduce emissions and increase efficiency. Experimental and modeling studies lead to the design of better combustion devices. EETD researchers work with Berkeley Lab's National Energy Research Scientific Computing Center (NERSC) to model combustion processes using high-performance supercomputers. Turbulent combustion takes place in all heat and power generating systems, including combustion engines in automobiles and industrial boilers and furnaces. By studying the properties of turbulent fluid motion in combustion chambers, Division researchers have devised a low-swirl burner that emits 20 times less nitrogen oxide than current technology. (Nitrogen oxides are greenhouse gases, and when exposed to sunlight, also generate smog.) The burner could be used in the residential and commercial sectors in water heaters and boilers.

POLICY RECOMMENDATIONS

While there is so much that universities and other local entities can do to reduce their carbon footprints, global warming really must be addressed at the national level if we as a nation are going to have the kind of impact we must have to prevent further destruction of our atmosphere. To that end, passage of the S.2191 or similar legislation to impose strict limits on greenhouse gas emissions, is absolutely critical.

In even more specific terms, Congress can approve legislation that would address the following:

Buildings.

Two-thirds of all US energy is consumed in buildings, and the standing stock as well as the design of new buildings is a vital issue to address to meet national climate goals. Universities are ideal laboratories for new, 'best practices', because they bring public and private sector funds, challenge and evolve green energy standards (e.g. LEED ratings), and can be monitored with unusual detail.

Support for universities to commission, design, and evaluate the best practices in green buildings would have important, and relatively rapid impacts on the sector.

Climate Goals

As took place at UC Berkeley, climate protection goals, can both evolve rapidly on campuses, and can then feed back to the wider set of professional groups (construction industry, electrical work, water/civil engineering) who provide services and build infrastructure for campuses. A cost-effective set of federal initiatives exist to accelerate this process. Among the initiatives that could be considered are:

i) Demonstration projects for Plug-in hybrid vehicles are well-suited to campus deployment due to the central motor-pool and fleets that campuses maintain.

ii) Carbon pricing
Campuses are very good test-beds for novel accounting and economic schemes, including carbon footprint analysis, and direct pricing. More than half of the states in the union now have (or are completing) comprehensive "climate action plans" that align them with the level of effort expected if they were separate nations under the Kyoto Accord.

At present 30 of 50 states have adopted 'Renewable Energy Portfolio Standards' that call for 10 to almost 30% of their energy to come from low- and no-carbon sources over the next two decades. These state-level efforts have been driven in many cases by important research and demonstration efforts at universities. One direct area of interaction at the federal level is to consider assessments of the economic costs and benefits of federal clean-energy standards, and to examine how US DoE, HUD, and US EPA funds could be used to support these state efforts.

These states have also formed three regional cap-and-trade alliances and trading in GHG credits, comparable to the system already in operation in Europe, will begin in the US as early as the third quarter of 2008.

Support for graduate research

The most important aspect of facilitating universities to be the laboratories for innovation is graduate students conducting research and implementation projects on campus and beyond. One way to facilitate this is to expand the pool of graduate fellowships, such as the NSF and EPA (STAR) awards. A new category of 'sustainable energy' fellowships, or added slots within the existing NSF and EPA programs would be another way to do this. These positions are also among the most cost-effective ways to build the intellectual capital needed to meet the nation's long-term energy challenges.

Senator KLOBUCHAR. Thank you very much.

Dr. Johnson.

STATEMENT OF JACQUELINE JOHNSON, CHANCELLOR, UNIVERSITY OF MINNESOTA, MORRIS

Ms. JOHNSON. Thank you, Senator Klobuchar, members of the Committee. In the spirit of full disclosure, I suppose I need to begin by saying that I have absolutely no connection to Yale University, and I do hope you won't hold that against me.

Senator CRAIG. That is very appropriate at this moment, Doctor. [Laughter.]

Ms. JOHNSON. Thank you very much for inviting me to address the Committee on behalf of my campus. In the year 2010, the University of Minnesota, Morris, will be carbon-neutral. We will have accomplished this reduction of greenhouse gas emissions through the onsite generation of nearly all of our electrical and thermal needs using renewable, sustainable local resources.

How is this possible, you ask? I am about to tell you. Minnesota, Morris, one of five campuses of the University of Minnesota system, is a decidedly rural, residential public liberal arts college of 1,700 students. On a hill overlooking our prairie campus, a 1.65 megawatt wind turbine currently powers 50 percent of our campus buildings. It is the first turbine of its kind to be constructed at a public university, and it has been in operation since Earth Day 2005.

Tucked behind our campus physical education center, a small unobtrusive building is currently under construction. It will house our biomass gasification plant scheduled for its first burn in May of this year. By burning locally procured non-food based biofuel feedstocks, principally cornstover—if you wonder what that is, it is the stocks of the corn—and mixed prairie grasses, we will essentially replace our natural gas supply and our natural gas dependency.

In addition to providing a minimum of 80 percent of campus heating needs, we anticipate that this plant will put approximately $500,000 back into the local economy annually. Thus, instead of sending dollars out of State to purchase natural gas, we will deposit these resources into the pockets of area citizens.

But that is not all. In the fall of 2008, we will add a steam turbine to this gasification system. Operating on the green steam, which is a product of the gasification process, the steam turbine will produce electricity for us on those days when the wind isn't blowing and it provides a redundant source of electrical power that goes back into the grid on those windy days that are the hallmark of the prairie. This same green steam that provides heat for our campus in the winter will connect to an absorption chiller in the summer to cool our buildings.

And there is more. In the spring of 2009, we will add a second wind turbine on the hill which when it is operational will provide the remainder of our electrical needs and then some, eventually allowing us to put the excess electricity produced on our campus back onto the grid.

Of course, like many American colleges and universities, we are taking other steps to reduce our greenhouse gas emissions. Our fleet includes hybrid and zero-emission vehicles. We recycle. We

conserve. We have an active local foods initiative. We are designing new and renovating old buildings with attention to LEED specifications.

How does this fit into our academic mission and our undergraduate liberal arts focus? Our students have been and are at the forefront of our green initiatives. They are active participants in studying the impact of these initiatives through an interdisciplinary studies major and of course a number of other majors as well, a robust undergraduate research program, service learning, and a variety of active internships. Students work directly with Morris faculty. They present nationally at conferences. They co-author papers with faculty members. They are our best spokespersons.

How have we managed financially and are we saving money? Our work is financed through investments made by the University of Minnesota system, whose regents in 2004 adopted a system-wide policy related to sustainability. Our work is also supported through investments made by the State of Minnesota. In addition, we have received grants from the U.S. Department of Energy and from the U.S. Department of Agriculture.

In December 2007, we were authorized by the Internal Revenue Service to issue three clean renewable energy bonds and we are currently in the process of negotiating an energy service contract. We will have achieved our goal through an integrated set of financial tools.

Do these investments save us money? The answer is both yes and it depends. For example, as long as the price of natural gas stays at or above $8 per BTU, we save money by using biomass gasification. While CREBs are no-interest bonds, they still must be paid back. We don't have deep pockets or abundant resources, just imagination, vision and resolved.

Moreover, we are spending close to home. We are reinvesting dollars in rural America. And we have only just begun. We believe that the work happening on our campus provides prototypes for transforming the future of rural America in a way reminiscent of the Rural Electrification Act of the 1930's. We believe that this onsite renewable electric and thermal generation system provides a model not only for other colleges and universities, and for small communities and for neighborhoods in the United States, but that it also has great relevance for developing countries, truly a model of global significance.

We also have an obligation to use the investments that have been made in our campus infrastructure to train a new work force for a new economy, green collar jobs, career ladders that provide technical, intellectual and entrepreneurial pathways for the future. We believe that when we reach our goal in 2010, we will be the first college in the United States to have reduced greenhouse gas emissions in this way through onsite generation. BW, before wind, our fossil fuel footprint was 12,000 tons of carbon dioxide per year. By 2010, we will have reduced that footprint to zero. We will have achieved carbon neutrality.

I am just about finished, if I could have just a few more seconds here.

I am thinking that some of you are listening to this and you are saying to yourselves, where on earth is Morris, Minnesota? So let

me end my remarks by helping you to get your geographic bearings. The best way that I can think of to do this is by sharing with you a story that involves one of our alums, who is a University of Minnesota, Morris, graduate of course, and a graduate law degree from Georgetown. She currently sits as a Justice on the Minnesota State Supreme Court. This is Justice Lorie Gildea. She describes the location of the University of Minnesota, Morris, like this. She says: "It is west of Harvard, east of Stanford, and a whole lot closer to heaven." So we just thought you might enjoy that.

[Laughter.]

Ms. JOHNSON. University of Minnesota, Morris, students like Justice Gildea are outspoken and they are action-oriented. We encourage students and faculty to ask and answer the big questions of our time. Our work in reducing greenhouse gas emissions speaks directly to these characteristics and qualities.

At the University of Minnesota, Morris, we provide a liberal arts living and learning environment that is literally both renewable and sustainable.

Thank you very much.

[The prepared statement of Ms. Johnson follows:]

University of Minnesota, Morris
Executive Summary
Senate Committee on Environment and Public Works
April 3, 2008

In the year 2010, the University of Minnesota, Morris will be carbon neutral. We will have accomplished this reduction of green house gas emissions through the on-site generation of nearly all of our electrical and thermal needs, using renewable, sustainable, local resources.

How is this possible?

The University of Minnesota, Morris, one of five campuses of the University of Minnesota system, is a decidedly rural residential public liberal arts college of 1700 students. On a hill overlooking our prairie campus, a 1.65 megawatt wind turbine currently powers 50% of our campus buildings—one million square feet. It is the first turbine of its kind to be constructed at a public university, and it has been in operation since Earth Day, 2005.

Tucked behind our campus Physical Education Center, a small, unobtrusive building is currently under construction. It will house our biomass/gasification plant, scheduled for its first "burn" in May of this year. By burning locally procured non-food-based bio-fuel feed stocks—principally, corn stover and mixed prairie grasses—we will essentially replace our natural gas supply and our natural gas dependency.

In addition to providing a minimum of 80% of campus heating needs, we anticipate that this plant will put approximately half a million dollars back into the local economy annually. Thus, instead of sending local dollars out of state to purchase natural gas, we will deposit these resources into the pockets of local citizens and thereby energize the local rural economy.

But that's not all.

In the fall of 2008 we will add a steam turbine to this gasification system. Operating on the green steam which is a product of the gasification process, the steam turbine will produce electricity for us on those days when the wind isn't blowing, and it provides a redundant source of electrical power that goes back onto the grid on those windy days that are the hallmark of the prairie. This same green steam that provides heat for our campus in the winter will connect to an absorption chiller in the summer to cool our buildings.

And there's more.

In the spring of 2009, we will add a second wind turbine on the hill, which, when it is operational, will provide the remainder of our electrical needs and then some…eventually allowing us to put the excess electricity produced on our campus back onto the grid.

Of course, like many other American colleges and universities, we are taking other steps to reduce our green house gas emissions. Our fleet includes hybrid and zero emission vehicles; we recycle; we have an active local foods initiative; we engage in energy and water conservation efforts; we are designing a new green living and learning residence hall and we are renovating one of the campus buildings that comprises our national historic registry district—both of these to LEED specifications.

I want to repeat again my opening sentence: in the year 2010—just two short years from now--the University of Minnesota, Morris, will be carbon neutral.

How does this fit into our academic mission and our undergraduate liberal arts focus?

Our students have been and are at the forefront of our "green" initiatives. They are active participants in studying the impact of these initiatives in several ways:

- an interdisciplinary environmental studies major;
- a robust undergraduate research program;
- a service learning program; and
- a variety of active internships.

Students work directly with Morris faculty, with researchers at an outreach center of the University of Minnesota's agricultural school in Morris, and with researchers at the local USDA Agricultural Research Station. They present nationally at conferences; they co-author papers with faculty members; they are our best spokespersons.

How have we managed financially, and has our work been cost-effective? Are we saving money?

Our work has been financed through investments made by the University of Minnesota system, whose Regents in 2004 adopted a system-wide policy related to sustainability. Our work is also supported through investments made by the State of Minnesota. In addition, we have received grants from the US Department of Energy and from the US Department of Agriculture. In December of 2007, we were authorized by the Internal Revenue Service to issue three Clean Renewable Energy Bonds, and we are currently in the process of negotiating an Energy Service Contract (ESCO). We will have achieved our goal through an integrated set of financial tools.

Do these investments save us money? The answer is both "yes" and "it depends". For example, as long as the price of natural gas stays at or above $8.00/BTU, (natural gas prices are currently higher than this), we save money by using biomass gasification. And, while CREB's are "no interest" bonds, they still must be paid back. Thus, while we save money by using wind to generate electricity, that money saved goes toward paying back our debt We don't have deep pockets or abundant resources—just imagination, vision, and resolve. Moreover, we are spending close to home; we are re-investing dollars in rural America.

And we have only just begun.

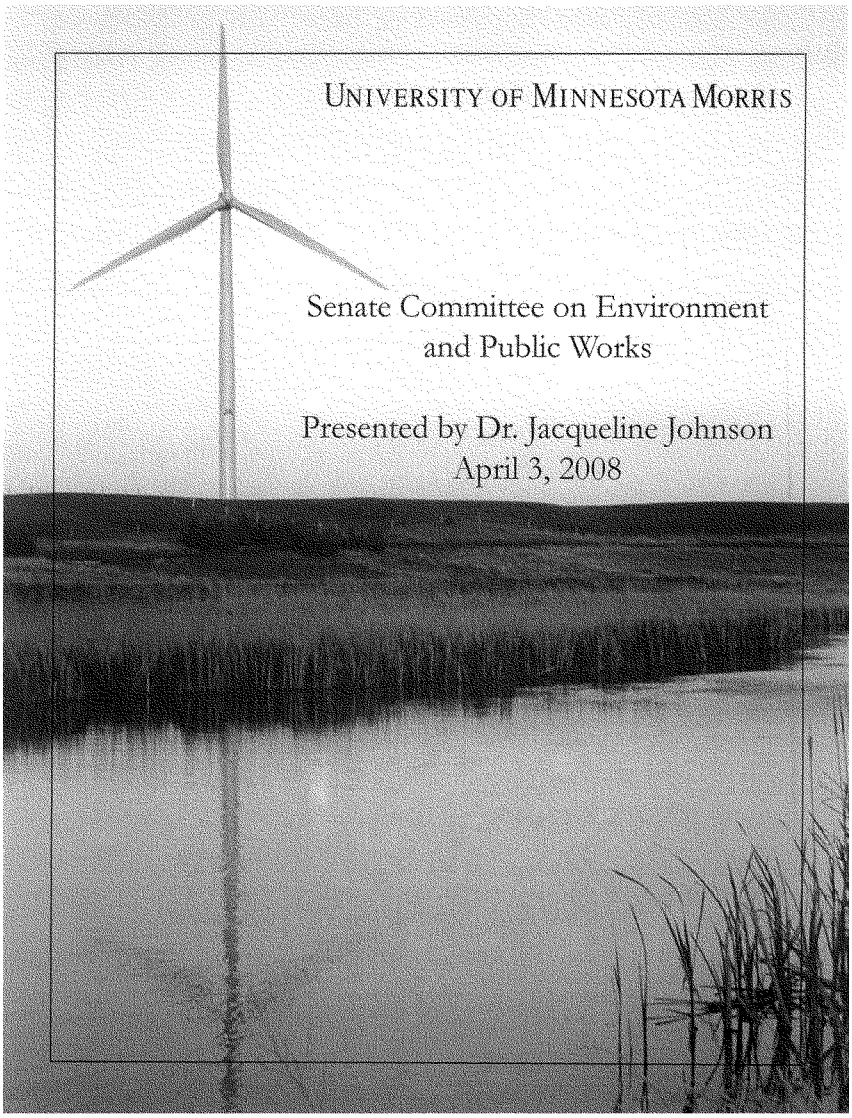
We believe that the work happening on our campus provides a prototype for transforming the future of rural America in a way reminiscent of the Rural Electrification Act of the 1930's. We believe that this on-site renewable electric and thermal generation system provides a model not only for other colleges and universities, for small communities, and for neighborhoods in the United States, but that it also has great relevance for developing countries—truly a model of global significance.

We also have an obligation to use the investments that have been made in our campus infrastructure to train a new workforce for a new economy—green collar jobs; career ladders that provide technical, intellectual and entrepreneurial pathways for the future. And even as I speak we are crafting new partnerships for this purpose that include collaborations with regional economic development organizations and initiatives, as well as area technical colleges.

We believe that when we reach our goal in 2010, we will be the first college in the US to have reduced greenhouse gas emissions in this way, through on-site generation.

