NC STATE UNIVERSITY

Centennial Campus

Smart Grid Feasibility Study

Report Prepared By:

Hillary Meredith, FREEDM Systems Center
Liz Bowen, NC State University Sustainability Office
Spencer Kurtz, Advanced Energy
Roxanne Ryan, NC State University Energy Management Office

Report Team & Process:

The team was chosen from a group of Energy Fellows at NC State University. They were tasked to develop and deliver a smart grid feasibility study to inform decision makers on the value and benefits of implementing smart grid technologies on Centennial Campus. The background and experience of the team members is diverse, including engineering, business management, environmental assessment, program implementation, and data analysis to give a multidisciplinary view of the project.

The process of writing the report involved conducting a stakeholder analysis, gaining understanding of the smart grid landscape locally and globally, analyzing the current campus infrastructure and energy use, and providing a list of relevant recommendations. This study should be used as a "living document" that can be advanced by NC State as the University makes decisions on the vision, focus, and progression of projects. It is not meant to be an exhaustive list of all the opportunities and challenges in developing a smart grid demonstration project on Centennial Campus.

Special Thanks & Acknowledgements

This report could not have been completed without the knowledge, expertise, and time of the following people. The team offers sincere gratitude for their assistance.

Team Advisors:
Ewan Pritchard, FREEDM Systems Center
Paul McConocha, NC State University

Mahomet Accilien, NC State University
Forrest Allen, NC State University
John Anderson, NC State University
Jack Colby, NC State University
Alan Daeke, NC State University
Bill Davis, NC State University
Eric Dean, NC State University
John Dilliot, University of California at San Diego
Tracy Dixon, NC State University
Carol Dollard, Colorado State University
Judy Dorsey, Fort ZED, Colorado
Ken Dulaney, Advanced Energy
Wade Fulghum, NC State University
Rajit Gadh, University of California at Los Angeles
Becky Harrison, Progress Energy
Michael Harwood, NC State University
Jeff Hightower, NC State University
Marc Hoit, NC State University
Joan Kowal, University of Maryland
Brewster McCraken, Pecan St., Inc.
Ryan Reid, University of Texas at Austin
Julie Robinson, NC Sustainable Energy Association
George Smith, NC State University
Peter Squire, NC State University
Rogelio Sullivan, FREEDM Systems Center
William Taylor, Drexel University
Brandon Vann, NC State University
Jim Walker, University of Texas at Austin
William Winner, NC State University

Table of Contents

Executive Summary

As the global momentum for energy efficiency and sustainability grows, so does the interest and need for smart grid demonstration projects in the Research Triangle Area. The Centennial Campus Smart Grid Feasibility Study is a support document to be used by NC State University in the strategic planning and implementation of a smart grid demonstration project. Much of the university research in this report shows that high profile university projects are often part of collaborative, regional smart grid projects, typically focusing on the research side of the project. Additionally, some universities have a comprehensive, coordinated effort to install smart grid technologies on their campus grid. By being among the first to implement a smart grid demonstration project on the University electric distribution grid while also offering training and research opportunities, NC State University is poised to distinguish itself among peer institutions.

NC State University's Centennial Campus is in prime position, within the Research Triangle's Cleantech Cluster, to build an effective smart grid demonstration project with minimal investment. Preliminary infrastructure, planning, and knowledge already exist on the Campus. Centennial Campus has the unique advantage of proximity to smart grid industry leaders, non-profit organizations, and research centers on and near campus as well as convenient access to the State Capitol and the Raleigh-Durham Airport.

It is recommended that if the University chooses to move forward with smart grid implementation on campus, an officially sanctioned Smart Grid Advisory Board should be established. This Advisory Board would be responsible for supervising the creation of a detailed implementation plan, pursuing funding, and hiring staff to manage the effort. The University should continue to collaborate with internal and external stakeholders throughout the entire process to ensure the economic, social, and environmental impact of the project.

As part of an implementation plan, the following strategies are recommended (see the Recommendations and Project Options section for a more detailed list):

- Increased data acquisition and control
    - Integration of existing systems
    - Grid & building level upgrades
- Distributed energy generation
    - Combined heat and power plant
    - Increased renewable generation
- Energy Storage
    - Thermal storage
    - Electric storage
- Plug-in electric vehicle Infrastructure planning

This study details the smart grid business case, current interest, and infrastructure in place for smart grid, initial recommendations for a smart grid project, and next steps to deploying smart grid that will support opportunities for Centennial Campus to build NC State's reputation as a leader in engineering and transformative technologies.

Introduction to Smart Grid

The electrical utility grid is going through a major paradigm shift in its use of information technology and communication systems, similar to what the internet did for computing. It is uncertain exactly what a smart grid will look like in 20 years; however, existing technologies can be installed and steps can be taken to prepare the utility grid for future innovation. In “The Smart Grid: An Introduction” the U.S. Department of Energy describes their overall vision of smart grid using the following eight key characteristics that provide for immediate benefits, like energy savings and increased reliability, but also allows for future technologies to be easily integrated:
.

- **Intelligent:** Able to sense grid conditions and respond autonomously and faster than a human could.
- **Efficient:** Able to meet increasing energy demand without adding infrastructure.
- **Accommodating:** Allows for easy integration of any power source and future technology innovations.
- **Motivating:** Allows for real time communication of power use with consumers and encourages consumer change.
- **Opportunistic:** Creates opportunities for innovative companies to take advantage of the accommodating nature of the grid.
- **Quality-focused:** Delivers high quality power necessary for the increasingly digital world.
- **Resilient:** Resistant to attack and natural disasters.
- **“Green”:** Supports environmental improvement and slowing global climate change.

Through analysis of the local smart grid landscape, campus climate, stakeholders, and current trends the Centennial Campus Smart Grid Feasibility Study team developed the following preliminary vision of smart grid for NC State University:

Preliminary Smart Grid Vision for NC State University

The smart grid at NC State University will increase data acquisition and control to enable reductions in energy consumption and costs, while providing reliable and efficient electricity to meet the University’s teach and research mission. It will also build on the established local innovative smart grid sector in Raleigh and provide a collaborative hub for the nearly 60 Triangle based smart grid related companies to interact and showcase technologies. Through strong collaboration and partnerships with non-profits, local governments, businesses, and the community, NC State University will continue to distinguish itself as a sustainability leader and remain at the forefront of cutting edge technology.

Centennial Campus Smart Grid Business Case

Today’s utility grid is aging and stressed with increasing demand for electricity. Although today’s electricity system is 99.7% reliable, power outages and interruptions cost US citizens $150 billion each year.[1] The

[1] [DOE The Smart Grid : An Introduction]

cost of building new generation has also increased dramatically due to the rising costs of metals and equipment[2] and tighter emissions standards.

According to the National Energy Technology Laboratory's report for the Department of Energy, "Building a Smart Grid Business Case,"[3] smart grid deployment has an opportunity to make improvements in the following areas, all of which support the needs of NC State University Stakeholders:

- **Reliability** – reduced outage frequency and duration, adequate power quality, and improved customer service
- **Security** – reduced vulnerability to attack and natural events
- **Economics** – downward pressure on future electricity prices, opportunities, and options for consumers to save on their energy bills
- **Efficiency** – energy conservation by consumers, reduced system losses and reduction in operation, maintenance, and capital expenditures
- **Environmental Friendliness** – enablement of intermittent renewables
- **Safety** – protection for line workers and the public

The University has the advantage of being located in Raleigh, North Carolina, recognized in a Duke University study as the second largest city in the US for smart grid software development and the third largest state for smart grid vendors.[4] The only other city with more smart grid software development firm headquarters is San Francisco with six firms, compared with Raleigh with five firms. The region is also home to Research Triangle Park, a robust research and development base, and the Research Triangle Clean Tech Cluster, part of the International Clean Tech Cluster Network. Progress Energy and Duke Power, the major investor owned utilities in North Carolina, each received $200 million for Smart Grid Investment Grant through the Department of Energy. In addition, the region received over $23 million in energy related ARRA funding, with 87% related to energy efficiency. Smart grid is a key sector for employment growth in North Carolina over the past two years, according to the North Carolina Sustainable Energy Association NC Renewable and Energy Efficiency Industries Census. (See Figure 1: *North Carolina Sector employment growth since 2009 by business focus, 2011)*

Nearly 75% of the smart grid products and services added to the industry are purchased within North Carolina, which does show adoption of various smart grid technologies in the state[5]. Currently, the Triangle lacks a defined smart grid implementation project. Fort Bragg Army Base near Fayetteville, NC has been working towards implementing a microgrid for the past two years and has implemented smart grid products and services. Duke Energy's McAlpine Substation is an implementation project near Charlotte that has installed smart grid and renewable technologies. NC State University can learn from these local smart grid projects and others throughout the United States to develop a robust and practical smart grid demonstration project.