BW---before wind—our fossil fuel footprint was 12,000 tons of carbon dioxide per year. By 2010, we will have reduced that footprint to 0. (Please refer to the bar graph included in your packet). We will have achieved carbon neutrality.

University of Minnesota, Morris students are out-spoken and they are action-oriented. In the best tradition of liberal learning, we encourage students and faculty to ask and answer the "big questions" of our time. Our work in reducing greenhouse gas emissions speaks directly to these characteristics and qualities. At the University of Minnesota, Morris we provide a liberal arts living and learning environment that is –literally-- both renewable and sustainable.


UNIVERSITY OF MINNESOTA MORRIS
Senate Committee on Environment
and Public Works
Presented by Dr. Jacqueline Johnson
April 3, 2008

UNIVERSITY OF MINNESOTA MORRIS

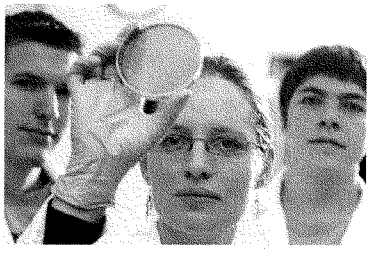
The Morris campus a unique history. In the late 1800s, the campus housed an American Indian boarding school, first operated by the Catholic Order Sisters of Mercy and later by the U.S. government. In 1909, the school closed and the campus was given to the State of Minnesota with the stipulation that American Indian students could attend school tuition free, a tradition that still holds true today. In 1909, the University of Minnesota established the West Central School of Agriculture boarding high school on the campus. By the late 1950s, a group of west central area citizens formed the West Central Educational Development Association, which lobbied the legislature for the creation of a distinct liberal arts college within the University system to be established in Morris. On September 26, 1960, the University of Minnesota, Morris opened its doors. Today, nearly 12,000 UMM graduates lead successful lives in communities around the world, occupying careers in teaching, law, business, the arts and sciences, agriculture, and public service.

UMM Today

As one of five campuses of the University of Minnesota, the University of Minnesota, Morris (UMM) has a unique mission and offers the best features of higher education—a small, close-knit campus complemented by the power of a world-renowned research University system.

With an enrollment of about 1,700 students and more than 145 teaching faculty, the Morris campus attracts students from throughout Minnesota, 28 additional states and 14 foreign countries. UMM offers outstanding academic programs in support of its mission to provide an exceptional liberal arts education. Thirty majors from a variety of disciplines are organized, in part, into four divisions: Education, Humanities, Science & Mathematics, and the Social Sciences.

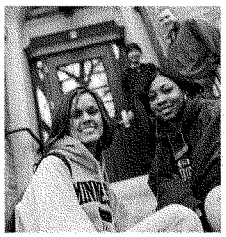
The "Morris experience" emphasizes faculty/student collaborative research, study abroad and service learning. UMM claims the highest percentage of the prestigious Horace T. Morse University of Minnesota Alumni Association Award for Outstanding Contributions to Undergraduate Education recipients within the University of Minnesota system. UMM faculty are dedicated to excellence undergraduate teaching and conduct scholarly activities and research with their students. Ninety-eight percent of UMM's tenured and tenure-track faculty hold a doctorate or highest degree in their field.



UMM has received national recognition for its academically gifted student body, its commitment to diversity, its emphasis on student leadership and the exceptional student-centered learning environment created by its dedicated faculty and staff.

Facts and Figures

• UMM rivals the top private liberal arts colleges in selectivity, academic rigor, and educational opportunities—at a public school price. The annual cost for tuition, fees, and room and board for 2007-2008 is $15,702. Ninety-one percent of UMM students received financial aid in 2005-06.



• UMM is repeatedly designated as "Best in the Midwest" in The Princeton Review's survey of college students.

• UMM is consistently ranked among the top 100 colleges nationally as a best value for both in-state and out-of-state students by the Kiplinger Best Values in Public Colleges annual survey.

• UMM is a partner in shared facilities and initiatives such as: the Regional Fitness Center, a cooperative effort between the campus, the community, and the county; Big Cat Stadium, a football facility used by both the Morris Area School District and UMM.

• Currently, 50 percent of UMM students participate in Service Learning, halfway to the campus goal of 100 percent participation.

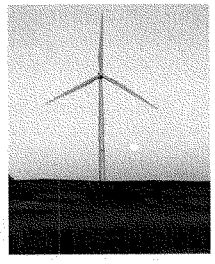
• The University of Minnesota, Morris Center for Small Towns and the City of Morris received the prestigious Carter Partnership Award for Campus-Community Collaboration in November 2006.

Our Green Campus

The University of Minnesota, Morris is at the forefront of change. Our history is one of helping students reach their full potential as citizen leaders, and we're striving to create physical and educational transformation that emphasizes fair treatment of all people, respect for our natural resources, and financial stewardship. UMM walks on a path created by our elders; our hope is to continue to place the bricks of stewardship on which future generations may walk.

- Troy Goodnough, UMM campus sustainability coordinator

The University of Minnesota, Morris has advanced sustainable, environmentally friendly initiatives since Earth Day 2000. These efforts have grown to levels of national leadership and now touch nearly all aspects of campus life—power, food, water, transportation, waste-stream infrastructure, academic study, and quality of life. Partnerships with the University of Minnesota and a multitude of organizations, neighbors, and friends have been essential in this work. State and national resources have advanced these collective efforts.



UMM is a member of the Association for the Advancement of Sustainability in Higher Education (AASHE) and the Upper Midwest Association for Campus Sustainability (UMACS).

In June 2007, UMM Chancellor Jacqueline Johnson and more than 250 other college and university presidents formally committed to sharply reduce and eventually eliminate campus global warming emissions by adopting the American College & University Presidents Climate Commitment during summit of higher education leaders in Washington, D.C.

UMM's Engaged Students

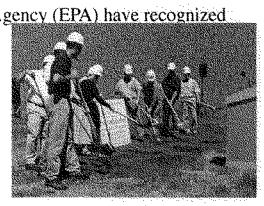
UMM students are leaders in this transformation by actively participating in the campus shared governance process and serving on committees that explore the use of resources. Students routinely travel around the country and the state to learn more about sustainable energy, food systems, and more. Students encourage discourse that is focused on sustainability by bringing to the campus community movies, speakers, and events such as the National Campus Energy Challenge.

UMM's vision for 2010: carbon footprint redection of 100 percent and achieve total energy self-sufficiency!

A National Leader in Green Energy

An on-site wind turbine supplies power to half of UMM's buildings. The first large-scale wind research turbine ever constructed at a U.S. public university is located at the nearby University of Minnesota's West Central Research and Outreach Center (WCROC).

The U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency (EPA) have recognized UMM as a member of the Green Power Leadership Club for UMM's outstanding commitments and achievements in green power. In 2005, the DOE and EPA presented UMM with a Green Power Leadership Award for commitment to on-site generation of renewable energy.



A biomass gasification demonstration and research facility will use corn "stover," or stalks, from the region's farmers to generate steam to meet 80 percent of the campus' heating and cooling needs. This community-scale project, slated to begin operation in April 2008, combines local production and use of renewable energy with state-of-the-art research and demonstrations focusing on biomass, biofuels, anaerobic digestion, and renewable hydrogen.

In 2008, UMM received authorization to issue Clean Renewable Energy Bonds (CREBs) for three purposes: construct a second wind turbine near the WCROC, add a steam turbine that will convert to electricity the "green" steam from the biomass facility, and purchase a third wind turbine located in western Minnesota, that will be shared with the Mille Lacs Band of Ojibwe. The CREBs will continue to move the Morris campus forward as a national leader in renewable energy systems.

UMM is participating in the pilot phase of a rating system for sustainability in higher education called STARS—Sustainability Tracking, Assessment, and Rating System. UMM joins 90 other college and university campuses to test the self-assessment tool developed by the Association for the Advancement of Sustainability in Higher Education (AASHE). Participants will provide feedback to AASHE throughout 2008.

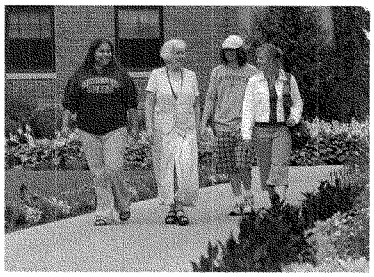
The Wind to Hydrogen to Anhydrous Ammonia Pilot System currently in development at the University of Minnesota West Central Research and Outreach Center will use wind generated hydrogen and will combine it with nitrogen extracted from the air. This process will form anhydrous ammonia. Anhydrous ammonia is the major source of nitrogen fertilizer for corn and basis for producing other forms of nitrogen fertilizer. The dramatic increase and volatility in natural gas prices has resulted in excessively high costs for nitrogen fertilizer both in terms of domestic production and use. In fact, more than 50 percent of the nitrogen fertilizer used in the United States is now imported.

Local Foods go to College—Pride of the Prairie

UMM'S local foods initiative is one of the longest-running local foods efforts in Minnesota higher education. UMM is a founding partner in the Pride of the Prairie Local Foods Initiative. Each semester, UMM hosts a Pride of the Prairie Food Expo and Farmer's Market, featuring locally, organically grown, and sustainably grown foods. Minnesota Grown Food Alliance certified foods are served regularly in the campus' dining facilities.

Green Education
An new interdisciplinary major in environmental studies complements the renewable energy and sustainability initiatives that are already in place or in progress at UMM. The major draws from courses in the social sciences, humanities and sciences and include a required internship or research experience.

A LEED (Leadership in Energy and Environmental Design) certified Green Prairie Living and Learning residential life facility is planned to open in Fall 2009. The facility will provide contemporary undergraduate student housing for 80 students in an eco-friendly model designed for sustainable living and community building. In summer months the building will house and provide learning spaces for researchers, visiting scholars, undergraduate and graduate students, and engaged citizens–for research, workshops, and programs linked to the community based renewable energy platforms and green initiatives in Morris.



Conservation and Recycling
By using the Toyota Prius—a gas/electric hybrid vehicle that drives about 120,000 miles each year, the campus has offset more than 21 tons of carbon dioxide (about 2,200 gallons of gasoline). This is approximately the same amount of carbon dioxide (20 tons) that the average American produces every year (as determined by the Union of Concerned Scientists).

Campus facilities leaders commissioned a campus water resource conservation study in 2002. As a result of the study, fixtures with water-saving features, such as restrictors in bathroom sinks and showers, low flow water toilet tanks, and automatic urinal flushers, have been installed campuswide.

UMM recycles tons of waste each year—aluminum, corrugated cardboard, and office paper, among other refuse. In 2007, UMM recycled 65 tons of waste at $211 per ton saving $13,715.

UMM's Partners
Morris campus achievements—supported by the State of Minnesota, the University of Minnesota system and the Green Prairie Alliance, a local collaboration that includes Morris' USDA Soils Lab, the Department of Natural Resources and local farmers—are further affirmed by our membership in the American College & University Presidents Climate Commitment. The WCROC is the site of a wind turbine that supplies energy to UMM. Scientists at the "soils lab," as the USDA-ARS is commonly known, research energy crops for the future. The alliance partners are working hard to make Morris a destination for the people of the State of Minnesota, the region, and the world who want to learn more about a future that will be less dependent on foreign and nonrenewable sources of energy.

UNIVERSITY OF MINNESOTA

MORRIS

600 East 4th Street
Morris, MN 56267

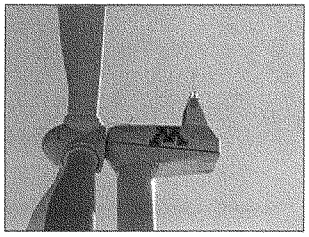
www.morris.umn.edu

1-888-UMM-EDUC

McKinstry

Project Experience

UNIVERSITY OF MINNESOTA
MORRIS



UNIVERSITY OF MINNESOTA MORRIS

COMPREHENSIVE ENERGY EVALUATION AND MASTER PLAN

PROJECT INFORMATION:

Project Dates: June – Nov. 2007

Project Value: $50,000.00

Project Results:
Identified $7 million dollar, self-funding project to reduce carbon emissions by more than 80%

PROJECT DESCRIPTION:

The University of Minnesota Morris (UMM) had an established goal of becoming carbon neutral. Prior to engaging McKinstry, UMM had already constructed a 1.65 MW wind turbine, and had received legislative funding for the construction of a biomass gasifier and steam boiler. However, even with these significant investments they were unsure how close these steps would take them to carbon neutrality, and uncertain how to best reach their goal. They chose McKinstry to analyze their campus energy supply and demand. This analysis included an evaluation of the campus energy demand, an evaluation of the campus energy supply side options, the development of a plan for an energy education and awareness system, and a plan for actively managing energy production, storage, and consumption on campus.

Key Personnel

Tom Laufenberg—Project Director
Greg Ackerson—Master Planner
Paul Gustafson—Program Manager

PROJECT BENEFITS:

McKinstry's completed analysis resulted in the development of the McKinstry Carbon Management Tool. This interactive, predictive tool visually demonstrates the impacts and interactions between a multitude of conservation, energy storage, and supply-side options. This ultimately resulted in the identification of a self-funding project with a 13 year payback, which not only resolved the campus' chilled water shortage, but also results in a reduction of their carbon emissions of more than 80%. This will allow UMM to purchase carbon offsets for the remaining carbon footprint, and achieve their goal of becoming carbon neutral.

REFERENCE: LOWELL RASMUSSEN,
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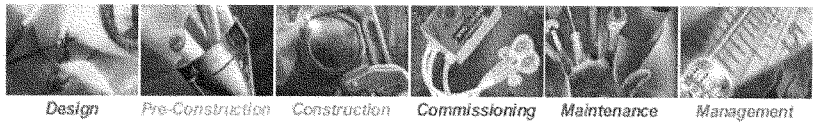
RASMUSLC@MORRIS.UMN.EDU



Design | Pre-Construction | Construction | Commissioning | Maintenance | Management

In response to Electricity Delivery and Energy Reliability Research, Development, and Analysis Program Area of Interest 2: Renewable and Distributed Systems Integration (DE-PS26-07NT43119)

Integrated Community-Scale Renewable Energy Systems: Developing and Demonstrating a National Model

Jointly Submitted by the University of Minnesota West Central Research Center and the University of Minnesota, Morris

Michael Reese and Lowell Rasmussen as Co-Principle Investigators

Table of Contents

	Page Number
Title Page	
Table of Contents	1
Project Narrative	2
Section 1. Statement of Overall Objectives	2
Year1	3
Year 2	5
Year 3	5
Year 4	6
Year 5	7
Section 2. Technical Description	8
1.0 Introduction	8
2.0 Hybrid Wind Energy Systems	10
2.1 Wind Energy	10
2.2 Renewable Hydrogen and Ammonia	11
2.3 Ammonia as a Hydrogen Carrier	12
2.4 Current Ammonia Production	14
2.5 Ammonia Production	14
2.6 Energy and Fertilizer Costs	15
2.7 Water and Other Core Chemicals	15
2.8 Winds to Hydrogen to Ammonia Pilot Facility	16
2.9 Hydrogen-and Ammonia-Powered Electrical Energy Generation	16
3.0 Biomass Gasification System	20
3.1 Heating and Cooling	20
3.2 Steam Turbine and Phase Change Storage Device	23
3.3 Biomass Producer Gas Genset	24
4.0 Biodiesel Genset	25
4.1 System Specifications	25
4.2 Operating Strategy	26
5.0 Consumer Information Gateway Development	26
5.1 Smart Metering and Advanced Control Technology	26
5.2 Economic Decision Tools	27
5.3 Environmental Decision Tools	28
5.4 Information Systems and Use	28
5.5 Public Access and Outreach	29
Section 3. Summary and Self Evaluation	30

PROJECT NARRATIVE

Section 1

STATEMENT OF PROJECT OBJECTIVES (SOPO):

TITLE OF OVERALL WORK TO BE PERFORMED: Development, Testing, and Demonstration of an Integrated and Community-Scale Renewable Energy production system with real time interactive communications for storage, generation, and distribution management.

OBJECTIVE OF OVERALL WORK: An integrated renewable energy system will be developed and will serve as a model for the nation resulting in critical information and technology to efficiently duplicate the energy system across the country. Renewable energy generation, energy storage, dynamic scheduling, and large passive energy loads will be utilized to manage the distributed resources, meet distribution level load requirements, and provide peak energy for transmission load requirements.

SCOPE OF OVERALL WORK TO BE PERFORMED: Over the five year term of the project, renewable energy systems will be developed, tested, and integrated to ensure reliability and function. In Year 1, several generation technologies will be added to the existing 1.65 MW wind turbine and biomass gasification heating and cooling system. The generation units include a 120 kW hydrogen and ammonia fuel cell and 60 (H2) and 120 kW (NH3) internal combustion engine gensets, an engine genset that utilizes biomass synthesis gas, a 400 kW biomass steam turbine, and a thermal storage device. The generation systems will be installed and tested for function, reliability, and economic and environmental impact. In order to provide the necessary redundancy, two 500 kW biodiesel engine gensets will be installed to complement the system in Year 2.

Once individual testing is complete in Year 3, the systems will begin to be integrated and tested as one system. Economic and environmental modeling will begin to determine which operation regiments are most desirable considering the available resources, costs, and emissions. The basis for the dash board controls will begin in Year 1 and will continue to be enhanced throughout the project. Beginning in Year 3 Smart metering and Awareness and Education portals will be located in strategic areas throughout the campus. The Smart Metering and Awareness and Education Portal features will be tested to function in concert with the integrated renewable energy generation and load management systems. Finally in Year 5, all individual components and the refinements that have been developed in Year 1-4, will come together as a comprehensive demonstration to fully function as an integrated system. The five deliverables will be completed in Year 5 and they include:

1. **A Roadmap and Manual for the Integration of Community-Scale Renewable Power Systems**
2. **Market Tested Energy Awareness and Education Strategies for Optimized Utilization of Microgrids and Distribution Systems**
3. **Economic and Environmental Decision Models for Distributed Power Generation Systems**

4. **National Workshop on Renewable Generation Integration**
5. **Comprehensive Demonstration with World-Wide Access via Real Time Internet Portals**

Year 1 - Development and Testing of Diverse On-Demand Renewable Energy Systems for Peak and Baseload Power

A. OBJECTIVES
Specifications for several state of the art energy production and storage systems will be developed to build on the robust distributed energy platform that already exists at the site. These new systems will increase the ability of the distributed generation capacity to meet the needs of the U of MN Morris campus and provide a working test site to determine the impact of distributed power generation on an existing working power grid.

The objective of Year 1 is to develop and test diverse sources of renewable energy. An integrated system will require energy from multiple sources. Each source provides specific benefits to the system but also has shortfalls:

Wind Energy: Cheapest source of renewable energy (not including hydro power) / Intermittent or variable nature limits use.

Hydrogen and Ammonia: Production enables wind energy to be stored / Hydrogen is difficult to store and handle.

Fuel Cells - Very efficient with no emissions / very expensive.

ICE Gensets- Proven technology and low capital costs / emissions and high fuel costs.

Biomass Gasification - Great potential for multiple uses / unproven technology.

Thermal Storage - Great potential / unproven technology.

The above systems will be individually developed and tested in order to optimize performance.

B. SCOPE OF WORK
The campus power utilization will be analyzed and the new generation /storage equipment will be sized and installed in the first year. This will include:

a. One 120 kw ammonia generator
b. One 120 kw ammonia fuel cell
c. One 100 kw producer gas generator
d. One thermal storage unit

A hybrid wind system, biomass gasification system, and a biodiesel genset system will be developed and individually performance tested to characterize operation and provide for the basis of optimization.

Hybrid Wind Energy System:
A 120 kW ammonia genset and a 120 kW ammonia fuel cell will be developed (fuel cell) and installed within the Renewable Hydrogen and Ammonia production facility at the University of Minnesota West Central Research and Outreach Center. A 60 kW hydrogen genset is funded

and will be added to the system as well. The novel direct-ammonia fuel cell will be purchased from NHThree, LLC. The fuel cell used cutting edge technology which allows for both the direct use of hydrogen and ammonia as a fuel as moderate temperatures. Dr. Jason Ganley, Howard University Chemical Engineer professor and principle in NHThree, LLC developed the technology and will construct the pre-commercial 120 kW fuel cell. The fuel cell will then be installed (Q4), performance tested (Q5-8), integrated (Q9-16), and then demonstrated under commercial conditions (Q 17-20).

Biomass Gasification System:
A 400 kW steam turbine and thermal storage device will be added to the district heating and cooling biomass gasification system. In addition, a 100 kW biomass syngas genset will be added and performance tested.

Biodiesel Genset System:
Two 500 kW biodiesel gensets will be installed and performance tested. The diesel gensets are a proven technology and will provide reliable peak power and redundancy.

C. TASKS TO BE PERFORMED

Task 1.0 Personnel

Develop job descriptions in Q1 and hire in Q2:

a. Project Coordinator
b. Junior Scientist
c. Design Graduate and undergraduate research objectives
d. Sustainability Coordinator (10%)

Task 1.2 Equipment

Develop specifications in Q1 and purchase in Q2:

a. 120 kw ammonia generator
b. 60 kw ammonia fuel cell
c. Phase change liquid thermal storage system
d. Biomass Steam Turbine Q1-Q4
e. Fabricate all systems Q2-Q4

Task 1.3 Software/data Q1-Q3

a. Establish campus energy utilization history Q1
b. Establish matrix of energy consumption and environment Q2
c. Build matrix under current transmission loads Q3

Task 1.4 File reports for Q1-Q4

a. Quarterly reports for Q1 –Q4
b. Management report for year 1
c. Annual indirect costs report.

Year 2 Individual production platforms (Q5-Q8).

A. Objectives
Each aspect of the expanded renewable energy platform will be tested to determine the optimum operational parameters for each system. This data will be built into the database.

B. Scope of Work
The two primary platforms of wind and biomass will be operated to determine the synergies between the systems and where the systems can provide the most dependable outputs.

C. Tasks to be Performed

Task 2.0 Personnel
- a. Performance reviews for project coordinator and junior scientist
- b. Select graduate student research participant Q5
- c. Select undergraduate research participants Q5

Task 2.1 Equipment
- a. Fuel cell development and testing Q5-Q7
- b. Specify dashboard equipment controls and communication standards Q5
- c. Purchase dashboard system Q6-Q7
- d. 100 kw producer gas cofired biodiesel generator
- e. Specify two 400 kw biodiesel generators Q5
- f. Install producer gas genset. Q6
- g. Install thermal storage. Q5

Task 2.3 System testing
- a. Bring each system up and run production tests Q7-Q8
- b. Test under :
  1. No load
  2. Partial load
  3. Full load

Task 2.4 Data and software Q6-Q8
- a. Establish performance curve for all systems Q7
- b. Establish carbon footprints for all systems Q8

Task 2.5 File reports for Q5-Q8
- a. Quarterly reports for Q5 –Q8
- b. Management report for year 2
- c. Annual indirect costs report.

Year 3 Systems and economic development.

A. Objectives
The operating characteristics of each platform will be logged and all inputs and outputs will be analyzed to give a accurate indication of the cost of production from each platform.

B. Scope of Work
Trial runs will be conducted under actual operating conditions to understand the true costs of each platform.

C. Task to be Performed

Task 3.0 Personnel Q9
- a. Performance reviews of project coordinator and junior scientist
- b. Interim research report from graduate student Q10
- c. Select Undergrad Students 2-3 Q9

Task 3.1 Equipment
- a. Specify equipment for onsite building information systems Q9
- b. Purchase onsite information equipment Q10
- c. Purchase smart meter Q9-16
- d. Establish LAN and AMI for all distributed systems Q10
- e. Purchase 2 400 KW biodiesel Generators Q9

Task 3.2 System integration
- a. Trial runs for wind- anhydrous ammonia platforms Q 10-Q12
- b. Trial runs for biomass- thermal storage platforms Q10-Q12
- c. Trail runs for dashboard control systems Q10-Q12
- d. Start economic modeling Q9
- e. Start Environmental Modeling Q9

Task 3.3 Data and software
- a. Develop rate templates for rate matrix Q11
- b. Optimize distribution based on performance and grid inputs Q11
- c. Develop projected return on investment based on rate matrix Q12

Task 3.4 File reports for Q9-Q12
- a. Quarterly reports for Q9 –Q12
- b. Management report for year 3
- c. Annual indirect costs report.

Year 4 System integration, peek demand control and demand side management.

A. Objectives
All distributed systems will be integrated to in a universal communications interface to allow the interactive real time communications between all systems. Establish the consumer gateway development. (Optional Sub-Area 2C)

B. Scope of Work
The interactive dashboard will provide the backbone for the communications protocol. All systems will be connected into the dashboard back bone.

C. Tasks to be Performed

Task 4.0 Personnel

a. Performance reviews for project coordinator, junior scientist Q13
b. Final research report by graduate student Q13
c. Undergraduate research reports Q13
d. Begin planning of national conf Q15

Task 4.1 Equipment

a. Select Universal Communication Interface (UCI)
b. Specify final demand side meter components Q13
c. Purchase demand side meter components Q14
d. Complete energy/carbon kiosks Q14
e. Provide necessary switchgear and disconnects to allow for grid parallel and grid connected trials Q14

Task 4.2 Data and software

a. Build peek demand limiting protocols with utilization interface Q14
b. Complete energy/carbon web site Q15
c. Program dashboard for full operation Q16
d. Run trials in both gird parallel and grid connected modes Q16

Task 4.3 File reports for Q13-Q16

a. Quarterly reports for Q13 –Q16
b. Management report for year 4
c. Annual indirect costs report

Year 5 Comprehensive demonstration

A. Objectives
The final stage of this project is to run real-time demonstrations of a renewable distributed energy production tied to the demands of both the campus community and the status of the grid. The interactive nature of this project should provide improved efficiencies for both the campus and the power grid. A demonstration of the consumer gateway using AMI and distributed dashboard will be conducted.

B. Scope of Work
Year 5 will allow the demonstration of the aggregation and integration of all distributed operations with data collection. Data will be collected for both grid parallel and intentional islanding of the distributed network. With help from NETL the campuses will conduct a nationwide conference on how this system can extend the communications network beyond the substation and can be developed into a tool to manage both energy and carbon footprints.

C. Tasks to be Performed

Task 5.0 Personnel

a. Performance review for project coordinator and junior scientist Q17
b. Undergraduate research reports Q17

Task 5.1 Roadmap and manual for integration of community scale renewable energy systems into established power grids to manage and improve performance of transmission grids and reduce stranded capacity on the grid (Q20).

Task 5.2 Market testing of energy awareness and control strategies for optimization of microgrids and distribution systems (Q20).

Task 5.3 Economic and environmental decisions models for distributed power generation (Q20).

Task 5.4 Conduct national workshop for distributed renewable generation, nontraditional energy storage and impact on grid performance (Q20).

Task 5.5 Comprehensive real time and real application of distributed generation and its effect on transmission capacity and performance using smart meters and advanced software applications.

Task 5.6 File reports for Q17-Q20

a. Quarterly reports for Q17 –Q20
b. Management report for year 5 Q20
c. Annual indirect costs report Q20
d. Close out reporting Q20

Section 2

TECHNICAL DESCRIPTION

1.0 Introduction

The University of Minnesota, Morris campus and the West Central Research and Outreach Center are jointly developing, in collaboration with several public and private partners, a globally unique, integrated community scale renewable energy system with mixed sources of energy generation and load management capabilities. These systems alone will provide a significant resource and demonstration for the nation and the funding requested through this solicitation will further enhance the value for communities, businesses, and utilities across the world. Perhaps no other entity across the world can bring to this solicitation the diverse renewable energy systems as proposed as well as the opportunity for integration, discovery, and practical demonstration.

The project team requests $ 6,973,729 to meet the solicitation objectives. The main features of the current and proposed system include: wind energy generation, biomass gasification, biodiesel generation, and energy storage, such as hydrogen and ammonia production and utilization, and thermal storage technologies. The diversity of this system combined with the practical energy utilization and research capabilities allows for multiple avenues of discovery, development, and demonstration. The funding requested in this proposal will provide for integration of the existing renewable energy systems with systems requested in this proposal and allow for the ability to more effectively manage distribution and transmission systems by utilizing passive load sinks and on-demand distributed and renewable generation.

Renewable energy generation, energy storage, dynamic scheduling, and large passive energy loads will be utilized to manage the distributed resources, meet distribution level load requirements, and provide peak energy for transmission level load requirements.

The major deliverables are:
1. Roadmap and manual for integration of community scale renewable energy systems into established power grids to manage and improve performance of transmission grids and reduce stranded capacity on the grid (Q20).

2. Market testing of energy awareness and control strategies for optimization of microgrids and distribution systems (Q20).

3. Economic and environmental decisions models for distributed power generation (Q20).

4. Conduct national workshop for distributed renewable generation, nontraditional energy storage and impact on grid performance (Q20).

5. Comprehensive real time and real application of distributed generation and its effect on transmission capacity and performance using smart meters and advanced software applications.

Many of the major integration demonstration components are in place or already funded and in development. Current research platforms include a $2 million 1.65 MW Vestas V-82 wind turbine that has been operational since March 2005. The turbine provides electrical energy to the UMM campus via a 1 mile University-owned 12.5 kV line. A globally unique Wind to Hydrogen to Ammonia system has been funded by the Minnesota legislature and will be operational fall 2008. The hydrogen will be used for electrical energy generation and as a core ingredient for the production of anhydrous ammonia. Anhydrous ammonia is extensively used in the Midwest for nitrogen fertilizer and is a high demand and saleable product. The ammonia may also be used for electric energy generation and therefore is an energy storage medium.

This hybrid wind system will feature a 400 kW electrolyzer, hydrogen storage, 120 kW hydrogen-powered internal combustion generator (ICE genset), nitrogen generation, and an anhydrous ammonia reactor and storage.

This proposal requests the addition of a 100 kW hydrogen fuel cell, 60 kW ammonia-powered ICE genset, 100 kW direct ammonia fuel cell, and two 500 kW biodiesel gensets to this hybrid wind system.

A biomass gasification system was also funded by the Minnesota legislature and will be operational spring 2008. The system will utilize corn stover and other agricultural residues and energy crops to provide heating and cooling for the 2000 student University of Minnesota, Morris campus. The Morris campus is a signatory of the Presidents Climate Challenge and has adopted a goal of being carbon neutral by 2010. Approximately 3000 lbs of biomass will be gasified per hour of operation which will produce 15,000 lb of steam in the heat exchanger. As currently funded, the steam will support the heating and cooling functions of 80% of the campus district system. Two natural gas boilers provide steam for peak demand and redundancy during repairs and maintenance. Funding is requested to add to this system a 400 kW steam turbine, a 19 million BTU phase change thermal storage device, and a 100 kW cofired biomass producer gas/diesel genset.

All of the core systems are practical renewable energy production systems providing power to the campus and grid but also function as research and demonstration platforms for the University of Minnesota. The current systems are "wired" for research with the capability to capture all relevant data. Funding is requested for data acquisition mechanisms on all systems purchased as part of this proposal.

Hydrogen and ammonia gensets and fuel cells as well as three biodiesel gensets will be added to the hybrid wind system. A biomass steam turbine, syngas engine genset, and a phase change thermal storage device will be added to the gasification system. Battery and flywheel storage, photovoltaic solar, dynamic scheduling systems, and plug-in hybrid electric and fuel cell vehicle use as peaking power and load management systems will be modeled to incorporate into the comprehensive demonstration.

2.0 Hybrid Wind Energy System

2.1 *Wind Energy*

Even though wind energy is generally considered as economically viable and returns considerable dollars into local communities, severe electrical transmission constraints have greatly limited wind energy development in the Midwest. The Midwest Independent System Operators (MISO) governs the transmission grid in the region and reports that there are 7,000 MW of wind energy in the queue across the Midwest and ready for deployment if transmission becomes available. Over half (3600 MW) would be constructed in Minnesota. Ron Arnest, MISO Wind Energy Manager, has stated that it will be another ten years before transmission capacity will allow for much of the wind energy in the queue and ready for construction in Minnesota. Across the western regions of Minnesota and eastern Dakotas there are approximately thirty one physical transmission constraints. These constraints are called the North Dakota Export Boundary (NDEX). This boundary has a stated maximum load capacity of 1950 MW which is far short of what is needed to move wind energy east towards load centers. Even though millions of dollars of transmission upgrades are in the planning stages, the wind energy resource potential is significantly greater than what can and will be built to accommodate the resource. An ideal wind energy system will provide peak energy to the transmission grid

when needed, energy to meet the local distribution grid requirements, and then will be utilized as energy sink for value added products and / or stored energy.

The West Central Research and Outreach Center's 1.65 MW turbine provides a unique model in which the energy is first used by the UMM campus. The campus uses about 80% of the power generated and the remaining 20% is then sold to Ottertail Power Company. The turbine has a sweep of 82 meters and sits upon a 70 meter tower. Net production from the turbine over its two year time frame has averaged 5.4 million kWh per year.