---

[2]National Energy Technology Laboratory for Department of Energy, "Building a Smart Grid Business Case", August 2009

[3] National Energy Technology Laboratory for Department of Energy, "Building a Smart Grid Business Case", August 2009

[4] Lowe, Marcy, Hua Fan, and Gary Gereffi. *Smart Grid Core Firms in the Research Triangle Region, NC*. Center on Globalization, Governance & Competitiveness, Duke University, May 2011

[5] Crowley, Rich and Paul Quinlan. *NCSEA NC Renewable and Energy Efficiency Industries Census*, November 2011

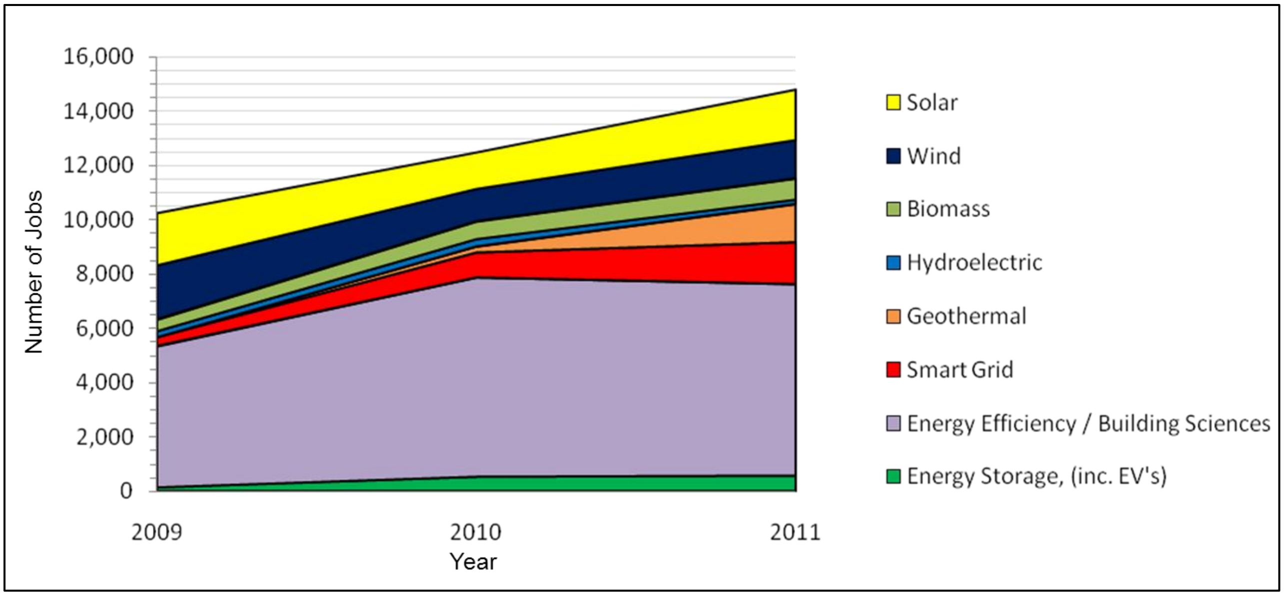


Figure 1-North Carolina Sector Employment Growth since 2009 by Business Focus

Despite North Carolina's growth in smart grid software development, and smart grid company headquarters, there is not a significant high-profile demonstration project installed in the Triangle area. NC State University's Centennial Campus is in an ideal position to take advantage of this implementation gap due to regional momentum around energy efficiency, energy independence, and support of smart grid. Centennial Campus can also build on its unique and collaborative environment of corporate, government, and non-profit partners. There are several smart grid focused organizations on and around Centennial Campus, some of which have expressed interest in a possible demonstration project.

Centennial Campus At-A-Glance

- 1989- first building opened with University tenant
- 1,120 acres
- 3 million square feet of constructed space
- 32 buildings
- 1,350 faculty, staff and post-docs
- 3,400 university students
- 2,470 employees of corporate and institutional partners
- 75 NC State departments, centers and institutes

Centennial Campus Smart Grid Organizations

- Duke Energy Envision Center
- ABB Smart Grid Center of Excellence
- Advanced Energy Corporation
- FREEDM Systems Center
- North Carolina Solar Center
- Green Energy Corporation
- McKim & Creed
- MC Dean
- Mang Ying Wind Power

According to the Research Triangle Clean Tech Cluster, there are nearly 60 organizations working on smart grid technologies and strategies in the Triangle area. See *Appendix A: Triangle Area Clean Tech Companies* for a full list. Many of these companies are members of the FREEDM Systems Center which is the only National Science Foundation funded engineering research center focused on revolutionizing the nation's utility grid. The center has access to nearly 50 Industry members who would be supportive of a demonstration project and some of whom could provide equipment, labor, and/or training to benefit the effort. See *Appendix B: Current FREEDM Systems Center Industry Members* for a full list.

As NC State University grows in student body, staff, and campus size, the need for energy grows as well. Through various energy management decisions, the campus has already established many of the building blocks to expand into a full-scale smart grid demonstration to help manage forecasted growth in energy demand. The most notable of these decisions are peak demand shaving techniques, HVAC and lighting setbacks, installing building automation systems (BAS), and the building of the Cates co-generation plant. There are still many opportunities for cost savings and energy reduction through utilizing more refined smart grid technologies and building on infrastructure already in place on Centennial Campus. As detailed in the *Alignment with Established NC State University Plans* section of this report, implementation of smart grid technologies also supports existing University plans.

Not only is a smart grid demonstration project positioned to contribute to energy savings, reliability, and cost reductions, but it will also demonstrate how smart grid technologies perform in building and grid infrastructure, provide critical tools for education on key smart grid technologies for emerging energy experts, attract industry and talent, and provide a fertile ground for hands-on research. External partnerships, such as those with City of Raleigh, the Research Triangle Clean Tech Cluster, and surrounding industries can help provide funding, education, talent, and marketing for the University.

Smart Grid at Other Universities

NC State University is not the only university in pursuit of a smart campus grid. Public, land-grant peer institutions and private research universities have smart grid activities. One of the main differences is how a coordinated smart grid project on campus is defined and marketed. This information was collected from each University's website as well as the energy management contact for the university and it is subject to change at any time. *Table 1: Smart Grid University Comparisons* should be used to identify opportunities for NC State and draw basic comparisons.

Primary Integrated Technologies and Applications	Smart Grid Universities									
	Colorado State*	UT Austin	UCLA	Drexel	UCSD	UC Davis*	Illinois-Urbana*	Rutgers*	U of Maryland*	NCSU
Demand Response Technologies										
Smart Meters										
Building Automation										
Energy Storage										
Renewable Generation										
Individual Billing										
Research and/or Training										
Coordinated Smart Grid Project on Campus										

Table 1-Smart Grid University Comparisons

*Peer Institutions as recognized by NC State's 2011-2020 Strategic Plan

There are some universities collaborating with utilities and municipalities on smart grid implementation projects. Universities often contribute as research and training partners in the greater regional smart grid efforts, but it is rare to have a coordinated smart grid demonstration effort on campus. Many, like NC

State University, are tackling the modernization of the electrical grid in an ad hoc manor, with only two peer institutions actually defining their efforts as smart grid.

Organizationally, many successful projects have strong cross-sector partnerships with the local government, businesses, non-profit organizations, and utilities. Some of these projects have a solid business case, detailed implementation plan, and provide for public outreach and education. Also, they may have an established governing body for decision making and some projects are run by an energy manager or a grant's principal investigator.

See *Appendix C: Smart Grid at Other Universities* for the current list of smart grid contacts and website links for the university projects researched for this study.

Notable Projects

Centennial Campus Smart Grid Stakeholders identified specific smart grid projects for the Energy Fellow team to research. The team interviewed each university contact and toured Colorado State University's FortZED project to help understand the scope of these universities' smart grid projects.