2.2 *Renewable Hydrogen and Ammonia*

Large wind energy generation is a mature and commercially accepted technology. However, the utilization of the vast wind energy resources in the Midwest can be drastically enhanced through the production of value added products and the subsequent use of these products to regenerate electrical energy.

One of the most profound uses of wind energy and perhaps the ideal bridge technology to a renewable hydrogen economy in Minnesota and the Midwest could be the production of anhydrous ammonia. Anhydrous ammonia has many applications but the most important use is as nitrogen fertilizer. Over $300 million of anhydrous ammonia is used as nitrogen fertilizer in Minnesota agriculture alone. Since anhydrous ammonia (NH3) is hydrogen rich, it also can be used to generate electrical energy in fuel cells and internal combustion engine generation sets.

This direct-ammonia fuel cell represents a leap forward in stationary fuel cell technology and contains intellectual property developed by Dr. Jason Ganley and owned by NHThree, LLC. The fuel cell is unique in its capability to economically utilize both hydrogen and direct-ammonia as fuel and at a relatively low operating temperature. Lab-scale testing of this direct-ammonia fuel cell at Howard University indicates the potential to dramatically lower the capital and operating cost of stationary fuel cells.

The Hydrogen Engine Center in Algona, Iowa has developed an ammonia internal combustion genset. The genset is near term commercial technology and represents the tried and true internal combustion engine.

Renewable ammonia feedstock provides a clear path to commercial deployment of fuel cells and ICE gensets compared to pure hydrogen due to the ease of ammonia storage, extensive handling and storage infrastructure, high demand and use as a nitrogen fertilizer source, high energy density, and its relative safety. The fuel cell and gensets will be assembled, installed, and performance tested for energy production, efficiency, and durability under a range of operating parameters. Standard Operating Procedures (SOPs), Guidelines to Deployment and Installation, and business level feasibility study will be developed as deliverables.

Testing will be conducted at the globally unique University of Minnesota Wind to Hydrogen to Ammonia Pilot Facility in Morris, MN. The pilot facility is scheduled for completion in summer 2008 and will utilize wind energy from an existing 1.65 MW turbine to electrolyze water to produce hydrogen. Nitrogen will be separated from air and will be combined with the renewable hydrogen to produce anhydrous ammonia. The ammonia will then be used for both electrical energy generation and nitrogen fertilizer. The ability to utilize ammonia for electrical energy generation provides a means to store wind energy for use as peak and / or baseload power applications. Since the pilot facility will also include a test-bed for fuel cells and gensets, it is an

ideal location to demonstrate the novel direct ammonia fuel cell and ICE Genset and hasten their deployment in commercial markets.

The goal of this subtask is to test a pre-commercial direct ammonia fuel cell within a wind to hydrogen to ammonia system. The intent is that the information generated will lead to the commercialization and deployment of the technology.

Sub -Deliverables • Deployment and demonstration of the a direct-ammonia fuel cell • Characterization of the direct-ammonia fuel cell energy production, energy efficiency, and durability under a wide range of operating parameters • Optimization of fuel cell operating parameters • Development of direct ammonia fuel cell: o Semi-annual performance reports o Guidelines to the Deployment and Installation o Standard Operating Procedures (SOPs) • Business level feasibility study

The State of Minnesota is a national leader in the development and deployment of renewable energy technologies especially in the ethanol and wind energy industries. Successes of the locally owned ethanol production facilities and wind farms have boosted rural economies and have provided a stimulus to further develop rural renewable resources. However, there continues to be many factors limiting the State of Minnesota from fully realizing its position as the national leader in renewable energy. The most dramatic bottleneck is the inability to fully utilize the vast wind energy resources. Most of the state's wind energy resources are located away from the large electrical loads of the metropolitan areas and there are limited transmission assets to move the energy to the load.

Hydrogen produced from wind energy is touted as the energy carrier of the future and is considered one of the main development areas of the US Department of Energy. Much of the US Department of Energy's research and development emphasis has been in developing fuel cell vehicles which will use hydrogen fuel. However, economically penetrating the transportation fuel (and electrical generation) markets with hydrogen fuel will be difficult considering the current production costs from wind energy estimated at $5.55 / kg (NREL, 2005). This amount translates to $5.55 per gallon of gas equivalent. Hydrogen is difficult to store and this fact will be another bottleneck in deployment of hydrogen as a transportation fuel and as a wind energy storage medium. Due to several desirable characteristics, ammonia may be an ideal bridge to the hydrogen economy.

2.3 Ammonia as a Hydrogen Carrier

The U. S. Department of Energy has studied the possibility of using ammonia as a carrier of hydrogen for the transportation fuel industry and recently released a report titled *Potential Roles of Ammonia in a Hydrogen Economy*. The following excerpt describes the characteristics of ammonia as a hydrogen source and carrier.

"Ammonia has several desirable characteristics that suggest its use as a medium to store hydrogen. First, it can be liquefied under mild conditions. The vapor pressure of ammonia at room temperature is 9.2 bar (~121 psig). Its physical properties are similar to those of propane (see Table 2.1). This means that ammonia can be stored in a simple, inexpensive pressure vessel. Second, ammonia has a large weight fraction of hydrogen. Hydrogen constitutes 17.65% of the mass of ammonia. When these two factors are combined, the result is a liquid that is simply contained, with a volumetric hydrogen density about 45% higher than that of liquid hydrogen. Ammonia can be decomposed (cracked) over a catalyst to produce the desired fuel—

hydrogen (H2) along with nitrogen (N2) a non-toxic, non-greenhouse gas. In addition, ammonia might be an excellent transition fuel. It can be burned directly in an internal combustion engine (ICE) with no carbon emission, converted to electricity directly in an alkaline fuel cell, or cracked to provide hydrogen for non-alkaline fuel cells (FC). Central production from hydrocarbon fuels (e.g., natural gas) would provide opportunities for CO2 capture; transportation and distribution would be simpler and cheaper than hydrogen delivery; and final use in an internal combustion engine or fuel cell would produce no carbon dioxide. Some of the physical and chemical properties of ammonia are listed in the following table."

Ammonia Properties (DOE, 2006)

Hydrogen Content					
H_2 weight fraction	17.65	wt.%	H_2 volume density	0.105	kg/liter
Solid Phase					
Melting point	-78	°C	Latent heat of fusion (1 atm at triple point)	-337.37	kJ/kg
Liquid Phase					
Vapor pressure (21°C)	8.88	bar	Liquid density (1atm @ boiling point)	682	kg/m^3
Boiling point (@ 1.0 atm)	-33.5	°C	Liquid/gas equivalent (1 atm and 15°C)	947	vol/vol
Latent heat of vaporization (1 atm @ boiling point)		1371.2		kJ/kg	
Critical temperature	132.4	°C	Critical pressure	112.8	bar
Gas Phase					
Gas density (1 atm at boiling point)	0.86	kg/m^3	Gas density (1 atm at 15°C)	.73	kg/m^3
Compressibility (Z) (1 atm at 15°C)	.9929		Specific gravity (air=1) (1 atm at 20°C)	.597	
Specific volume 1 atm at 20°C)	1.411	m^3/kg	Viscosity	.000098	Poise
Heat capacity at constant pressure (Cp) (1 atm at 15°C)	.037	kJ/(mol.K)	Heat capacity at constant pressure (Cv) (1 atm at 15°C)	.028	kJ/(mol.K)
Critical Density:	0.24	g/ml	Entropy, Gas @ 25°C., 1 atm. :	45.97	cal/mol°C
Thermal conductivity		22.19		mW/(mK)	
Misc					
Water solubility (1 atm at 0°C)	862	vol/vol	Autoignition temperature	630	°C
Lower flammable limit in air	15%	By volume	Upper flammable limit in air	28%	By volume
Molecular Weight:			17.03		

2.4 Current Ammonia Production

Natural gas is the current hydrogen source for anhydrous ammonia through a process called Steam Methane Reforming. Natural gas cost and use are projected to rise throughout the next 20 years as domestic production will concurrently decrease (DOE, 2003). Fifty percent of nitrogen fertilizer is imported and 28 percent of domestic fertilizer plants have shut down due to high domestic natural gas prices. Utilizing natural gas in the production of anhydrous ammonia also contributes to green house gas emissions. In contrast, wind energy is perhaps the cleanest source of energy, continues to advance in technology and efficiency, and is becoming competitive with even the cheapest sources of fossil fuels.

2.5 Ammonia Production

Most of the processes for producing synthetic nitrogen first begin with hydrogen production. As late as the 1980's, electrolysis of water was a dominate production route for hydrogen but was eventually supplanted with the less expensive natural gas steam methane reforming. Since the 1930's, the Haber - Bosch process has been the standard route used to produce ammonia from hydrogen. This process is used with both electrolysis of water and steam methane reforming of natural gas production routes.

The Haber - Bosch process is the reaction of nitrogen and hydrogen to produce ammonia. The nitrogen and hydrogen are reacted over an iron catalyst under conditions of approximately 200 atmospheres (or 2940 psi) at 450°C (or 842°F). The chemical reaction is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \Delta H$$

The reaction of nitrogen and hydrogen is reversible, meaning the reaction can proceed in either the forward or the reverse direction depending on conditions. The forward reaction is exothermic (it produces heat and is favored at low temperatures). A fine balance is needed in the reaction. Increasing the temperature tends to drive the reaction in the reverse direction, which is undesirable if the goal is to produce ammonia. However, reducing the temperature reduces the rate of the reaction, which is also undesirable. Therefore, an intermediate temperature high enough to allow the reaction to proceed at a reasonable rate, yet not so high as to drive the reaction in the reverse direction, is required. Usually, 450°C is used. An iron catalyst is used to make the process faster and more efficient.

A catalyst increases the rate of reaction between nitrogen and hydrogen. Early in the 20th century, a German academic chemist, Fritz Haber, and an industrial colleague, Carl Bosch, found that a mixture of Fe_2O_3 and Fe_3O_4 catalyzes this reaction at temperatures in the range of 400°C to 600°C. The yield of ammonia was further enhanced by working at gas pressures between 200 and 400 atmospheres. Although now modified and improved, the Haber-Bosch process continues to be the most common method for making ammonia. The nitrogen is obtained from liquefied air, and the hydrogen is usually obtained from natural gas decomposed by heating (Steam Methane Reforming).

The ammonia is formed as a gas but on cooling in the condenser, liquefies at the high pressures used, and is removed as a liquid. Un-reacted nitrogen and hydrogen is fed back in to the reaction. Recirculation is generally required since the reaction is not very efficient yielding between 15-30 % anhydrous ammonia per pass over the catalyst.

At the turn of the 20th century the traditional natural source of nitrogen (primarily guano) was limiting world-wide food production. Norsk Hydro, Dow Chemical, and many other companies began the race to produce synthetic nitrogen fertilizer. Utilizing hydro electric power and proprietary electrolyzers, Norsk Hydro began with a plasma arc technology to produce ammonia but eventually formed a business arrangement to use the Haber Bosch technology. Norsk Hydro grew to become the largest nitrogen fertilizer company in the world until spinning the company off in 2005. Today's natural gas steam methane plants have grown to immense scale producing in the range of 1000 to 8,000 tons per day. These economies of scale are necessary due to the utilization of natural gas in the production of hydrogen. The resulting hydrogen product must have impurities removed and these processes necessitate large production facilities. In comparison, hydrogen produced via electrolysis has a high purity and no further "scrubbing" steps are necessary therefore the production system can be relatively small.

2.6 Energy and Fertilizer Costs

The energy required to create anhydrous ammonia accounts for over 90% of the cost of production. So as the demand and cost of natural gas increases and the cost of wind energy decreases, the market will reach a nexus in which the cost of production will be equal. A benefit of wind energy is that once a wind farm is built, the cost of production is stable and locked in over a long term period (usually 20 years) since most of the expense is attributed to capital equipment. Conversely, natural gas based ammonia production is subject to an extremely volatile and erratic feedstock market. What are the risks and impact for future energy and ammonia prices? In reference to energy prices, Tony Nunan, Risk Manager at Mitsubishi recently stated "The supply margin is so thin, every little blip is going to move the market. And the acute geopolitical risks have lessened but the chronic geopolitical risks are still there." Also, the rapid increase in energy use by third world countries will continue to provide a solid force to drive up the energy markets including natural gas. Since 2000, Chinese oil consumption has doubled accounting for over half of the increase in global use. During the past decade, Chinese car ownership has grown from 10 cars per 1000 people to 20 cars per 1000 people. In comparison the United States currently has 950 cars per 1000 people. It is anticipated that there will be an even more rapid increase in car ownership in China over the next decade. The end result in the volatile energy market may be that locally owned and integrated renewable energy systems may be more efficient and competitive than large natural gas based ammonia plants. Obviously, there are other alternatives to wind to ammonia such as gasification of coal and biomass and the utilization of nuclear power for electrolysis but these energy systems have their own deficiencies. Both coal and biomass gasification systems require scrubbing and therefore require larger, more costly facilities. New nuclear power will be expensive and difficult to build and permit.

2.7 Water and Other Core Chemicals

Ground water use and availability will be a continuing concern for local energy production. A wind to hydrogen to ammonia system will produce approximately 5.2 lbs of anhydrous ammonia per gallon of water. For example, if a farmer applies 150 lbs of nitrogen per acre on his corn field this would be the equivalent water use of 35 gallons of water per acre. Through biochemical processes, the corn plants will convert a portion of the hydrogen from ammonia back to water. Oxygen is also generated in the electrolysis of water and in the pilot facility the oxygen will be vented to the atmosphere. The nitrogen source is air. Air is 78% nitrogen and can be extracted from the air through various methods. One electrolyzed gallon of water will result in approximately .93 lbs of hydrogen. When .93 lb of hydrogen is combined with nitrogen through the Haber Bosch Process the result is 5.2 lbs of anhydrous ammonia (NH^3). The other

product of the wind to ammonia system is process heat energy. The pilot facility will not utilize the heat energy but a commercial system may be able to capture it for greater efficiency.

2.8 Winds to Hydrogen to Ammonia Pilot Facility

The WCROC Wind to Hydrogen to Ammonia pilot facility is currently under design by Sebesta Blomberg and Associates. The design incorporates plug-n-play capabilities to include the requested hydrogen and ammonia- powered electrical generation systems. Construction of the Wind to Hydrogen to Ammonia system is scheduled to begin fall 2007 and the facility should be operational in fall 2008. The system will feature a 400 kW electrolyzer and a modified Haber Bosch reactor that will produce a maximum of 1 ton per day or 365 tons of ammonia per year. The reactor will be approximately the size of a 50 gallon drum. The system will also include a hydrogen engine genset. Once in operation the facility will produce anhydrous ammonia for use on the West Central Research and Outreach Center fields in addition to some excess which will be sold or used in other energy systems. Data will be collected to determine the actual costs of production, efficiencies, water use, and several other variables. The data will then be analyzed to further optimize the system. A valid wind to ammonia model will provide the following benefits:

- Opens a new market for an estimated 2 gigawatts of nameplate wind capacity within the state stimulating wind energy development across Minnesota and the Midwest.
- Diminishes the need for additional transmission capacity to accommodate wind energy.
- Enables utility companies to manage the variable nature of wind energy and electrical demand by providing a large and passive energy sink.
- Provides substantial economic development opportunities for farmers and rural communities.
- Decreases green house gas emissions by eliminating fossil fuels currently used in the process.
- Provides a secure, domestically produced nitrogen fertilizer source and protects a vital agriculture industry within the United States.
- Firmly establishes Minnesota as a world leader in renewable hydrogen production and wind energy.
- Creates a solid foundation from which to grow Minnesota manufacturing companies and attract complimentary hydrogen related industries.

2.9 Hydrogen- and Ammonia- Powered Electrical Energy Generation

Technical Aspects: Hybrid Wind System Project Description

This project proposes to deploy, demonstrate, and test a novel pre-commercial 120 kW fuel cell and ICE gensets utilizing renewably produced hydrogen and anhydrous ammonia.

The Midwest portion of the United States has superior wind resources and the largest demand and use of nitrogen fertilizer in the nation and perhaps the world. The necessary infrastructure for anhydrous ammonia transportation, storage, and application to agriculture fields is located near small rural towns across the Midwest. The University of Minnesota West Central Research and Outreach Center is developing a Wind to Hydrogen to Ammonia Pilot Facility to demonstrate, validate, and optimize the technology. This pilot production facility is funded in part by the Minnesota Legislature.