University of California at San Diego

The University of California at San Diego's microgrid is one of the most advanced in the world, serving a daily population of 45,000 students, faculty, and staff with demand response, building automation, smart meters, renewable generation, and energy storage. The campus itself is approximately 1200 acres, with 13 million square feet of building space. Its microgrid has an instantaneous peak demand of 43 megawatt (MW) with a single connection to the utility at 69,000 volts and the campus self-generates about 30 MW of its annual load on campus. There are 100 major buildings on the energy management system designed by Johnston Controls, with about 60,000 – 70,000 data points connected to the master controller. Viridity Energy received a $1,660,000 grant from the California Public Utilities Commission for a distributed energy optimization project at the university.

University of Texas, Austin

Similar to NC State, the University of Texas at Austin does not have a specific smart grid implementation project on their campus distribution grid, but has many energy efficiency efforts run through the Utilities and Energy Management Department, the Sustainability Office, and the newly formed Building Conservation Group. The university built their first campus power plant in 1930 and currently maintains their own utility designed for reliability separate from the local utility, Austin Energy. The university also has 536 killowatt (kW) of solar power installed on the Main and Pickle campuses combined. In addition to the efforts on campus, the university provides research expertise for the well known Pecan St. project, a $10.4 million smart grid demonstration project that is part of a mixed-used, sustainable urban neighborhood.

Colorado State University

Colorado State University is home to the Engines and Energy Conversion Laboratory (EECL), a research and testing lab used by the Department of Mechanical Engineering. The EECL is a part of the FortZED regional "zero energy" district which includes part of downtown Fort Collins and part of the University within its boundary. Contained within the laboratory are multiple generators (natural gas gensets and microturbines), load banks, frequency and voltage stabilizers, and switchgear - all connected to the grid with the ability to import and export power. The distributed generators are capable of producing and exporting approximately 2 MW of electricity.

FortZED is a set of projects and initiatives, funded by the Department of Energy and created by public-private partnerships, which uses smart grid and renewable energy technologies to achieve local power generation and energy demand management. The EECL is participating in both the demonstration and research portions of the FortZED project.

University of California at Los Angeles

The University of California at Los Angeles generates 90% of the power it uses on campus with a 44 MW co-generation plant built in 1994. 7%-8% of the power produced at the co-generation plant comes from biogas from a local landfill which is co-fired at the plant[6]. The majority of smart grid work being done at UCLA is research conducted at the Smart Grid Energy Research Center (SMERC). The center partners with utilities, local government, policy makers and technology companies. Some of the key research SMERC is working on are: automated demand response, electrical vehicle Integration, and cyber security.[7] UCLA's smart grid will communicate over a wireless network[8].

Centennial Campus Climate

In order to determine the feasibility of a smart grid demonstration on campus, and the scale and scope of a demonstration project, it is crucial to understand the current campus infrastructure. This infrastructure consists of Building Automation Systems (BAS), the electrical distribution system, renewable energy sources, campus user needs and opinions, and current University strategic plans.

Alignment with Established NC State University Plans

One of the key components in the creation of a feasibility study for smart grid on Centennial Campus is how it aligns with the various strategic plans developed by the NC State administration. These plans include the Strategic Sustainability Plan, the Climate Action Plan, the Strategic Energy Management Plan, and the Centennial Campus Master Plan. These four plans outline both short-term and long-term strategies for achieving sustainability for the future at NC State. These plans recognize sustainability strategies with quantitative measures, monitoring, benchmarking, and capacity for adjusting trends in sustainability targets. The plans also recognize qualitative measures that have social and environmental impacts. A smart grid demonstration project would advance these plans and expand the mission of the University.

Strategic Sustainability Plan

Charge: *"Addresses the immediate need to take action to advance sustainability, and sets a vision for growing the intellectual and scholastic scope of the university while using fewer resources."*

The Strategic Sustainability Plan (SSP) [9], a five-year, near-future plan, is a physical document called *The Foundation for Advancing Sustainability: A Strategic Plan for NC State University,* and unites the other two major planning efforts at NC State since 2009: the Climate Action Plan, which is a 40-year, long-term

[6] Katz, Nurit. UCLA: A Living Laboratory for Sustainability, Website, Spring 2011
[7] Gadh, Rajit. UCLA Smart Grid Energy Research Center, Website, March 2012
[8] Gadh, Rajit. WINS Smart Grid: UCLA Wireless Internet Smart Grid Connection for the Utility Industry, Website, March 2011
[9] Colby, Jack and Dr. William Winner. *NC State University Sustainability Strategic Plan.* Campus Environmental Sustainability Team and University Sustainability Office, April 2011

plan and the Strategic Energy Management Plan, which outlines immediate actions for using energy more efficiently.

A smart grid demonstration would be a significant step in achieving the following strategic goals for sustainability that are laid out within the SSP:

- Achieve 30% reduction in building energy consumption by 2015 against the 2003 baseline
- Improve energy data management capabilities and make data-driven decisions utilizing enhanced energy data
- Train and educate staff and building end-users to properly operate and maintain building systems in an energy efficient manner
- Ensure a cost-effective and reliable energy supply by developing business scenarios and strategies for diversifying fuel sources

Climate Action Plan

Charge: "*Realize full climate neutrality by 2050*."

The principle behind the Climate Action Plan (CAP)[10] is to identify goals and strategies that will result in reduced greenhouse gas (GHG) emissions and thus reduced impact on the environment.

> ***Climate Action Plan Recommendations***
> *Construct a co-generation plant, install large solar PV, ensure all buildings are energy star certified (options 6,19,23,28). Increase saturation of*

According to the CAP, indirect emissions, or "scope 2" emissions, from the consumption of electricity accounted for approximately 53% of the university's GHG emissions in 2008. This is projected to increase by almost 25% if the University continues "business-as-usual". An obvious effect of implementing smart grid technologies at NC State would be increased efficiency and reliability of the campus grid, along with real-time adjustment of building systems, such as lighting and HVAC, for optimal effectiveness in response to varying demand. In turn, these effects will play a large roll in reducing the Scope 2 indirect GHG emissions from the generation of the electricity that is consumed on campus.

Strategic Energy Management Plan Alignment

> ***Strategic Energy Management Plan Recommendations***
> *Smart meters and integrated BAS in every building (options 1 and 8), construct co-generation plant (option 23), install solar PV (option 19), Retrocommissioning, building scheduling, and occupancy sensors*

Charge: *"Reduce energy consumption and improve energy efficiency…consistent with the needs for a safe, secure, and inviting campus community."*

The Strategic Energy Management Plan[11] details 41 approaches for energy efficiency, spanning five different program areas. Employing smart grid technology directly fits into all of these program areas of 1) Energy Data Management, 2) Energy Supply Management, 3) Energy Use in Facilities, 4) Equipment Efficiency, and 5) Campus Energy Integration in some capacity. See *Appendix D:*

[10] NC State University Climate Action Plan, Campus Environmental Sustainability Team and the University Sustainability Office, December 2010

[11] NC State University Strategic Energy Management Plan, Energy Management, Utilities and Engineering, November 2010

Strategic Energy Management Plan Alignment Highlights for a more complete list of smart grid and plan alignment.

Centennial Campus Master Plan

Charge: *"Recognizes the impact that a beautiful, well-planned, academic setting has on the learning process and on the well-being of those who work, study, and visit at NC State"*

> ***Centennial Campus Master Plan Recommendations***
> *Support a Centennial Campus "neighborhood", emphasize collaboration between Facilities and academics, and pursue strategies that contribute to campus sustainability*

The Master Plan[12] describes a community, made up of many smaller "neighborhoods", one of which could be focused on energy, smart grids and smart buildings. One of the Master Plan's guiding principles is the integration of academic, programmatic, and physical planning which could inform the smart grid demonstration project. Another guiding principle of the Master Plan is environmental, economic, and social sustainability – strong value adds of smart grid.

There are a number of new buildings planned for Centennial Campus, some of which may be good candidates for including in a smart grid demonstration: James B. Hunt Library, Executive Conference Center and Hotel, Apartment Complex, Centennial Campus Student Housing, Engineering IV and V, and the Shores Phase II Residential Project.