Current Ammonia Production from Natural gas is the current hydrogen source for anhydrous ammonia through a process called Steam Methane Reforming. Natural gas cost and use are projected to rise throughout the next 20 years as domestic production will concurrently decrease (DOE, 2003). Fifty percent of nitrogen fertilizer is imported and 28 percent of domestic fertilizer plants have shut down due to high domestic natural gas prices. Utilizing natural gas in the production of anhydrous ammonia also contributes to green house gas emissions. In contrast, wind energy is perhaps the cleanest source of energy, continues to decline in production cost per kilowatt hour, and is becoming competitive with even the cheapest sources of fossil fuels.

Ammonia Fuel Cell Applications

Anhydrous ammonia can be produced from wind energy, easily stored and transported, and has multiple end uses. Considering these attributes, renewable ammonia has the potential to dramatically increase utilization of the vast wind resources located across the Midwest and provide significant economic benefits. A key bottleneck is the development of economical and efficient ammonia-fueled electrical generation systems which could provide baseload and peak power in a highly flexible energy system.

Hydrogen- and Ammonia- Powered Electrical Energy Generation The developing hybrid wind energy system provides an opportunity to install and operate a test- bed of hydrogen- and ammonia- powered electrical energy generation as well as their use as energy storage mediums. The hydrogen and ammonia test-bed and demonstration will include both a hydrogen fuel cell and internal combustion genset and a novel direct ammonia fuel cell and internal combustion genset.

A startup company called NHThree, LLC has developed a pre-commercial direct ammonia fuel cell that is developed from low cost material. Funding for a comparable 60 kW direct ammonia fuel cell is requested as part of this proposal.

Ammonia fuel cells (AFCs) are considered to be a bridge technology to hydrogen fuel cells in that the storage infrastructure is in place all throughout the country. There are also some advantages to ammonia fuel cells versus hydrogen fuel cells.

AFCs can be less expensive to build than Proton Exchange Membrane (PEM) because AFCs contain less noble metal catalyst material. A cost analysis has shown that the cost of the AFC will be US$100 to $150 per kW without accessories and US$180 to $200 per kW with accessories, while the cost of the PEM is US$1,000 to $1,500 per kW without accessories, and US$2,000 to $3,000 per kW with accessories (citation!).
AFCs require less accessory equipment. Noisy and power-consuming air-compressors and PEM separator humidifying machines are necessary for PEM fuel cells operating at kW levels over 60°C. Humidifiers must keep the PEM separators moist 24-hours a day which makes it almost impossible to shut down a kW level PEM fuel cell for long periods of time. If the PEM separators dry out, a difficult and expensive process must be followed to re-wet the separators. Also, water builds up in those PEM fuel cells and must be driven out by air compressors. Air compressors and humidifying machines are not needed by AFCs.
AFCs produce higher voltage than PEMs. The operating cell voltage of an AFC is 0.8 volts while that of the PEM is 0.6 volts. 100 AFC cells produce 80 volts. 100 PEM cell produce 60 volts.

AFCs can be shut down for long periods of time. The ability to shut down a fuel cell for maintenance or rest is very important. Most AFCs do not contain separators which must be kept moist at all times, but instead have a built-in circulating electrolyte system and therefore no water-build-up problem. Humidifiers and air compressors are unnecessary. The typical process to shut down an AFC is simply turn the switch to the OFF position. The electrolyte is automatically removed from the stacks and the AFC becomes inactive.

An AFC may have a longer in-service life. Its electrodes are not in operation while the fuel cell is shut down and the electrolyte drained out of the cells. The electrodes in a PEM are usually continuously active and never come to rest, therefore may be less durable.

AFCs can operate on Hydrogen derived from Ammonia. Anhydrous ammonia (NH3) is rich in hydrogen and one of the best carriers of hydrogen as it is not a hydrocarbon (methanol, ethanol and gasoline are hydrocarbons and produce harmful emissions). There are no emissions from AFCs. Hydrogen can be produced from ammonia through an Ammonia Cracker. This hydrogen carries with it a trace of ammonia gas which enters the fuel cell with the hydrogen. This does not hurt the AFC as ammonia is an alkali. However, a PEM fuel cell, which is acidic, cannot tolerate even a trace of ammonia and therefore cannot avail itself of hydrogen derived from ammonia.

The objective of this proposal is to deploy, demonstrate, and test a novel pre-commercial 120 kW fuel cell utilizing renewably produced hydrogen and anhydrous ammonia.

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XXX **CONFIDENTIAL MATERIAL BEGINS HERE XXX**

. **XXX CONFIDENTIAL MATERIAL ENDS HERE XXX.**

The overall approach is to move a novel, direct-ammonia fuel cell from lab-scale development into a pre-commercial application, and then conduct performance testing. The pilot testing and information generated will be utilized to develop publications that will greatly enhance the potential commercialization of the technology.

Fuel Cell Purchase and Development Upon Notice to Proceed from the NETL, the University of Minnesota will place an equipment order with the NHThree, LLC for the purchase of a novel 120 kW direct-ammonia fuel cell with advanced technology as described above. Upon Notice to Proceed from the University of Minnesota, the company will begin fabricating the fuel cell under the direction of Dr. Ganley. Fabrication and development will take approximately 4 quarters. Component costs will be recorded for future business level feasibility study.

During fabrication of the design and installation, the University of Minnesota will be in the process of constructing the Renewable Hydrogen and Ammonia Production.

3.0 Biomass Gasification System

3.1 Heating and Cooling

Biomass provides opportunities for rural economic development, diminishes the impact of greenhouse gases on the environment, provides a viable option to natural gas and other fossil fuels, and decreases the need for foreign sources of energy. Despite these well-documented advantages, widespread implementation of agricultural based biomass energy systems will not take place until a variety of questions –technical, financial, and managerial- are addressed. Thus far, technology deployment, at best, has been limited across the United States. Without deployment, there have been limited efforts in developing information for sustainable management of biomass resources.

With $9 million in support from the State of Minnesota, the University of Minnesota, Morris (UMM) is preparing to break ground on a new biomass gasification facility, which will form an integral part of its existing district heating and cooling system. In addition to being an operating system, the facility will serve as a University research platform for the development of community scale, biomass energy systems. This system will provide a biomass heating and cooling model that can be replicated across a wide range of facilities. It will also provide research opportunities in developing bioproducts from the synthesis gas stream.

High natural gas and fuel oil costs experienced in recent years can be devastating to rural businesses, local governments, and schools. A local solution exists in the crops grown in farm fields but there are obstacles in utilizing this resource. UMM, U of M West Central Research and Outreach Center (WCROC), and the U of M Initiative for Renewable Energy and the Environment (IREE) identified this issue as a high priority and have been working together to establish a community scale biomass energy system. This system is designed to serve as a functioning model, as well as a state of the art research facility.

Since 2000, UMM has been struggling to cope with the volatility of natural gas and fuel oil prices. This is both the primary and secondary source of heating for the campus operations. To address this volatility, UMM has engaged in studies, research and has established working relationships with key environmental and energy research groups, agricultural support groups, state and federal agricultural research institutions, key industry representatives, engineering and technical consultants, environmental advocacy groups, as well as the campus and local community.

In the summer of 2003, UMM contracted with the University of North Dakota Energy and Environmental Research Center (EERC) to conduct a biomass assessment of the west central Minnesota region. The results indicated 677,000 tons of biomass feedstock available within a 100 mile radius of the UMM. The UMM Biomass Gasification System is projected to use between 7,000-9,000 tons per year, all of which can be obtained within a 20 mile radius.

In spring 2004, UMM issued a Request for Proposals (RFP) for a biomass boiler system to be incorporated into the current natural gas fueled district heating and cooling facility. Information received from this RFP indicated that biomass gasification systems might be the most appropriate technology for small to moderate sized biomass energy systems. Additional information gathered indicated that stoker grate furnaces are not well suited to handle the variability of biomass fuel stocks. This small to moderate scale gasification system fits the local nature of biomass systems. Biomass systems are inherently local because as the size of the

facilities increase, biomass feedstock must be transported from greater distances thereby increasing the cost of transportation and resulting energy generation.

In January 2005, UMM ran a test burn of corn stover through a contract at a gasification test unit in Carterville, Ill. to address unanswered questions regarding emissions the University of Minnesota, Morris, the Minnesota Corn Growers Association, Chippewa Valley Ethanol Company (CVEC), IREE, and the Agricultural Utilization Research Institute (AURI) co-funded the test burn, which was conducted with an independent testing firm monitoring gasification and emissions criteria. The test, conducted by Coal Tec Energy USA, Inc., and subsequent report by Recovered Energy Resources, LLC (RER) focused on: sustained operations using fuel mixtures including corn stover and corn stover with ethanol mash, Heat and material balance to identify system efficiency, Emissions monitoring, Fuel analysis, Ash analysis, Identification of issues, opportunities, and expected solutions and/or costs associated with those issues. The summary report from RER focused on all aspects of the burn. Findings include:

Gasification was sustained with all fuels tested. Fuel was fed at a rate of approximately 3,500 lbs per hour. Material handling for all fuels was successful. Subsequent testing of the feed system determined it could handle corn stover that had not been resized. Control of harmful emissions was generally successful with only minor issues to address. The ash material did not clinker or cause any handling problems. The system operated at a very high efficiency. The efficiency of the corn stover gasification was 99.6 %. This is the percentage of volatile matter and fixed carbon that was gasified. The system operated easily with the variety of fuel mixtures, without constant changes to the operational settings of airflows and fuel feed rates. The feed rates and moisture content of the fuel was changed occasionally without major issues. The ash quality did not present significant issues that would create environmental concerns.

The report also identified issues for the project engineers to address and rectify in the design process, including:

- The airflow needs to be better controlled.
- The feed system needs to be designed to operate in a less labor intensive manner and with the ability to accommodate a wider array of feedstock.
- The ash system did experience some bridging.
- The particulate carryover was not visible in the stack but the fine filters (PM10) captured some material.
- The emission stream contained HCl, which originated from corn stover. The system is being designed and constructed to address chlorine content.

We are vigorously researching and designing this biomass system so that it can be incorporated into public facilities such as courthouses, schools, hospitals, as well as into manufacturing and other private facilities. This is an extremely important and attractive factor of this project since many public facilities were constructed during the building booms of the late 1960s and early 1970s and many of these same building heating and cooling systems are near the end of their useful life and soon scheduled for replacement. Faced with fluctuating energy costs, environmental issues, energy security concerns, and the desire to sustain local economies, the building managers of many of these public facilities are searching for information on alternative sources of energy systems. The UMM Biomass Gasification System will address many uncertainties and will serve as an invaluable resource for these people and their communities.

There are added benefits to a gasification system in the ability to utilize the synthesis gas stream to produce other bio-based products as well as developing improved combined heat and power applications. The proposal will provide the opportunity to explore and refine these opportunities.

Construction will begin on the UMM Biomass Gasification System in summer 2007. The unit will produce up to 25 million BTU per hour and the energy will be used to produce steam for heating and potential generation of electricity. The building has been designed to accommodate a steam turbine for co-generation of electricity as a possible addition in the future and the turbine funding is being sought through the Clean Renewable Energy Bond program.

The UMM biomass gasification system will be one of the first of its kind in the U.S. and will serve as a model for other communities, both rural and urban to better use our nation's natural resources. As may be expected, we have identified several challenges to the further deployment of this technology and have received support from the USDA DOE Biomass Research and Development Initiative to allow us to address these obstacles and to develop tools enabling further development and deployment of biomass gasification systems. A Biomass Gasification Toolbox is currently under development and includes:

- Standard operating procedures (SOPs) for biomass gasification systems, guidelines and best management practices for biomass cropping systems,
- Templates for market contracts and pricing structures based on biomass feedback, and financial and economic impacts, and
- Best Management Practices for Biomass Energy Cropping Systems.

As biomass systems become more familiar, the tools and guidelines developed in the Biomass Toolbox will prove an invaluable resource for communities across our nation. The experience gained and the information being developed enables this project team to move forward on biomass based electrical energy generation and storage systems. The biomass-based electrical energy generation and storage systems will provide a key function in providing base-load power for an integrated renewable energy system. Also, efficient combined heat and power biomass systems such as the UMM campus system will allow for the improved management of both the distribution and transmission grids.

Doug Maust of HGA, Inc. Architects Engineers Planners (HGA, Inc.) is the principal engineer for the Biomass Gasification system, which will be funded by the University of Minnesota, Morris, University of Minnesota Initiative for Renewable Energy and the Environment, and the State of Minnesota. The final design has been completed and approved by the University of Minnesota with official ground breaking scheduled for July 27, 2007. Environmental representatives of the U of M have developed environmental permits with the Minnesota Pollution Control Agency (MPCA). These permits will allow for the research and demonstration necessary to gain pertinent data and knowledge to establish agricultural biomass permit guidelines. Biomass feedstock will be gathered as the demonstration and research facility is being constructed and will be stored at the West Central Research and Outreach Center.

3.2 Steam Turbine and Phase Change Storage Device

The campus is planning the installation of a 400 kw steam turbine which will be run with the biomass boiler. This grant provides the opportunity to add a state of the art thermal energy

storage solution at the University of Minnesota, Morris. The biomass boiler will be fueled by a number of renewable energy sources, including corn stover and switchgrass among others. The biomass boiler will produce steam at 300 psig which will be used to power a 400 kW backpressure cogeneration steam turbine which will generate electricity and reduce the steam pressure from 300 psig to 18 psig so that it can be fed into the University of Minnesota, Morris' campus steam grid and be used for space, pool, and domestic hot water heating. In summer operations, the gasifier and the steam turbine genset will provide a portion of the electric base load of the campus, and tie into the integrated information gateway. The end result will be a reduction in both the electricity consumed from the local utility, and a reduction in the natural gas and oil consumed for heating requirements. All of these components will be working with the existing campus wind turbine and the load serving utility to manage the renewable energy resource base, and reduce the impact on the utilities supply grid during peak demand periods.

In addition to the steam turbine described above, this grant proposes to investigate, and if appropriate install, a new thermal storage technology which uses a proprietary phase change material. This thermal storage solution has been installed in Canada in a few test sites, but has not been installed or tested in the United States. The thermal storage product will be used to increase the efficiency of the existing campus electric powered cooling systems. This thermal storage solution has been developed by Groupe Enerstat, a Canadian company based in Quebec. They have developed and patented a unique phase change material that allows the capability to choose a specific phase change temperature. This project will have a phase change temperature of 42 degrees F pre-set in this unit. This phase change temperature will allow the system to gain free cooling efficiencies during the spring and summer. Any time the outside air temperature is below 42 deg, a dry cooler will be utilized to charge (freeze) the vessel, and then during the day the stored energy will provide cooling to the campus and eliminate the need to run the chillers and cooling towers. The ability to utilize this free cooling feature is a benefit unique to this proprietary phase change material, and provides significant load reduction in the shoulder (spring and fall) months. In addition to free cooling, there are also efficiency gains during the hot summer months when free cooling is not available. In those times, the existing chillers will run during the cooler night conditions in order to take advantage of the more favorable wet bulb conditions, which will increase the efficiency of the system. When chiller operation is necessary, they will be set to run at full load conditions in order to optimize efficiencies. This form of operation is made possible due to the capability to store the output in the thermal storage solution. The chiller should never need to run at part load (poor efficiency) conditions. Instead, the chiller system will use the thermal storage product to trim any part load conditions the campus is requiring and storing any excess capacity that would be resulting. This solution not only reduces the electricity consumption by utilizing free cooling and increasing the efficiencies of the systems, but it also has a significant impact on the demand reduction of the campus. When necessary to run the chillers and other cooling equipment, the system will be operating during non-peak demand times and thereby shaving significant loads off of the campus demand profile. This solution will reduce the campus' peak demand by a minimum of 325 kW. This alone represents an 18% reduction in peak demand.

This thermal storage solution will also improve the financial performance of the wind turbine. Currently the wind turbine produces about 20% more electricity than the campus can consume, and this excess is sold back to the local electrical utility at avoided cost. The bulk of this over-production and subsequent sale of electricity occurs during non-peak, nighttime hours. This is less than an optimal solution for the campus and is less than optimal for the utility as they are purchasing power from the campus when demand (and value) for electricity is at the lowest

point. By operating this thermal storage solution during the night when the bulk of the excess wind power exists, the excess electrical energy will be converted it into thermal energy, and then stored until needed. So not only does this solution decrease the electrical demand on the campus and subsequently on the electrical utility, it also takes the excess wind turbine electrical output at night and stores it for later usage.

The addition of the steam turbine and the thermal storage device will:

- Significantly improve the operational efficiency biomass gasification system.
- Result in 485 kW demand reduction from thermal storage solution out of a total demand of 1900 kW. This represents a 26% reduction in demand.
- Provide a more robust integrated energy platform.