Current NC State University Infrastructure

It is important to understand the existing infrastructure on Centennial Campus, and to acknowledge that NC State has already taken first steps towards smart grid implementation. There are several key infrastructure components which must be addressed: The distribution system, which delivers power to campus buildings; meters, which measure how much energy is consumed; communications, which allow components to interact with one another; building automation systems (BAS), which control how buildings operate; and renewable energy sources, which provide more environmentally friendly energy. Please refer to *Appendix E: Centennial Campus Infrastructure Map* for specific building information.

Distribution System and SCADA

The 15 MW Centennial Campus substation, owned by Progress Energy, has three electrical feeder cable loops that are routed to 23 buildings and three parking decks in addition to the steam and chilled water plant. As Centennial Campus grows in square footage, an additional substation, built and owned by NC State, is being considered.

> ***Distribution System Recommendations***
> *Electrical, steam and chilled water connected to distribution system (option 22), upgrade to fully integrated SCADA (option 10), co-generation on Centennial Campus (option 23 and 28), purchase current substation (option 26)*

There are six main circuits - two express feeders to the Centennial Campus Utility Plant and four to the rest of Centennial Campus. A master plan for a Supervisory Control and Data Acquisition (SCADA) system was first

[12] *NC State University Physical Master Plan: A Campus of Neighborhoods and Paths,* NC State University, October 2007

written in 2005 and there is ongoing research for installing an upgraded system.

The SCADA system receives inputs from remote terminal units (RTUs) at each substation. It is not considered user friendly and there is an effort to upgrade to 64 bit servers with a more user friendly interface. Centennial Biomedical Campus substation does not have a RTU in place, but there are plans to install this in the near-term.

There are plans for Enterprise Level Control System (ELCS) and SCADA web-based graphical user interfaces, allowing facility and energy managers increased control. This includes benefits such as building alarm notifications and response system, fusing building system functions with utility plant functions, peak demand limiting, and load shaving strategies.

Smart Meters

There are currently 53 smart electric meters on campus, thirteen of which are on Centennial Campus. A big step for smart grid readiness is adequate building level metering that allows for real time bi-directional communication. In addition to the already installed and integrated meters, Energy Management has also developed a Long Range Metering Plan which details additional metering needed in order to transition the campus to a fully integrated system with real time utility data available for every building on campus.[13] Installing smart meters will allow for more detailed tracking of building energy usage and make it possible to perform wave form analysis of the building, The plan is a prioritized database of meters to be installed and upgraded, so that as money comes available, educated decisions can be made as to which meters to upgrade first.

> ***Smart Meter Recommendations***
> *Install more bi-directional smart*

InStep, LLC.'s EDNA/ Electronic Billing System (EBS) is the billing system for utilities on campus. Meter data is the primary input to EBS, and is currently viewable through ECLS. Meter data is either read in automatically by smart meters, or entered manually by a meter reader.

Communications

Smart meters communicate TCIP/IP over Ethernet fiber and there is a robust fiber network and wireless network throughout Centennial Campus. All occupied buildings on Centennial Campus have NC State network connectivity via fiber except for Centennial Middle School, Golf Maintenance Bldg., Golf Clubhouse, The Shores residential complex, and Red Hat. There is also wireless connectivity through CentMesh network. The CentMesh pilot covers Main Campus Drive, Varsity Drive, and Partners Way areas Centennial Campus – though the long-term goal of the project is to cover all 1,334 acres of the campus.

Building Automation Systems

Building Automation Systems (BAS) are an important component of building level smart grid. Currently, over 100 buildings on NC State University campus and all 23 buildings on NC State Centennial Campus, have BAS that allow building systems to be controlled and monitored remotely. In order to harness the full potential of a smart grid and BAS, building operators need to be able to see and control all the buildings

[13] NC State University Long Range Metering Plan, Energy Management, Utilities and Engineering, April 2012

that use one of three types of BAS from a single interface. To make this possible, the University is taking the first steps towards transitioning all BAS over to a single unified system, Tridium Niagara, or ELCS.

BAS Recommendations
Install energy dashboards in each building (option 5), upgrades to BAS (options 1-3, 12), add more points to the Modbus system to allow for additional smart meters (option 8, 9) and add lighting controls (option 3)

There are three BAS manufacturers currently used on Centennial Campus. They are: Johnson Controls, Schneider Electric, and Siemens, each manufacturer has a proprietary web portal to access building level data for their respective systems. The Tridium Niagra system communicates with and controls all three BAS. Please see *Appendix F: ELCS Diagram* for a diagram of the NC State metering, building control, and SCADA network hierarchy.

Renewables

Renewable energy exists on campus in the form of solar photovoltaic and solar thermal installations. There are seven installations operating on campus, two of which are located on Centennial Campus and contribute 42 kW to the energy load. The Keystone solar PV project was an in-kind donation to the FREEDM Systems Center by AEG. The Research IV thin film solar modules were donated by Hamlin, and Advanced Energy's partners donated the wires and inverter for the project.

Renewables Recommendations
Increase penetration of renewable on campus (bio-gas

Many projects are in the pipeline to increase solar energy on Centennial Campus and Sustainability Office Staff is streamlining the administrative and financing process for new solar projects. In the spring of 2012, NC State Environmental Technology students will perform an engineering solar feasibility study on Centennial Campus buildings to determine which buildings will be the best candidates for solar photovoltaic and solar thermal.

Wind energy is not feasible at NC State University or the entire piedmont region of North Carolina. The average speed of wind in the Raleigh area is 7.6 MPH[14] and the minimum wind speed needed to produce adequate energy are called Class 3 winds and have an average annual wind speed of at least 13 MPH.[15]

EV Charging Stations

Plug in electric vehicles (PEV) and plug in hybrid electric vehicles (PHEV) are seeing a significant surge in the vehicle mass market. Charging infrastructure must be in place to accommodate the increasing number of PEV's.

By May 2012, Centennial Campus will have ten Level 2 EV charging stations installed. Two EV charging stations can be found at each of the following locations; Partners I & II, Research IV, Keystone Science Center, 914 Partners Way Deck, and 851 Partners Way Deck. There are two additional EV charging stations at McKimmon and two at the Solar House, outside the boundary of Centennial Campus, bringing the total number of campus charging stations to fourteen.

[14] NOAA Satellite and Information Service Average Wind Speeds National Climatic Data Center, US Department of Commerce

[15] Wind Energy Development Programmatic EIS Wind Energy Basics Bureau of Land Management

Centennial Campus Energy Usage

A key step towards determining the feasibility of smart grid on Centennial Campus is to determine where potential savings can be realized. Smart grid offers great opportunities for peak demand control and reduction and overall energy use. By understanding the usage patterns of the campus, predictions can be made about the magnitude of savings that are possible from different smart grid strategies. See *Appendix G: Centennial Campus Energy Usage* for an in depth analysis of current energy use.

Existing Smart Grid Strategies on Campus

NC State is already employing smart grid strategies and as a result is seeing real cost and energy savings. The success of the strategies which are already in place is perhaps one of the most compelling arguments in favor of establishing a coordinated smart grid effort on Centennial Campus.

Load Shedding

Load shedding, or peak shaving, is conducted on the warmest days of the billing cycle, during the peak hours of operation on buildings with BAS. The goal is to predict, during each billing period, where the university is going to create its demand peak, and then take steps to reduce this peak, which in turn reduces the demand charge. In fiscal year 2011, the University successfully avoided $175,000 in utility demand charges as a direct result of load shedding efforts.

Peak shaving is a collaborative effort between Energy Management, Building Maintenance and Operations (BM&O), and the Central Utility plant operators. Energy Management staff monitors weather forecasts and decides which days to conduct load shedding. BM&O then uses the BAS to switch HVAC systems to economizer mode, which allows for larger deviations in building temperature, and makes use of outside air to regulate building temperatures. The Central Utility Plants let chilled water temperatures drift from 40°F to 46°F, as well as power down an electric chiller and firing up the non electric steam chiller.

Building Scheduling

By ensuring that buildings are properly scheduled to run only when occupied, the University can reduce energy cost greatly. Energy Management is currently conducting a pilot to determine what level of savings can be expected from fine tuning building schedules. The initial building was SAS Hall, which realized $22,000 or savings in fiscal year 2011, solely from schedule adjustments. The pilot has since been expanded to include Park Shops and Withers Hall. Savings data is still being collected for these pilots. By July 2012 Energy Management will have implemented tighter building schedules on eleven additional buildings, four of which are on Centennial Campus, those buildings are: Partners I, Partners II, Partners III, and Research IV.

> ***Campus Energy Usage Recommendations***
> *Thermal storage, load shedding, Energy Star certification, BAS scheduling and increased control (options 3, 4, 6, 12, 13, 20, 21)*

Energy Star

University Housing, in collaboration with Energy Management, has successfully earned Energy Star Certification for three residence halls on campus: Carroll, Sullivan and Tucker. In Tucker Residence Hall alone, $10,000 in energy-conservation measures were put in place during the 2009-10 fiscal year. These include: scheduling HVAC systems for optimum performance, LED lighting upgrades in the common spaces, occupancy sensors in the bathrooms, and energy-conservation education for residents. In the first year, the upgrades lowered Tucker's energy consumption by 1,337,758 kBTUs, which helped keep 104 tons of GHG from entering the atmosphere, according to ENERGY STAR's building portfolio manager.

Co-Generation

The co-generation plant that is being installed at the Cates Central Utility Plant will cost $61 million. The 11 MW co-generation plant is expected to save the university approximately $3 million a year.

Installing another combined heat and power plant on Centennial Campus is an opportunity for energy savings. Upgrading the electrical grid will make the installation of co-generation on Centennial Campus easier, and will allow for optimal performance from the plant.

Stakeholders on Campus

The attitudes and opinions of all the individuals and organizations that might be effected by a smart grid demonstration project must be considered and understood. Stakeholder engagement should continue to include relevant individuals and organizations in the community throughout the planning and implementation of a project. Two forms of stakeholder analysis were conducted as part of this project.

Student Sustainability Attitude Survey

In October and November of 2011 a survey titled, *Student Sustainability Attitudes Survey* was conducted by Energy Management and the University Sustainability Office to gauge the attitudes of students towards sustainability in general as well as sustainable projects and initiatives at NC State. The survey showed that students care about energy conservation and the environment and want NC State to be a leader in these areas but feel the university is not doing as much as they should and could. Below are a few key results from the survey.

Student Recommendations
A demonstration project that balances the desire of students and faculty to interact with data and equipment without compromising reliability and security.

- 90% of students feel it is important for NC State to practice good energy management.
    - Of this, nearly half indicated that it was very important
- 83% indicated they thought it was important for Americans to conserve personal use of electricity.
- 78% of students indicated that they feel it is important for NC State to be a leader in sustainability and the environment.

Stakeholder Engagement and Analysis

To help shape this study in the early stages, the team focused on stakeholder engagement and analysis. The team worked to identify key stakeholders, including staff from Centennial Campus, Academics, Facilities and Operations, Utilities, Engineering, Power Systems and Building Automation. The team then split up into two groups and arranged one hour, in-person interviews. In the interviews, the team and stakeholders discussed project goals, concerns and benefits of smart grid, and project opportunities. See *Appendix H: Stakeholders Interviewed* for the list of individuals interviewed.

Stakeholder Recommendations
Conduct stakeholder forum, vet implementation plan and solicit feedback, marketing and outreach on project, and

During the interviews, stakeholders noted concerns regarding project cost and what party would lead the effort. There was also some skepticism about assigning an estimated value to potential energy savings. Stakeholders also shared their perspective regarding benefits of smart grid to the University such as the opportunity to use the campus as a classroom and to be a leader in energy management. Stakeholders also mentioned support of local industry and government as a benefit. See *Appendix I: Stakeholder Smart Grid Concerns and Benefits* for a full list of concerns and benefits.

Current Trends

In 2010, the US Federal Government spent $7.09 billion on developing a smart grid technologies and implementing projects. There are signs that smart grid strategy will revolutionize the way utilities do business in the next ten years. According to Duke University's Center for Global Governance and Competitiveness, the Triangle already boasts at least 59 smart grid companies working in the region. In 2011, the smart grid sector in NC was estimated to employ over 1500 people in North Carolina, as referenced in the NC Sustainable Energy Association 2011 Industries Census. There are signs that this momentum is growing, through increased job creation, as discussed in the Business Case section.

Utility Status

At the time of this writing, Duke Power and Progress Energy are filing a third time for a merger through the Federal Energy Regulatory Commission. This merger would center the largest utility in the world in North Carolina. The state has already become a magnet for smart grid companies interested in providing products and services to this large utility. The Energy Fellow team met with Becky Harrison of Progress Energy, the utility that provides electric power to the University. She shared Progress' smart grid vision: to have the ability to manage loads differently to respond to changes on the grid and flatten the load profile. Currently, a NC regulated utility's expense associated with smart grid are not recoverable through rate changes. Rates will most likely change in the future to help manage the utility's load profile and increase utility revenue as customers increase distributed generation assets.

Utility Recommendations
Build a co-generation plant (23,28) and larger scale solar PV(19).

Legislative and Regulatory Status

Legislative support ranges from financial support for regional initiatives, developing standards, increasing renewable energy penetration to tax credits for job creation and research in the sector. There are four relevant bills at the Federal level and one pending bill at the State level. For more information on relevant smart grid legislation see *Appendix J: Legislative and Regulatory Staus* or visit the Smart Grid Clearing House website at http://www.sgiclearinghouse.org/Legislation.

Electric Utility System Communication Protocols

One of the key components to improving upon the capabilities of smart grid technologies is to continue to assess the development of the software and standardized protocols that will be used to automate any extensive smart grid system.

Standardized and universally recognized protocols in the power sector are difficult to find. This makes interoperability between devices a significant engineering challenge. Various vendors have proprietary communication standards that do not communicate well with other devices. Although software-based substation automation systems (SA systems) have become the norm, they still have many challenges, such as: the interoperability of devices and protocols, IEDs (Intelligent Electronic Devices) that do not have communication capability; and, a large number of physical connections. For a brief overview of three widely-accepted communications protocols: Modbus, DNP 3.0 and IEC 61850, see *Appendix K: Utility System Communication Protocols.*

Grid Security & Privacy

Much of the benefit of a smart grid comes from being able to collect data and share it between systems that can respond to that data. However, as with any networked system, there are security concerns that arise from the transfer of data. It is estimated that by 2015 there will be 440 million hackable points on the electric grid, and $21 billion will be spent on cyber security.[16] Some examples of hackable points are smart meters, routers, and control devices at substations. Security is an issue that needs to be addressed in any discussion of smart grid on Centennial Campus.

Some stakeholders are concerned about student, staff, and faculty privacy and security. If the grid were to be hacked or compromised in some way, the effects on the university could be significant. Power loss could affect every aspect of business on campus, research could be lost or damaged, students work and classes could be interrupted, and business tenants could lose valuable time and information. In addition to the concern of a wide spread power loss, there is worry that with if the grid were to be hacked all the extra data required to operate a smart grid could allow sensitive or confidential information to end up in the wrong hands. The National Institute of Standards and Technology is working on interoperability and security standards to address these issues; therefore, security improvements should be tracked and considered in any smart grid deployment plan.

Recommendations & Project Options

In order to guide the implementation of smart grid on Centennial Campus, the team established a list of recommendations and project options that could be adopted by the University. It is recommended that the University support and officially sanction a Smart Grid Advisory Board. This Advisory Board should supervise the hiring of a project manager to coordinate the writing of a detailed implementation plan and demonstration project. Funding and in-kind donations should be explored in the form of government grants, private donations, and equipment donations from industry. For a list of background information that informed the recommendations in this paper please see Appendix L: Smart Grid Project Goals.

The list of project options was developed through a combination of research and discussions with NC State stakeholders. The stakeholders were asked their vision of the energy future for Centennial Campus and what they considered to be key components of a smart grid. Project stakeholder comments formed the backbone of the project options in the report. Any smart grid demonstration project on campus should include options for: 1) More integrated utility system communications, 2) Stronger electrical distribution system data acquisition and control, 3) Increased deployment of renewables, 4) Implementation of on campus energy storage, and 5) More building level automation and control.

[16] Storm, Darlene. 440 Million New Hackable Smart Grid Points, Computerworld, October 2010

NC State University, as a community, must continue to explore new and innovative education and research opportunities to remain a globally recognized leader in science, technology, engineering, and mathematics. A smart grid demonstration project on Centennial Campus provides that opportunity. There are many elements to smart grid that are universal (e.g. occupancy sensors, smart meters) but others that could distinguish the university in the region and globally (e.g. vehicle-to-grid integration, DC distribution circuit). Alignment with established plans, economic development, and research opportunities should all be considered when determining the type of smart grid implementation project NC State University would like to build.