3.3 Biomass Producer Gas Genset

Using high mineral content agricultural fuel stocks has created challenges in finding the right combination of gasification , heat recovery and emissions control equipment, There may well be an opportunity when this technology is paired with a cofired naturally aspirated biodiesel genset.

Typical wood gasification systems struggle with the production of tar in the producer gas stream. It requires extensive work to scrub the producer gas to get it to a point that the tar does not deteriorate the engine performance.

Test gasification of 65 tons of cornstover has shown very low concentrations of tar in the gas stream. The predominate fuel contaminant in corn stover producer gas is HCL gas. The solubility of HCL by water makes this contaminant simpler to remove. In addition the wet scrubbing of the producer gas also removes fine particulate matter which also could affect engine performance. Cooling the gas also increases the BTU density for the cofiring application.

A first of its kind research opportunity will be created by paring a low BTU biodiesel genset with a biomass gasifier. The gasifier is an atmospheric pressure vessel which operational parameters require limited oxygen in the gasification chamber. HGA engineers along with undergraduates will research the outcome of recycling the entire exhaust stream of the biodiesel generator back into the gasifier as underfed hot air. This improves efficiencies of both the gasifier and the genset as well as subjects any unburned carbon back through the fuel pile to be converted to producer gas. This has significant potential implications on the emissions foot print of the genset and could mitigate carbon dioxide production "Regasifing" the exhaust steam may make this cofired unit another baseline distributed generation platform that can help offset wind variability.

4.0 Biodiesel Genset

4.1 System Specifications

In this segment of the proposed project, two biodiesel gensets will be added to the microgrid with the already existing and operational 1.65 MW Vestas V-82 wind turbine. The biodiesel gensets will be integrated with the wind turbine in order to provide a platform for base load or peaking power on the distribution and / or the transmission grid. Additional redundancy will be achieved by integration of other hydrogen and ammonia gensets and fuel cells, a biomass syngas genset and the biomass steam turbine specified in other segments of this proposal.

- Two diesel generators of rated output of 500 kW each. The diesel generators will be fueled with B100 (100 percent biodiesel) and / or B50 (50 percent biodiesel). The diesel engines may, as an option, be fitted with jacket water and exhaust gas waste heat recovery systems, giving them a total energy efficiency of 75-80%, compared to a typical efficiency of 35-40% without heat recovery. The feasibility of recovering the exhaust heat will be explored further by the engineering team in order to quantify the net value to the system. The funding requested includes the waste heat recovery jackets. If the engineering team decides based upon further analysis that the waste recovery jackets do not significantly add to the system efficiencies, the funding for the heat recovery on the engine gensets will be returned to the granting agency. If installed, the diesel waste heat recovery system will be integrated with the existing campus steam plant, which uses natural gas and oil-fired boilers to produce stream, which is distributed throughout campus for building heating and cooling.

- Bulk fuel storage tanks to store biodiesel fuel for use by the diesel generators.

- A graphical workstation, located in the UMM cogeneration plant, will serve as the primary operator interface for the entire system. It will communicate with PLC controllers included on individual pieces of energy storage and supply, the predictive weather and demand server, as well as the campus energy management system. It will perform the following tasks:

    - Wind turbine dispatch (allow/inhibit wind turbine operation as necessary, and adjust their maximum power limit)
    - Diesel dispatch (Start/stop the diesel generators and determine their operating power level)
    - Heat recovery system management
    - Wind turbine status monitoring
    - Thermal storage management
    - Campus demand side management through the energy management system
    - Performance data logging (kWh and run-time totals, alarms, etc.)
    - Fault detection and annunciation
    - Provide for remote access via internet connection

This operator interface will communicate to the operator the predicted campus load along with the optimal mix of storage and supply solutions available to the campus. It will also provide to the operators the day-ahead on-peak hours from the local utility, allowing the campus operators to manually override the automatic controls in response to inputs from the local utility.

4.2 Operating Strategy

The system would be designed with the assumption that the campus will remain connected to the local electric utility, Ottertail Power. However, the primary purposes of this connection would to provide voltage and frequency stability on the campus electrical system and to provide backup power in the event of a fault or insufficiency of generating capacity in the renewable power system. At least initially, the renewable power system will be operated so as to exactly meet the local campus electric demand, regulating the net demand from the electric utility to near zero.

A certain level of redundancy in biodiesel generator capacity ensures that the integrated renewable power system can always meet the campus power electric power demand without requiring power purchases from the electric utility or provide load and demand management of the distribution and transmission grids, even though one diesel generator might be out of service for repairs or routing maintenance

5.0 Consumer Information Gateway Development (Sub Area 2C)

5.1 Smart Metering and Advanced Control Technology

This project will also be implementing and testing advanced control technologies and smart meters for active energy management. This includes providing a predictive look at weather conditions, and using historical data, predict campus energy load and ultimately manage the multiple energy sources and storage devices with their independent efficiency profiles to meet the campus energy needs. Smart metering and advanced control technology will be installed, tested, and refined during the first four years of the proposal. Upon refinement, the smart meters and advanced controls will integrate the renewable energy and energy storage systems to complete a comprehensive demonstration in year 5.

The first step will be to gather the historical energy consumption data for the campus and overlay it onto the historical weather data in order to determine the impact of weather on their energy consumption. Once this database has been created and loaded into the server, the server will start to access public sites on the internet to gather weather forecasts. Once the weather forecast has been determined for the campus, the server then compares the forecasted weather to the historical usage database in order to predict the energy consumption of the campus. This solution uses fuzzy logic in order to look at the predicted load and compare to all of the available storage and supply sources in order to optimize the supply side energy efficiency of the campus. For example, the predictive nature of this solution will allow, in periods of mild weather and low energy demand, for the charging of various storage solutions to the necessary level instead of wasting energy trying to fully charge them and then not utilizing the full charge of energy.

This fuzzy logic also compares the efficiency curves of each energy supply source, along with their predicted output based upon predicted wind speed and direction, to then plot out an energy supply scenario which maximizes the efficiency of the entire system by mixing and matching the individual supply and storage sources. The first supply side output in this solution will be the wind turbine. Based upon the forecasted wind speed and direction, the predicted wind turbine output will be calculated throughout the day. This will then provide the campus a predicted gross energy demand curve throughout the day, along with the portions of this demand curve which will be supplied by the wind turbine. After this net demand curve is known, the solution will then use fuzzy logic to compare each of the other supply side storage components and their availability, along with each of the available supply side electrical generation sources. Each of these generation sources will have an efficiency curve which will be taken into account in order

to provide to the campus a daily plan showing what the optimal mix of storage and generation will be in order to meet their predicted demand. The campus energy systems operators will be

provided with this daily plan and can then follow it, or modify it if needed in order to meet some of the other research needs of these various energy sources.

5.2 Economic Decision Tools

Another piece of this control solution will include controlling the campus energy supply components to provide the maximum impact on the campus peak demand loads. As part of this, individual building loads will be metered at major electric load centers, along with metering each energy supply source and energy storage source. This data will be available for real time analysis and monitoring by the campus staff, researchers, students, and by the local electrical utility. This data will be available as part of this advanced control solution, and it will also be posted onto a secure web-site several times a day in order to provide the local utility with access.

The local utility (Otter Tail Power) has the ability to provide price-signal offerings to the campus. These include three different tariffs that are based on their present hourly forecasted system marginal pricing ("day-ahead pricing"). The first tariff is Real Time Pricing (RTP) Rider C-03M. This program provides hourly forecasted day-ahead pricing to their customers with customer voluntary curtailment. These customers can expand or curtail their usage based on the pricing. Otter Tail utilizes a two part Real Time Pricing program in which one part is a "baseload" of usage which is billed on a standard tariff, and a second part which is billed on real-time pricing.

The second tariff is called the Large General Service Rider C-12M. This program is very similar to RTP described above, except that the curtailment is mandatory versus voluntary and the pricing excludes a capacity component (i.e., the pricing is less than RTP). Otter Tail calls this pricing SMEP (System Marginal Energy Pricing).

The third tariff is called the Commercial Time of Use (CTOU) tariff M-04M. This program utilizes the pricing basis of the two above programs, but in a different way. The difference between this program and the two previous programs, is that the CTOU is like a regular time of use tariff, except that during on-peak periods, the customer receives a day-ahead schedule of the on-peak periods. If no on-peak periods are designated on the day-ahead schedule, intermediate and off-peak periods apply per the tariff. Essentially, this program allows the customer to plan ahead for known on-peak pricing periods. The customer can voluntarily decide to curtail usage or buy through the on-peak pricing period.

Otter Tail Power currently has an advanced metering installation on the electrical edge of the University campus which is used for monthly billing. They collect kW, kWh, and kvar every week by use of a cell phone connected to the electricity meter memory. This data is saved in 15 minute blocks, thus the utility can see usage for each 15 minute period of the day. This usage data is available to the University in both a raw data form as well as through a graphical output.

For customers who are on the day-ahead pricing rates, the utility collects the 15 minute data blocks on a daily basis and displays this information on their website so the customers can more closely monitor their usage patterns and make energy plans for the next day. Hourly updates of this data could be done during periods of high usage and during periods of high energy prices. This data from the Otter Tail website will be available to the University along with the data from the smart metering system being installed under this proposal.

As part of this proposal, the project team plans to utilize Otter Tail Power Company's modified day-ahead schedule based on the CTOU program. This would provide information to the University which would then allow them as an end user to select a "trigger price" such that when the day-ahead pricing exceeds the costs of the University's different generation components, the University could dispatch the different generation components to run. Additionally, at varying "trigger prices" the University could also engage different levels of peak demand limiting on their demand side. These different "trigger prices" would allow the University to change their electricity generation and consumption in response to the price based program Otter Tail offers, as well as any future incentive-based program they may offer in the future, as an effective means to reduce the peak load demand.

The final piece of this solution will be to actively perform peak demand limiting on the campus demand side. The proposed smart metering solution will allow for monitoring energy consumption in each building. As campus consumption begins to creep up and the amount of power purchased from the load serving entity (the local utility) starts to approach our demand limit, or starts to kick the campus into a higher rate structure, loads will be curtailed through the campus energy management system.

5.3 Environmental Decision Tools

In addition to "price triggers", the project team also proposes to model "carbon triggers". Similar to the concept of controlling costs associated with energy, the project team will also study the feasibility of imposing triggers to manage the campus carbon footprint. The next generation system will then be capable of balancing both price and carbon considerations.

5.4 Information Systems and Use

This website will provide communication to the load serving entity (the local utility) for their use. The local utility will also be communicating back to the campus via emails. The utility will be sending daily emails to the campus which will contain tomorrow's on-peak hours and associated pricing structure. The campus staff will then enter the data from the utility emails into the control system for its use and evaluation. This will allow the campus to change their electrical consumption pattern in response to information received from the utility.

The target consumer market for this consumer information gateway development is the commercial market segment. The project team is primarily focusing on the higher education market however the information applies to several other market sectors. The total kW in a typical customer in the higher education market segment ranges from 1,500 kW to 1,500,000 kW on average. Of this total load, roughly 15% to 25% is controllable with a thermal storage solution and another 5% to 10% is controllable with no modifications to the campus infrastructure simply by enacting demand side management policies and procedures.

As described above, the architecture of the gateway system will be primarily web-based. The local utility will provide access to their secure web page to the University, including day-ahead rate scheduling and actual meter data in 15 minute increments. The advanced control solution which is described above and is part of this proposal will access the utilities secure web site and obtain energy and power information, as well as rate information from that site. This will be done on a daily basis in order to obtain the daily rate information from the utility. The information will be used to operate the on-site storage and generation equipment, but will also be used for peak demand limiting, which will include set points of the HVAC system, and the pool systems. This advanced control solution will be interfacing to the campus energy

management system as described above, in order to implement the desired demand side management. The energy management system will receive electrical signals from the PLC controllers being used for the advanced control solution, and will in turn send electrical signals back to the PLC controllers for feedback purposes.

5.5 Public Access and Outreach

In addition to the secure metering and controls and secondary system will be implemented to educate and inform campus students and staff about the current energy situation on campus. This will be done in the hope that educated decision makers will make better decisions and voluntarily curtail at least some of their energy impacts. The information provided to the students and staff will show:

1. The current energy mix being utilized on campus, clearly identifying each energy supply and storage source on a real time basis.
2. The environmental impact of each energy source and compare them against the impact of the local utility mix. In this way the public will see the real time impact of their energy use and the impact of the different sources. The impact time of day energy use has on emissions will be highlighted since most members of the public are unaware of the differences in environmental impact that time of day energy use has.
3. Demonstrate that in order to meet peak demand loads, the utility has to use different energy sources with different emission profiles (coal baseline plants versus gas peaking plants) than they use to meet baseline loads.
4. The impact of conserving energy during peak demand times has a significantly higher impact financially and environmentally than saving energy during non-peak times.

The information will be accessible via the internet and serve as a worldwide model and education source ultimately serving to educate and train people to make better energy decisions.

Section 3

SUMMARY AND SELF EVALUATION

This project will capitalize on a nationally unique combination of renewable energy platforms with a robust team of participants. The project will integrate the renewable energy systems and demonstrate grid communications beyond the substation to the end user sites by incorporating state of the art interactive communications to improve the performance of both the distributed generation efficiencies and the grid transmission efficiencies, by capitalizing on the synergies of both systems.

Merit Review Criterion Self Evaluation:

1. Technical Merit

1.0 Reasonableness of solution. This proposed plan relies on developing a technical level of communications in the grid and the distributed generation network that requires a universal communication interface as well as smart meters, and logic based on historical and present day data inputs. This level of technical integration has significant implications in any situation where distributed generation can impact grid connections to reduce peek demand on the transmission grid.

1.1 Soundness of proposal. Since the two campuses already have interconnected campus grids as well as connections on the existing investor owned utility grid, the extension of this distributed generation systems seem to be a reasonable outcome.

1.2 Statement of Project Objectives. The project is broken down into yearly increments from year one to year five. There are tasks broken down by subheadings throughout each year and are consistent throughout the project duration. Each task has a quarterly indicator which points to the time that this task will be started.

1.3 Work Plan. This is a complicated project with two campuses, two basic renewable energy platforms, two energy conversion systems other than electricity, and an interactive communication system that will move to a level that does not exist within the U of MN system. The work plan provides direction and detail for the PI's, Project coordinator, consultants and engineers, and finally the investor owned utility and the individual consumers.

1.4 The proposed time line provides a methodical and measured approach to building in the complexities of the distributed generation systems to the local grid. The fifth year will provide the demonstration site that will include a diverse power profile reflecting the peek demand loads through out the seasonal power requirements.

2. Significance and impact

2.0 Benefits of this technology are particularly significant for Western Minnesota. The transmission grid is constricted due to high level of wind resources in the area. MISO studies are backed up waiting for grid access. By incorporating distributed renewable

energy generation into the grid resources the net result would be more capacity to accommodate additional wind generation by reducing the peak demand loads on the grid.

2.1 The electrical generation industry in Minnesota is a net importer of energy at present. The service provider for the campus is a coal base load generator. Improving grid capacity and/or efficiency may reduce the amount of new coal fired generation that the company would need to bring on line to meet future peak demand loads on the grid.

2.2 The consumer information gateway is proposed to include not only electrical power use, but it intends to provide building occupants with a carbon footprint of how the building is operating. An educational campus seems to be an ideal place to bring about change in consumer behavior with real-time feed back on resource consumption.

3. Applicant and Participant Roles

3.0 The two U of MN campuses have achieved national recognition for renewable energy projects that are currently underway. Both PI's are successful grant administrators for local, state and federal renewable energy funding. The staffing plan for the project manager is to hire an electrical engineer who will have experience in universal communications interface, transmission infrastructure, and grid communications. Ottertail Power is a successful service provider with transmission facilities in four states.

3.1 The project work plan seeks out engineering expertise from three different engineering firms with specialties in hydrogen conversion (Sebesta), biomass conversion, (HGA) and grid communications (Mckinstry).

3.2 The staffing and professional resources at the U of MN as in institution can be brought into this project if necessary or desirable.

4. Commercialization Potential

4.0 The engineering firms brought into this project are already managing projects in each of their areas of expertise. The significant amount of matching funds from these firms is an indication of their assessment of how important it is to be involved with this project. Since this project is all inclusive from the local investor owned utility to the individual consumer, the potential for establishing additional markets is significant.

4.1 This proposal is the real time, real world application of new technology conducted on a public campus with robust infrastructure.

4.2 All major participants have included letters of support and the cost share has been met.

4.3 A deliverable of a national conference illustrates the benefit of having this project located at a public research institution. Data from this system, unless identified in a nondisclosure agreement, will be available to the public.