Table 2: Demonstration Project Options addresses these factors and is designed to help decision makers determine which components of smart grid to implement and when. The descriptions of each column are:

- **Currently in Discussion:** Option has been discussed by NC State Utilities and Engineering.
- **Consumer Change:** Differentiates between options which will impact consumers potentially requiring them to make changes to how they operate on a daily basis.
- **Reliability:** Supports or increases the reliability of NC State's energy distribution system.
- **Security:** Increases the protection of research and personal information.
- **Economics:** Supports reduction in energy use and saves or avoids costs.
- **Efficiency:** Increases the efficiency of staff time and energy use on campus.
- **Environmentally Friendly:** Supports NC State's goal of climate neutrality by 2050 or supports environmentally sustainable practices.
- **Distinguishes NC State:** Differentiates NC State University positively as an energy leader when compared to peer and other land grant research universities.
- **Safety:** A distinct increase in safety for utility workers as a direct result of implementing a particular smart grid option.

Project Options- Order of Magnitude Cost Classification:

Low- $1 to $99,999
Medium- $100,000 to $999,999
High- $1,000,000 and up
TBD- Cost information was not available at the time of writing

Table 2: Demonstration Project Options

	Options	Currently in discussion	Consumer Change	Reliability	Security	Economic	Efficiency	Environmentally Friendly	Distinguishes NC State	Safety	Estimated Cost	Potential Annual Savings
Phase 1 (now-5 years): Bidirectional metering, demand side management, and the "Self-Healing Grid" concept												
1	Building Automation Systems in all New Buildings	■		■		■	■	■			Low	$22,000 per bldg[17]
2	ELCS- Integrated Building Automation systems	■		■		■	■	■	■		Med	TBD
3	Add lighting control to BAS	■		■		■	■	■	■		Low	$7,200 per bldg[18]
4	Improved Building scheduling for existing buildings	■		■		■	■	■	■		Low	TBD
5	Energy dashboards in buildings	■							■		Low to Med	TBD
6	Energy Star Certification for all buildings	■				■	■	■	■		$750-$1500 / building	TBD
7	Occupancy Sensors for common areas					■	■	■			$100-$200 per sensor	50% lighting cost year
8	Install smart meters (building and sub-metering)	■		■							$2500-$5,000	TBD
9	Increase number of Modbus ports	■		■							$45,000	TBD
10	SCADA upgrades	■		■	■	■	■	■	■	■	High	TBD

17 Based off SAS hall pilot

18 Based off SAS hall pilot in which $4,000 in electrical saved at SAS in 3 months $4,000*4 = $16,000, 45% is due to lights, savings = $7,200

Table 2: Demonstration Project Options

	Options	Currently in discussion	Consumer Change	Reliability	Security	Economic	Efficiency	Environmentally Friendly	Distinguishes NC State	Safety	Estimated Cost	Potential Annual Savings
11	Automated Switches on distribution system										$100,000 each	TBD
12	Automated load shedding										$12,000	$175,000 and up
13	Use alternative generation sources to go "off grid" at peak times.										MED	TBD
14	Billing and pricing options- time-of -use etc.										LOW	TBD
Phase 2 (3-7 years): Increased saturation of renewable energy, increased energy storage, adaptive control, and secure communications												
15	All outdoor and emergency lighting is LED										Med to High	TBD
16	Level 2 PEV Charging stations										Level 2: $3,000[19]	TBD
17	10% of campus users drive PHEV										$40,000 each	TBD
18	PHEVs to grid (used for demand response; frequency and voltage										TBD	TBD
19	Large solar array (500 kW)										$2.5-$3 MM at $5-$6 a watt	TBD
20	Large thermal storage (Ice)										$200,000 – 250 ton	TBD
21	Electric storage										Med	TBD

[19] "Charging Station Installation Handbook for Electrical Contractors and Inspectors" prepared by Advanced Energy

Table 2: Demonstration Project Options

	Options	Currently in discussion	Consumer Change	Reliability	Security	Economic	Efficiency	Environmentally Friendly	Distinguishes NC State	Safety	Estimated Cost	Potential Annual Savings
22	All buildings are on the district distribution system										Med to High	TBD
23	Co-generation plant										$60-$80 million	TBD
24	Real-Time Adaptive Control										TBD	TBD
25	Current waveform analysis on individual circuits										TBD	TBD
Phase 3 (7-15 years): Intelligent energy management, small wind systems and fast Intelligent energy management, low head hydro and fast charging stations for electric vehicles, and higher system efficiency												
26	Purchase the Centennial Campus substation										$6-$8 million	TBD
27	Second substation										$6-$8 million	TBD
28	Co-fire biogas in cogeneration plants										TBD	TBD
29	Ring distribution system										Med	TBD
30	Optimize design of transformers										Low	TBD
31	Phasor measurement at the building transformer level										TBD	TBD
32	DC Distribution line										High	~$100k

Table 2: Demonstration Project Options

Building Recommendations

The team chose three key buildings on Centennial Campus for specific smart grid recommendations. These buildings include both University owned buildings and privately owned, and all three main types of spaces on campus: office, lab, and classroom. *Table 3: Centennial Campus Smart Grid Building Recommendations* outlines the team's recommendations for each building and a rough estimation of the potential annual energy cost savings that could be achieved: This information for many of the Centennial Campus Buildings can be found in the building energy audits conducted by the Energy Management Department.

Building	**Keystone**	**Partners II**	**Engineering Building II**	
Building Ownership	Privately owned	State Appropriated	State Appropriated	
Building Type	Office/Lab	Office/Lab	Office/Lab	
Square Footage	72,000	78,500	210,000	
Energy Use Intensity (kBTU/sq.ft.)	58	211	262	
Building Integration Recommendations				**Potential Annual Cost Savings**
Building Scheduling				$0.18 per sq ft
BAS Lighting Integration				$0.06 per sq ft
Smart Meters	✓			$0.00
Energy Dashboards				$0.00
Solar Array	✓			TBD
Electric Storage				TBD
Outdoor and Emergency LED Lighting				TBD
Occupancy Sensors[20]	✓		✓	$0.05 - $0.2 per sq ft
Potential Annual Cost Savings	$17,280.00	$30,615.00	$50,400.00	
Total Annual Cost Savings	$98,295.00			

Table 3-Centennial Campus Smart Grid Building Recommendations

Next Steps & Establishment of Advisory Board

The initial intent of the team project was to establish a Centennial Campus focused Smart Grid Advisory Board. Through continued research, interviews with NC State University stakeholders and meetings with The City of Raleigh, NC State Energy Office, and industry representatives it was determined that a general NC State University Smart Grid Advisory Board would be most beneficial to advancement of smart grid projects on NC State's campus. The board should assist with, and ensure, the adoption of smart grid on NC State University's campus and allow for integration of a Centennial Campus focused project. The advisory board should also act as a clearing house for all smart grid projects on campus. This will ensure that no matter who sponsors a smart grid project, they will all work together to create an integrated functional smart grid demonstration.

[20] State Energy Office, NC Department of Administration, US DOE - Occupancy Sensors Fact Sheet

The following appendices are attached that can help support the advancement of a smart grid advisory board:

- Appendix M: Advisory Board Roles & Responsibilities
- Appendix N: Advisory Board Draft Invitation Letter
- Appendix O: Advisory Board Potential Member List
- Appendix P: Suggested Smart Grid Collaborators

Through an Advisory Board, NC State can determine projects to pursue, secure resources (project management staff and funds), monitor energy savings and other key performance metrics, and evaluate the success of smart grid on campus. For the Board to be the most effective, collaboration with internal and external stakeholders is key. To support this collaboration, The Energy Council is conducting a Smart Grid/Smart Buildings Forum, April 2012 that will include students, staff, industry representatives, and the surrounding community.

Conclusion

A Centennial Campus smart grid demonstration project would represent the first coordinated effort on the campus grid on the transition to a campus-wide smart grid. Technologies must be easily adopted into an interoperable smart grid, since it will continue to evolve over the next 20 to 30 years. Challenges to the future success of the smart grid come from many fronts, such as the need for more consumer buy-in and cost reduction. A demonstration project and the components implemented must provide value either economically, socially, or environmentally to prove value to stakeholders. The tracking of key performance metrics that continuously and automatically score improvements generated by smart grid will be required if the effort is to be sustainable.

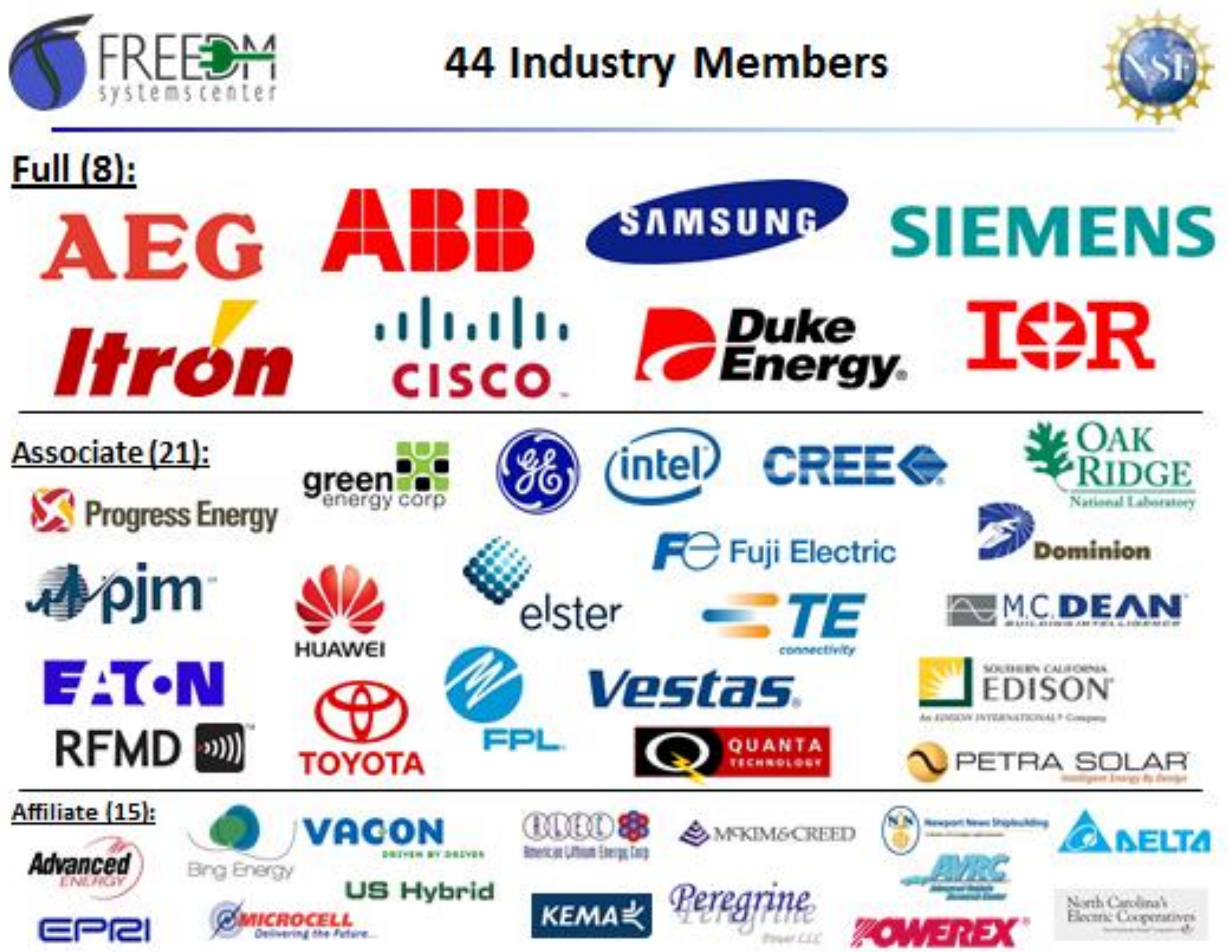
NC State University has support for a smart grid demonstration project from the City of Raleigh, Research Triangle CleanTech cluster, university staff, and surrounding industry. An Advisory Board will guide smart grid efforts to focus the direction of the University while providing an avenue for collaboration with internal and external stakeholders. A demonstration project provides the opportunity for NC State University to be a leader in emerging technologies, realize monetary benefit, and attract student and professional talent while taking advantage of the existing momentum for smart grid in the area.

Appendix A: Triangle Area Clean Tech Companies

List taken from the Research Triangle Region website.
http://www.researchtriangle.org/clusters/cleantech/major-organizations/

- Accenture
- Advanced Transportation Energy Center
- Advanced Vehicle Research Center of NC
- AT&T
- Black & Veatech
- Bull City Biodiesel
- Carolina Biodiesel
- Carolina Solar Energy
- Consert
- Council for Entrepreneurial Development (CED)
- Cree
- Delta Electronics
- Delta Group
- Dominion Power
- Duke Energy
- Eaton
- EDSA Micro
- ElectriCities of North Carolina
- Electronic Component Technologies
- Elster Metering
- Elster Solutions
- Energy Control Systems
- Energy ICT
- EnergyAxis
- FREEDM Center
- Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
- Green Energy Corp
- HCL Clean Tech
- IBM
- INI Power
- Itron
- JADOO Power
- JMC Inc.
- KEMA
- Liquidia Technologies
- Maverick Biofuels
- MegaWatt Solar
- Microcell
- N.C. Electric Cooperatives
- N.C. Biofuels Center
- Nature Energy Solutions
- Nitronex
- North Carolina Solar Center
- North Carolina State University
- Novozymes North America
- Piedmont Biofuels
- Plotwatt
- Power Secure
- Progress Energy
- Quanta Technology
- Red Hat
- Research Triangle Energy Consortium
- RTI International
- SAS Institute
- Scribner Association
- Semprius
- Sensus
- Siemens Energy
- Skyward Solar Power
- Solar Consultants
- Solar Gain
- Solar Solutions
- Solargenix Energy
- Southern Energy Management
- Southern Research Institute
- Strata Solar / Solar Tech South
- Tantalus Systems
- Truveon
- Tyco Electronics
- UL (Associate)
- United States Environmental Protection Agency

Appendix B: Current FREEDM Systems Center Industry Members



Appendix C: Smart Grid at Other Universities

Below you will find a link to the project website for each of the Smart Grid Projects described in table 1 and individual contact information for key personnel.

Colorado State University http://fortzed.com/ Carol J. Dollard, P.E., LEED AP Energy Engineer Carol.Dollard@colostate.edu 970-491-0151 - Office 970-566-2150 – Mobile	**UC Davis** http://westvillage.ucdavis.edu/ Facilities Design and Construction contracts@ucdmc.ucdavis.edu 916-734-7024

University of Texas at Austin http://www.utexas.edu/research/cem/smartgrid.html Steve Brahm - 512.232.1624 Ryan Reid, Asst. Manager, Utilities & Energy Mgmt reidrb@austin.utexas.edu Jim Walker, Director of Sustainability Jim.Walker@austin.utexas.edu	**University of Illinois** http://adsc.illinois.edu/research/power_grid_it.html Advanced Digital Sciences Center 217-244-1196
University of California at Los Angeles http://smartgrid.ucla.edu/ Facilities Management Phone: 310-825-3402	**Rutgers** http://www.rutgers.edu/ Michael Kornitas Energy Conservation Manager 732-445-4117 Ext. 196 mkornitas@facilities.rutgers.edu
Drexel University http://www.drexel.edu/drexelgreen/projects_smartgrid.html Bill Taylor Senior Plant Engineer 215-895-2827 taylorwt@drexel.edu	**University of Maryland** http://www.umerc.umd.edu/research/smart-grid Joan Kowal Energy Manager University of Maryland Facilities Management 301-405-5004 (office) 301-226-9330 (fax) 240-882-2585 (cell)
UC San Diego John Dilliott 858-822-2807 jdilliott@ucsd.edu	

Appendix D:Strategic Energy Management Plan Alignment Highlights

Charge: "Reduce energy consumption and improve energy efficiency…consistent with the needs for a safe, secure, and inviting campus community."

The Strategic Energy Management Plan[21] accomplishes its goal through 41 approaches for efficient energy use have been developed, spanning five different program areas. Employing smart grid technology directly fits into all of these program areas in some capacity, and the most significant are highlighted below.