4.4 The University of Minnesota has an impressive track record in converting research into business opportunities.

5. Other Selection factors

5.0 This proposal has areas of emphasis in distributed renewable energy, thermal storage, chemical storage, grid communications, and consumer information systems.

5.1 The generation platforms available in this project would cover most of the possible systems that are in production or are being developed.

5.2 The participants in this proposal range from corporate to individual and public to private.

5.3 With the significant investment already in renewable energy platforms, this location should provide maximum leverage for the use of the funds.

Senator KLOBUCHAR. Thank you, Chancellor Johnson. You have done our State proud, and mostly you have made Senator Craig happy. So this is good.

President Levin.

STATEMENT OF RICHARD C. LEVIN, PRESIDENT, YALE UNIVERSITY

Mr. LEVIN. Thank you, Senator Klobuchar and members of the Committee.

Thank you, Chancellor Johnson, for that inspiring case study. I will point out, however, that your description of your institution being west of Harvard, east of Stanford, and closer to heaven also suits Yale.

[Laughter.]

Mr. LEVIN. There is no doubt that we have a problem. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change concluded last year that in the absence of corrective measures, global temperatures are likely to rise between one and 6 degrees centigrade by the end of the century, with the best estimates ranging between two and four degrees.

Even a one degree increase will limit the availability of fresh water and cause coastal flooding in much of the world. Environmental damages and dislocation will be even more consequential if global temperatures rise by more than two degrees.

Universities have four important roles to play in the effort to curtail global warming. First, we must continue to advance our understanding of climate change. As Brown President Simmons said, it is in universities that these effects were first discovered. We need to discern the effects of climate change on the economy and the environment, and also understand the consequences of taking corrective action.

Second, universities must pursue research into carbon-free energy technologies such as solar, wind and geothermal power, as well as seek more efficient ways of using carbon-based fuels through improved building materials and design, and improved technologies for vehicles and power plants.

Third, we must educate students who go on to become future leaders and influential citizens. At Yale, we take this part of our mission extremely seriously. We offer over 60 undergraduate courses focused on the environment. Our School of Forestry and Environmental Studies has for decades produced some of America's most influential environmental leaders. The study of the environment and sustainability is now embedded in the curriculum of our graduate schools of business, architecture and public health.

Finally, universities can demonstrate to the Nation and to the world that substantial reductions in greenhouse gases are feasible and not prohibitively expensive. With 12,000 employees, Yale is the third largest private employer in Connecticut. There are 11,000 students on our campus and we have an annual budget of $2.5 billion. We are a large organization by any standard, the equivalent of a Fortune 1,000 company. We are large enough to be a model of responsible environmental practice for other universities and business organizations. We are large enough to demonstrate that greenhouse gas reduction is feasible and affordable.

As Senator Whitehouse indicated, in these efforts to demonstrate best practices in limiting carbon emissions, we are also teaching our students, who are full participants in this campus-wide effort. We are teaching them how to be responsible citizens of the world. Together, we are learning how to balance near-term economic considerations against the long-term health of the environment and the well being of future human generations.

We have committed to reducing the university's greenhouse gas emissions to 43 percent below our 2005 baseline by 2020. That is also 10 percent below 1990 levels. It is a goal that is within the range of estimates of what is required to keep global temperatures from rising two degrees centigrade. So far in the first 2 years of our program, we have reduced carbon emissions by 17 percent. To achieve this, we have retrofitted heating, ventilation and air conditioning systems in 90 of our roughly 300 buildings.

We have installed thermally efficient windows in many of our largest existing buildings, and in all of the new buildings we have constructed in the last decade. We have acquired new power plant equipment and modified some existing equipment to achieve substantial savings in fuel consumption. We have used a mix of conventional and renewable fuels in our power plant and in our campus bus fleet.

We have made a commitment that all of our new buildings will achieve a silver rating or better from the LEED building rating system. And engaging our students, we have reduced student electricity consumption by 10 percent in each of the last 2 years by sponsoring a competition among our residential colleges.

Other measures currently in the works should yield an additional 17 percent reduction in the next 3 years. These projects include the replacement of university-owned buses and trucks with hybrid models, a new co-generation plant, solar panels on selected buildings, and small wind turbines in the windiest sections of our campus.

In most cases, the present value of the energy savings from these projects exceeds the initial investment. In other cases, we will invest to achieve carbon savings even at a modest net economic cost, in part to demonstrate the feasibility of new technologies, and in part, to encourage policy change that would price carbon correctly.

I believe we can reach our greenhouse gas reduction goal at a cost of less than 1 percent of our annual operating expenses. In our view, this additional expense is justified and we believe the leadership of many other large organizations would come to the same conclusion.

Other universities are joining us in aggressively reducing their carbon footprints. By the end of the academic year, I expect that every one of our sister institutions in the Ivy League will adopt its own concrete greenhouse gas reduction goal. These efforts are being replicated at colleges and universities across the Nation and around the world, as you have heard today.

I hope the members of the Committee take heart in the knowledge that large organizations are concluding that they can and should take actions to reduce their carbon footprint significantly. I commend the Committee for its thoughtful consideration and ap-

proval of legislation that would establish a national system for reducing carbon emissions. Our future depends on it.

Thank you.

[The prepared statement of Mr. Levin follows:]

Opening Statement of Richard C. Levin
President, Yale University
Committee on the Environment and Public Works
April 3, 2008

Thank you Chairwoman Boxer, Ranking Member Inhofe, and members of the Committee for this opportunity to discuss Yale's efforts to reduce its greenhouse gas emissions and advance sustainable development.

Madam Chairwoman, there is no doubt that we have a problem. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change concluded last year that in the absence of corrective measures, global temperatures are likely to rise between one and six degrees centigrade by the end of the century, with the best estimates ranging between two and four degrees. Even a 1-degree increase will limit the availability of fresh water and cause coastal flooding in much of the world. And environmental damages and dislocation will be even more consequential if global temperatures rise by more than 2 degrees.

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- Retrofitted the heating, ventilation and air conditioning systems in 90 of our roughly 300 buildings;

- Installed thermally efficient windows in many of our largest existing buildings and in all of the new buildings we have constructed in the last decade;

- Acquired new power plant equipment and modified some existing equipment to achieve substantial savings in fuel consumption;

- Used a mix of conventional and renewable fuels in our power plant and in our campus bus fleet;

- Made a commitment that all of our new buildings will achieve a Silver rating or better from the Leadership in Energy and Environmental Design (LEED) Building Rating System;

- Reduced student electricity consumption by 10 percent in each of the last two years by sponsoring a competition among our residential colleges.

Other measures currently in the works should yield an additional 17 percent reduction. These projects include the replacement of university-owned buses and trucks with hybrid models, a new co-generation plant, solar panels on selected buildings, and small wind turbines in the windiest sections of campus.

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I hope the Members of the Committee will take heart in the knowledge that large organizations are concluding that they can, and should, take action to reduce their carbon footprint significantly. I commend the Committee for its thoughtful consideration and approval of legislation that would establish a national system for reducing carbon emissions. Our future depends upon it.

Senator KLOBUCHAR. Thank you so much to all of you. I am going to start with a few questions, and then turn it over to my fellow Senators. Of course, I will start with my chancellor here, Chancellor Johnson.

Could you talk about how you came upon this, that Morris started to get into this so early? Was it something about your mission or what you have historically focused on as a campus?

Ms. JOHNSON. I appreciate the question. Thank you very much, Senator Klobuchar. I think there are a number of reasons. One of the immediate reasons I believe had to do with the high cost of gas in 2000.

I think another one of the reasons does really have to do with the kind of populist, and as I mentioned earlier, action-orientation of the students, the faculty and staff who are on our campus. But you may not know that the University of Minnesota, Morris, started life as an American Indian boarding school in the late 1900's. It was founded by the Sisters of Mercy and turned over to the Federal Government who in turn in the early 1900's then established, after the American boarding school movement ended, an agricultural high school on the grounds.

So when you come to the University of Minnesota, Morris, and I hope that you will, you will see a collection of historic buildings that are on the National Historic Registry that are part of that era of an agricultural high school. I like to think that the work that is happening on the prairie right now in Morris and at the university is really in some ways reaching back to those elements of our heritage. It is a new way of working collaboratively with partners in the region and with our agricultural community. Thank you.

Senator KLOBUCHAR. I was just thinking as I heard this, there are more opportunities for a huge wind turbine in a rural university than there is in an urban one, although we now have on in Minnesota in a suburban shopping mall. Are there other rural universities that you know of that are doing similar things across the Country?

Ms. JOHNSON. Sure there are, including in the State of Minnesota. If you go to Northfield, you will see the big wind turbine there as well. And obviously, it depends on location. We actually are sponsoring it. We have a Center for Small Towns on our campus, and we will be hosting a symposium in June with special invitations having been issued to about 50 schools, private and public schools in the region who are very much like us, situated in rural communities.

We believe that the work that is happening on our campus, it is about wind; it is it about biomass and gasification, but it really is as much about this integrated system of renewable energy onsite. We think that it isn't just the unique characteristics of our geography that there are others who can replicate and reproduce the same kind of thing.

Senator Sanders had mentioned earlier the importance of dissemination, the importance of producing an educated citizenry. I think we are really in the midst of that in terms of building this research and demonstration platform on the prairie. We have good partners with an outreach center that is part of the University of Minnesota's agricultural school. We are lucky to be part of the sys-

tem. We also have a wonderful partner with the USDA Agricultural Research Station that is in Morris. We talk about this as the research triangle, and we say North Carolina, move over. But we really have great opportunities in our small town to do some of these things and to share them.

Senator KLOBUCHAR. OK. Thank you.

I have been trying to get Senator Sanders out to Minnesota, so maybe we will bring him out to the campus, although your campus may never be the same.

President Levin, as you know, we are considering, and this Committee has voted through legislation with a cap-and-trade. It seems that carbon offsets will be an integral part of any kind of future cap-and-trade program. I know that Yale is utilizing them to meet your own emission goals. Could you elaborate on the role of offsets in your climate strategy and the kind of research that is going on at Yale with carbon offsets?

Mr. LEVIN. Sure. Actually, except as a prize to the residential college that wins the energy savings competition, we are actually not focused on the purchase of carbon offsets in today's markets such as they are, in part because today's markets don't really reflect a scarcity price on carbon as markets will when the Lieberman-Warner bill is passed and enacted into legislation.

We are committed to participating in direct investments in carbon offsets. In other words, we have looked at and are likely to make in the future investments in wind farms in areas remote to the campus that won't actually feed the campus, but will feed the New England power grid and will be incremental sources of renewable supply.

So the carbon markets, as I suggest, really will work much better when they do reflect a true scarcity price. Right now, they do not, and in fact if one wanted to satisfy our large requirements, we could reach our 43 percent goal, which would require purchasing about 203,000 metric tons of CO_2 at a price that is actually fairly modest today, but that is not reflecting the true cost.

Senator KLOBUCHAR. Thank you very much.

Chancellor Birgeneau, I am out of time here, but I have some great questions of you about your green rooms, your green dorm rooms or whatever they are. So we will come back on the second round.

Senator Craig.

Senator CRAIG. Thank you all very much.

Clearly, our colleges and universities can lead in the areas that you are now speaking to, in the concept of university competition and the walled thinking and creating areas that our universities are supposed to be. The one thing that I have focused on is not distorting a marketplace or not creating artificial mechanisms, but truly allowing technology and the innovative mind to get there.

What your colleges and universities are doing today is outside any law that Congress could ever create. You are grabbing the issue. You are taking the issue and you are running with it in a fair and responsible way, as are my colleges and universities.

But let me have some fun with you for a moment. Let us turn to this weekend and March Madness and put our colleges and uni-

versities and our alumni to a test. Can we do that? So let me direct my questions, Madam Chair, to have some fun.

Let me start with Cal Berkeley first. Now, listen up folks, because I want to get it accurate and I want to get it right. Cal Berkeley, 110 metric tons in 2006. Is that accurate? Excuse me, 210,000 metric tons in 2006.

Mr. BIRGENEAU. I can't tell you if that is the exact number.

Senator CRAIG. I believe that is correct. And you have 23,482 undergraduate and 10,076 graduate students, 33,558 students. All right. So your carbon footprint would be, under current day calculations, about 6.3 metric tons per student year. OK? Let's put that up.

Now, we will go to you, Dr. Johnson. You do very well, by the way. You are going to score well here. You predict that you are a zero-emission campus by 2010.

Ms. JOHNSON. That is right.

Senator CRAIG. All right. And with what you have laid out, that is very possible. You also say that your footprint was 12,000 metric tons before wind.

Ms. JOHNSON. Yes.

Senator CRAIG. About 12,000 tons for 1,700 students, and you were at 7.1 metric tons per student year.

Ms. JOHNSON. That sounds probable.

Senator CRAIG. OK. But you haven't won yet. Remember, we are going to play this game out right through to the final playoff.

Now, Dr. Levin, your footprint today is roughly the same as Cal Berkeley's, is it not?

Mr. LEVIN. That is right, about 220,000 metric tons right now.

Senator CRAIG. Yes. However, your institution has one-third as many students, 11,000 students.

Mr. LEVIN. That is correct.

Senator CRAIG. All right. So your carbon footprint is three times as large as Cal Berkeley's. Is that correct?

Mr. LEVIN. That is true. We are in a harsher climate and we have——

Senator CRAIG. No excuses, now. No excuses. Remember, this is a playoff.

Mr. LEVIN. We are in a harsher climate and we have much higher per capita Federal support for research than Berkeley, and research is——

Senator CRAIG. Oh, you're competitive. Listen, we are going into the final stretch here so we are going to score you at 19.1 metric tons per student year. OK?

Mr. LEVIN. That is about right.

Senator CRAIG. Now, in that case, we always like to degrade our Country as being the greatest emitter. So Yale is the United States of university emissions at this point.

Mr. LEVIN. I think we are losing.

Senator CRAIG. You are. You are losing.

Mr. LEVIN. Right.

Senator CRAIG. That is why I am so pleased to have you get with it.

Now, we are going to score Boise State University, you know, that team with the blue turf that tipped upside down college foot-

ball history here a year ago. Guess where they are going to come in, because we have the things that we like. We have hydro. We have wind. We have a little coal, very little nuclear yet. How are we going to score Boise State University as it relates to their carbon footprint per student per year?

Voila. 2.7 metric tons per year Oh, those Broncos did it again. [Laughter.]

Senator CRAIG. My point here is really quite simple, and it is as important for our Committee as it is for the witnesses before us this morning. When we talk about the totality of responsibility that our universities have, and we do, and you have demonstrated that, and by using this little exercise, not in any way am I attempting to degrade your efforts. That isn't the purpose.

You are going to do what will really solve the climate change problem. We can manipulate markets here. We can command and control by public policy. But what is emerging out of this is a consciousness in America today that all new energy technologies have to be clean. It is really quite simple. We will accept nothing less than that.

Now, in the midst of getting there, and it will take several decades to get there, the question is, how do we remain competitive? We have to continue an energy supply. There is no doubt about it. And we need to continue to grow if we are going to remain competitive. And that is the margin of frustration in between.

So Madam Chair, as we look at Warner-Lieberman, as we ultimately decide a climate change policy, and hopefully we will not distort or damage markets or damage our competitiveness in the world marketplace. Where the market really is today is with these universities and what they will and their students will produce. That is what we will sell to the world. That is what we will make available to the world. And that is the course of future energy, and not us thinking we are so smart we can manipulate it and play games with it here.

I thank you for your leadership. I thank you for being here. While I am not an alum of Boise State, Boise State is going to be awfully proud of me today, and they are going to be proud of you.

Thank you.

Senator KLOBUCHAR. All right. Thank you, Senator Craig. Again, you could have invited Boise State and we hope we will have another hearing where we can give them their March Madness award.

Senator CRAIG. Madam Chair, I just talked with the ranking member of the Committee and he said that if the Committee and the Chairman want to do a second hearing and give us the accurate lead time to scope and lay it out, we would be more than happy to participate. We just might bring one of Idaho's clean universities to play.

Senator KLOBUCHAR. Excellent. We look forward to it.

Senator CRAIG. Thank you.

Senator KLOBUCHAR. Senator Sanders.

Senator SANDERS. Thank you.

And for Yale University, what you need is a major river and a dam in New Haven. That will help you a whole lot. You can work on that.

[Laughter.]

Senator SANDERS. I want to congratulate all of the campuses and the colleges and universities for what you are doing, but I agree with President Johnson that heaven is probably somewhere near rural America, and maybe in Vermont we share some of that as well. So I want to ask you a couple of questions because what you are doing sounds extraordinarily exciting. I would like to see that in Vermont. We are making a little bit of progress. We just haven't quite advanced as far as you have.

Talk a little bit about the wind turbines, and talk a little bit about the financial implications of what you are doing, because as is always the case, the initial investment is what is significant, coming up with the money to buy the sustainable energy and then the payback period over a period of time. And then talk a little bit, and then I want the others as well, about what role do you think the Federal Government can play? It always seems to me to be a very sad State of affairs if people say, well, over a 20 or 30 year period, we can actually save money, but we don't have the money to make those investments right now, which is why we are working on legislation to help colleges and universities make those investments. Could you comment a little bit about that?

Ms. JOHNSON. Thank you. I appreciate the question and also your leadership in terms of potentially providing some of these resources for colleges and universities around the Country.

The wind turbines are not only expensive, the big ones that we are putting up, but they are also right now not very easy to find. That may be another kind of interesting issue legislatively. It is very difficult——

Senator SANDERS. Excuse me. Were you unable to locate that in the United States? Are you importing this?

Ms. JOHNSON. We are in the process of identifying a second wind turbine. We hope to have that up about a year from now. The line is long for people who are trying to buy wind turbines and that is mostly going to private——

Senator SANDERS. If I could just interrupt you for a second to talk about what a pathetic State of affairs that is. I think all over this Country, people want to move in that direction and we can't even buy it because we are not even manufacturing these products in the United States, which is beyond comprehension. It is another issue. I didn't mean to interrupt you.

Ms. JOHNSON. And one of the issues for Minnesota does have to do with Vestas, who was a manufacturer of wind turbines and who is looking to locate somewhere in the United States, and we would love them to come to Minnesota. But I think you are right. The pro formas that we have established, I mentioned in my remarks that we don't have a lot of resources. We don't have ourself, the University of Minnesota, Morris, a big endowment, so we don't have a lot of funds to invest. So we are relying, for example, for the second wind turbine on the CREBs, the one that we have been issued for that. We need to find the turbine.

The pro formas, I believe, and I believe that material has been entered into the record, show us as paying back, as saving money, but using the money to pay back the investment over the course of something like 13 years. The average lifespan for a wind turbine

is 20 years. So we think even with that sort of long payback period when we are using no-interest bonds to purchase the turbine, we will still have some years of good investment. I think the investment goes beyond just the dollars that we are saving. The investment, of course, is also in the environment and I think that is an important piece of it as well.

So we think of that not just as an investment in the materials themselves, but also as an investment in the earth, if you will. That seems important. So I think the questions of financing are really important. I think that the opportunities for the Senate, for local legislators are there to find ways to assist those who want to do alternative and renewable energy sources. I think one of the challenges also has to do with getting energy back onto the grid and some of the resistance to that. We face that locally. That is more of a local issue. If you have excess energy, how do you get it onto the grid so that people can use renewable energy supplies there?

There are any of a number of policy implications that are connected to this, but again, including the implications that are related to being able to purchase a single wind turbine, which is where we are. Perhaps there are ways that people could organize collectively so nonprofit organizations, higher education organizations, could collaborate to purchase multiple wind turbines, and that might make it both more feasible financially, but also more possible for us actually to find a turbine.

Senator SANDERS. If I could ask the same question to our friends from Yale or Berkeley. Yes?

Mr. LEVIN. Yes. I just want to add that I agree with all of what Chancellor Johnson is saying. Some of these concerns, like the limited supply of the turbines, is presumably going to be short term. Capacity will ramp up if there is demand for the product.

Let me speak to the financing concern and tie it to why we need a cap and trade system with a market price on carbon. Wind power may look attractive today at the high prices we have for substitute fossil fuel energy production or electricity production, but there is of course a risk. One reason why it might be difficult to finance a wind turbine by going into the debt markets would be that there is no way to hedge the risk of fluctuating prices.

But if you have a cap-and-trade system, a market price of carbon, and a set of futures markets for carbon prices, then there would be a way. People prepared to take the risk could then be the buyers of risk, and the institutions that are investing and their direct creditors could hedge that risk, so it would make capital more available through the markets.

I am very much a fan of Senator Craig in this respect. I think we ought to rely on market mechanisms as much as possible.

Senator CRAIG. Excuse me, Senator.

I think your logic there fits. I mean, it clearly does. The problem we have with wind turbines today is that we were not producers of the kind that President Johnson talks about. They were European. They are now here and they are being produced here. But because of our tax credit, in all fairness, we are subsidizing wind today and it has made it popular. I am not criticizing that. I support it. But it has created a demand where you do stand in line.

I think your concern about non-profits, we would want to watch that very closely because what I don't want to happen is for everybody to become a non-profit then, to try to get to the front of the line. I think the marketplace, you are right President Levin, it is going to work this thing out. I don't decry it, Senator Sanders, because we simply weren't there. We are now there very aggressively and they are being produced in the Midwest. The factories are going up.

Senator KLOBUCHAR. Senator Sanders, do you want to respond before Chancellor Birgeneau answers?

Senator SANDERS. Well, I just did want to suggest that, as I understand it, we helped develop the initial wind technology, and for a variety of reasons that has gone to other countries. I think that speaks to the decline of manufacturing in this Country in general.

But let UC Berkeley answer, please.

Mr. BIRGENEAU. I would like to address the innovation and American ingenuity part of the challenge, which is that ultimately the U.S. must lead in this area, which means that we have to take advantage of the phenomenal research talent that we have in this Country and the passion of young people. In this new program, Energy Biosciences Institute, the global energy corporation, BP, which is based in London, was under tremendous pressure to fund that research either at Cambridge University or Imperial College.

They ultimately decided to send the money overseas to the State of California because of the entrepreneurial character of the Bay Area and the scientific power of the University of Illinois Urbana-Champaign, a great Midwest university, combined with Berkeley and Lawrence Berkeley National Lab, which is a Department of Energy laboratory.

Similarly, the Department of Energy is investing now, and has under-invested in energy research, and we need to see a significant growth in support of energy research both at the national laboratories and in our universities.

Finally, we have a generation of students who are absolutely passionate about sustainable energy. Much of my own knowledge comes not from our technical experts, but from our students. I think it is time for government agencies, perhaps the National Science Foundation, to create a new set of graduate fellowships which will be sustainable energy fellowships. There will be a queue a mile long of the most talented young people in the Country who would love to have fellowships of that sort in which they could devote their careers to solving this problem for the United States.

Senator SANDERS. Good idea. OK.

Thank you very much, Madam Chairman.

Senator KLOBUCHAR. Thank you, Senator Sanders.

Before I go to some other questions, on behalf of Senator Boxer, I ask unanimous consent to enter into the record a statement from the University of California at San Diego. Hearing no objection, so ordered.

[The referenced document follows:]

Senator KLOBUCHAR. Senator Craig.

Senator CRAIG. What happens among our very competitive institutions when they compete head to head? I just turned to staff and said, after you entered and for Senator Boxer's benefit, "and the

competition builds!" We are going to have a great second hearing. I look forward to it.

Senator KLOBUCHAR. It will be a lot of fun. I just can't wait.

OK, Chancellor Birgeneau, you mentioned in your testimony, just in fact in your last statement, about the BP grant. I think some of that is going to research on cellulosic ethanol. Are you familiar with that? It is very important in our State as we build and expand into cornstover, as the Chancellor pointed out, and switchgrass and prairie grass. Could you talk a little bit about that research?

Mr. BIRGENEAU. Sure, absolutely. The goal is to go beyond ethanol and to go beyond the corn to ethanol paradigm, to basically take the incredible progress that we have made in modern molecular medicine and take that knowledge base and transform it into the agricultural world. So there has been some work done already, for example, at our partner University of Illinois Urbana-Champaign, but the relative development of the technology on the plant side compared with the human body side is actually quite disproportionate.

Our goal is in essence to use modern genetic techniques to create artificial termites, so we would like to develop organisms which will very efficiently convert, let's say, miscanthus grass, which is a grass that grows well in the Midwest in the United States, including in your State, an incredibly high-density, low-fertilizer, low-water, perennial, and grows to a height of 12 feet.

If we can develop the chemistry that will enable us to efficiently convert those kinds of grasses, break down the lignin and the cellulose into their constituent sugars, and then ultimately into alcohols, which will probably be other than ethanol, we could conceivably replace 30 percent of petroleum products by naturally produced biofuels. That would have a huge impact on the U.S. economy, and this, of course, is carbon-neutral.

Senator KLOBUCHAR. Very good. My question about the Green Living Project, and this came out of your written testimony where you talked about the fact that you can convert these student resident hall rooms to be environmentally friendly without costing a huge sum of money. Could you explain how a green room differs from a traditional dorm room?

Mr. BIRGENEAU. This is actually a 100 percent student-driven initiative, so I gave a little bit of seed funding to our students and said, do something creative. So they just looked very carefully at the way their rooms worked, whether or not the computers turned off automatically when they left the room; whether or not the lights turned off automatically; whether or not they had waterless toilets; whether or not they had appliances which were green.

Just by integrating a whole series of steps, not any single one critical, but the integral is that they then have been able to convert their dormitory rooms. This has been student-driven, so that there are green rooms which are extraordinarily energy efficient. This is now leading into a large-scale research project at Berkeley of how we design homes so that homes are energy neutral.

Senator KLOBUCHAR. Very good.

President Levin, you mentioned that one of the most effective steps that Yale has taken is to retrofit the heating, ventilation and air conditioning systems in 90 of Yale's roughly 300 buildings. How

many of these 90 buildings are historic or older buildings? How do you do this in a cost-effective way?

Mr. LEVIN. Some of them are challenging. Some of our stone neogothic buildings are really not very feasible for undertaking this approach. But for the more modern buildings, it is actually quite cost-effective. This has a positive economic return at current energy prices to just go through and improve the control systems, introduce centralized controls over HVAC and lighting as well so that things switch off automatically when people leave the room, have motions sensors and adjust temperatures appropriately when the building is occupied and not occupied.

These are investments that actually yield a payoff at today's high prices of energy.

Senator KLOBUCHAR. Thank you very much.

Senator CRAIG.

Senator CRAIG. Again, thank you all very, very much.

Let me ask a generic question of you, all three, because clearly Congress in response to the American consumer and the environmental realities is awakening and that is appropriate. We should be. And that really started in 2005 when we created the new Energy Policy Act that is driving a variety of resources out there today. Again, we spoke to it last year, for example, when the discussion on cellulosic ethanol began we bumped that up to 32-plus billion gallons annualized, recognizing that a fair or larger portion of that total production ultimately would have to come out of cellulosic technologies.

At the same time, as we deal with intermittent energy sources, and of course you at your university, Dr. Johnson, mentioned that you are doing feedstocks, biomass energy. I guess I would call that baseload, and the wind is intermittent. Because we don't have storage capacities today for intermittent, we have to have backup because the wind does one thing that we know well. It doesn't blow all the time, and yet we ought to be able to grab it when it does. Hopefully someday we will be able to store it, and that will help us feed and integrate both baseload and intermittent sources into a grid system.

But having said that, and I trust all of you have looked at Warner-Lieberman. Some version of climate change legislation within the next few years will become public policy in this Country. It may not be that per se, but there are pieces of it that will probably become that.

Can we arrive at a reasonable climate change policy that drives markets and investments without nuclear energy? How would the three of you respond to that? As the No. 2 nuclear research university in the Nation, how would you respond to that?

Mr. BIRGENEAU. I am highly biased because 10 years ago I chaired a committee for the Department of Energy urging the U.S. Government to sustain programs in research in nuclear energy and nuclear reactors for other kinds of research.

Senator CRAIG. That is right.

Mr. BIRGENEAU. So I am a passionate supporter of nuclear energy. I think it should be a critical part of our energy strategy. Because of the disappearance of funding in that area in the 1990's,

nuclear engineering departments like ours at Berkeley really suffered.

Senator CRAIG. You almost lost it.

Mr. BIRGENEAU. We are in the process of revitalizing it. Fortunately, we didn't lost it and we are revitalizing it.

Senator CRAIG. You and MIT are leaders in those areas of research and development. Thank you.

Dr. Johnson.

Ms. JOHNSON. Well, I am not a physicist, so I feel a little bit out of my league here. But just to come back to the first element of your question, I think that has to do more broadly with can we have an impact on climate change. I think the answer is decidedly yes.

I want to just come back again to the concept to make sure that stays in front of people, and that is the concept that drives the University of Minnesota, Morris, and that is an integrated system of energy. We have researchers at the outreach center, and again I am not a physicist so I am out of my league here, but who are working on just exactly the capacities that you are talking about—wind, hydrogen, the possibility of storing energy so that it isn't just episodic and dependent on when the wind blows. But if you have ever been on the prairie, there probably 3 days out of the year that the wind doesn't blow.

Senator CRAIG. I have been there.

Ms. JOHNSON. So I think again the number of things that have been referred to here that have to do with the interests of young people, of college students in this, the educated citizenry, I think it is certainly the case that we can have, and as you see on our campus, that we are having a positive impact.

I would like to come back in 2 years and do your final four again.

Senator CRAIG. We will do it.

Ms. JOHNSON. I am not sure what the status is going to be.

Senator CRAIG. We are awfully close to deciding a total rating system.

[Laughter.]

Ms. JOHNSON. I think you might have a new winner.

Senator CRAIG. Well, I don't suggest that you dodged my initial question, then, because you have handled it well. I think it is full integration. Thank you.

Dr. Levin.

Senator KLOBUCHAR. President Levin.

Mr. LEVIN. Let me say first that I think supporting all of these technologies—nuclear, biomass, solar, wind is important because we can't know in advance which will pay off most. So giving appropriate support to advancing them all is important. Price signals through a cap and trade system actually do part of that. I think direct efforts and subsidies are probably necessary as complements, at least in these years.

Nuclear poses a particular challenge. I agree with Chancellor Birgeneau that we ought to be supporting research in that area. But actually the challenge is more than research in the nuclear area because we will have nuclear plants coming offline in the next 20 or 30 years, requiring substantial investment to stay online.

Senator CRAIG. That is right.

Mr. LEVIN. In fact, given the long lags in actually designing and getting a nuclear plant through the regulatory and political barriers because of siting controversies, we will have a very hard time, even if we ran full blast starting today, to actually keep our nuclear capability as high as it is today 20 years from now.

I agree with you. We have to address this. Nuclear plants are very efficient baseload electricity plants, and they are completely green. It is very logical to be working on them.

Senator CRAIG. And of the three universities, yours, Yale, probably is the larger consumer of nuclear-based electricity than the other two. That is a rather cursory glance. So the reality you talk about of sustaining what we have and maintaining its efficiency and its safety as it ages, we have addressed that to some extent in the 2005 Policy Act.

Frankly, just before we left for the Easter Recess, we did something else that advances that. We brought two new commissioners to the Nuclear Regulatory Commission. One of them is a former staffer of mine, Commissioner Kristine Svinicki, formerly from Idaho Falls, Idaho. They are now in the process of ramping up in a way that will change those timelines substantially as it relates to retrofitting and/or bringing new greenfield production facilities online.

To Cal Berkeley, pick up the phone and call DOE, because there is a new opportunity there, Chancellor. Last year, Senator Bingaman, Senator Domenici and I authored it we put in legislation that was signed by the President and now we are seeking to fund the Nuclear Science Talent provision to start bringing the incentives at universities back, to take those young bright minds through their undergraduate degrees to the masters and the doctorates in those fields, to broaden, if you will, the base of that talent, both for our Country and the world. So the role Berkeley plays, along with MIT, and my universities in Idaho is now working directly with the Idaho National laboratory and the Center for Advanced Energy Studies.

America has blinked and awakened to 20 years of abstinence, if you will, in the energy field. They are not very happy with us because of the prices involved and the realities that are about. So hopefully, with our universities playing very important roles in this, like the great Country we are, we will overcome it.

Thank you, all three, very much for being with us.

Senator KLOBUCHAR. I wanted to thank all of you for coming, and just let you know we have had four Senators here, which isn't bad for a smaller hearing. I think there is just a lot of interest that is generated. Clearly, we are going to have college and university hearing II as well.

I also wanted to thank you for the work you have done in being leaders in this area, with not only the campus, but in selling this to your alumni and to bringing the students on board. In my own observations getting around our State, it is really the younger people that have been leading the way. I am sure you have all seen this from 8 year olds with penguin buttons, to college kids that have shown up here in the Hart Building with green helmets for green jobs, chanting in the bottom of the Hart Building, but it has really been the students that have been leading the way.

We appreciate your leadership and look forward to working with you in the years to come. Thank you very much.

Thank you, Senator Craig, as well.

[Whereupon, at 11:15 a.m. the committee was adjourned.]

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