Energy Data Management 1.0 Highlights

1.4 Campus Automation Master Plan
1.6 Metering Long Range Plan

Smart grid technology can assist with additional monitoring and control capabilities in order to perform load shifting and shedding.

[21] http://issuu.com/ncsu_energy/docs/ncsu_energy_charge_v2

Energy Data Management Opportunities

Options that will increase the quantity and quality of data, as well as give ability to make decision and execute changes based on the data are: Smart meters and Integrated BAS in every building (options 1 and 8).

Energy Supply Management 2.0 Highlights

2.1 Combined Heat and Power Program
2.3 Central Plant Optimization
2.4 Electrical Demand Management
2.6 Renewable Portfolio
2.7 Industry Best Practices

Smart grid technologies will almost certainly be a crucial aspect of energy distribution at the new 11.5 megawatt Cates co-generation facility being constructed on central campus. It can also help identify the relation between energy consumed by specific equipment and the production of chilled water and steam. One of the most important aspects of how smart grid technologies helps with energy supply management is to assist with the reduction of peak demand during times when the cost is the highest, by "staging" equipment so there is not a huge spike in demand at one point. Managing NC State's growing renewable portfolio and instituting industry best practices can also be streamlined.

Energy Use in Facilities 3.0 Highlights

3.4 Building Conservation Incentives
3.5 Space Utilization and Scheduling
3.9 Building Automation Master Plan
3.10 Public Utility Incentives

Specific areas where smart grid could play a vital role in reducing energy use in facilities is space utilization and scheduling, which conserves energy in unoccupied buildings and also intersession energy savings initiative, which adjusts setpoints whether buildings are occupied or unoccupied. Smart grid technology can seamlessly integrate these setpoints and shutdowns by recognizing the occupancy and existing demand of a building and adjusting accordingly. The necessary smart grid equipment could be installed through retro-commissioning.

Equipment Efficiency 4.0 Highlights

4.3 Energy Efficient IT Systems
4.4 Equipment Energy Awareness Programs

As part of the equipment energy awareness programs, smart meters and relays can be installed along with variable frequency drives, for example, to fume hoods to ensure optimization for these large energy consumers. Smart grid technologies can also be implemented to create a more energy efficient IT system, such as updating data centers.

Campus Energy Integration 5.0 Highlights

5.1 Comprehensive Energy Policy
5.2 Sustainability/Energy Outreach
5.5 Living Laboratories
5.6 Centennial Partner Engagement

This includes all sustainability outreach programs geared towards those involved with the entire campus community, be it students or staff, and also the development of a comprehensive energy policy. Ideally, smart grid would be included as an integral part of a new extensive energy policy for NC State University because it can be used directly for energy production and distribution. Also, smart grid technologies could be used as part of “living laboratories,” creating some very hands on education and recruitment opportunities related to infrastructure development and operation. As mentioned previously, smart grid would also support collaboration of Centennial partners, many of whom are engaged in the smart grid sector.

Appendix E: Centennial Campus Infrastructure Map

NC STATE UNIVERSITY

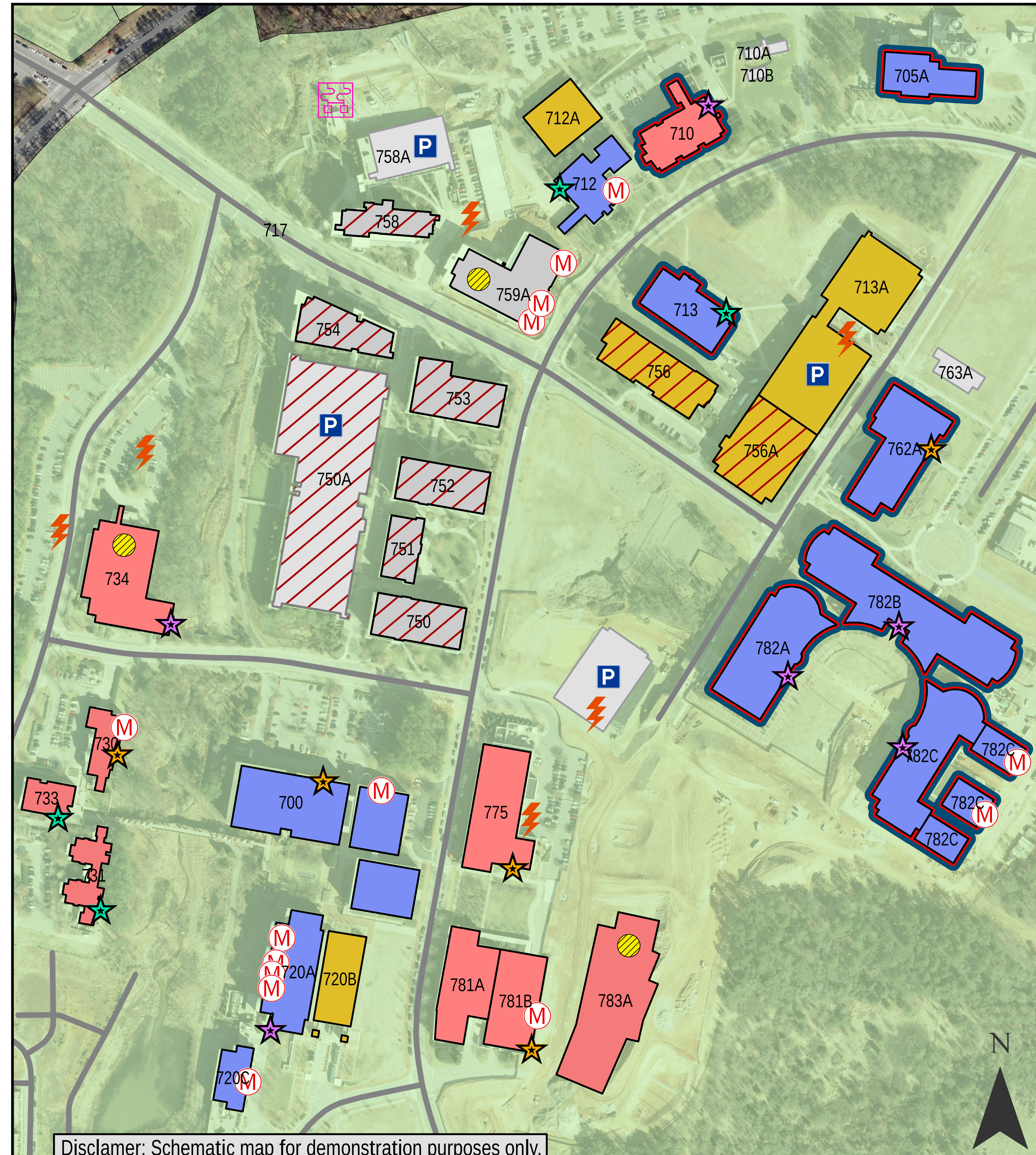
Centennial Campus Smart Grid Feasibility Study

Bldng. #	Name	Chilled Water	Steam	BAS View	BAS Control	Smart Meter	Built	Gross Sqft
700	College of Textiles			X	X	X	1990	307,163
705A	Centennial Campus Utility Plant	X	X	X			2004	44,978
710	Partners III	X	X	X	X		1999	63,760
712	Toxicology Building			X	X	X	2001	61,177
713	Partners III	X	X	X	X		2004	82,988
720A	Monteith Engineering Res. Center	X		X	X	X	1997	136,507
720C	Constructed Facilities Lab			X	X	X	1997	31,265
730	Research I			X	X	X	1988	41,254
731	Research II			X	X		1991	46,307
733	Research III			X	X		1994	25,326
734	Research IV			X	X		1996	81,030
759A	Keystone Science Center					X	2010	80,343
762A	BTEC Training & Education Center	X	X	X	X		2007	82,481
775	Partners I			X	X		1997	86,874
781A	Corporate Research I			X		X	1991	79,374
782A	Engineering Building I (EB1)	X	X	X	X		2004	158,849
782B	Engineering Building II (EB2)	X	X	X	X		2005	227,109
782C	Engineering Building III (EB3)	X	X			X	2010	253,859
783A	Hunt Library (under construction)	X	X	X		X	2012	253,028
786A	Dorothy and Roy Park Alumni Center	X	X	X	X	X	2006	58,313
790A	The Point – Chancellor's Residence					X	2011	8,957
792B	Friday Institute			X	X		2005	36,986

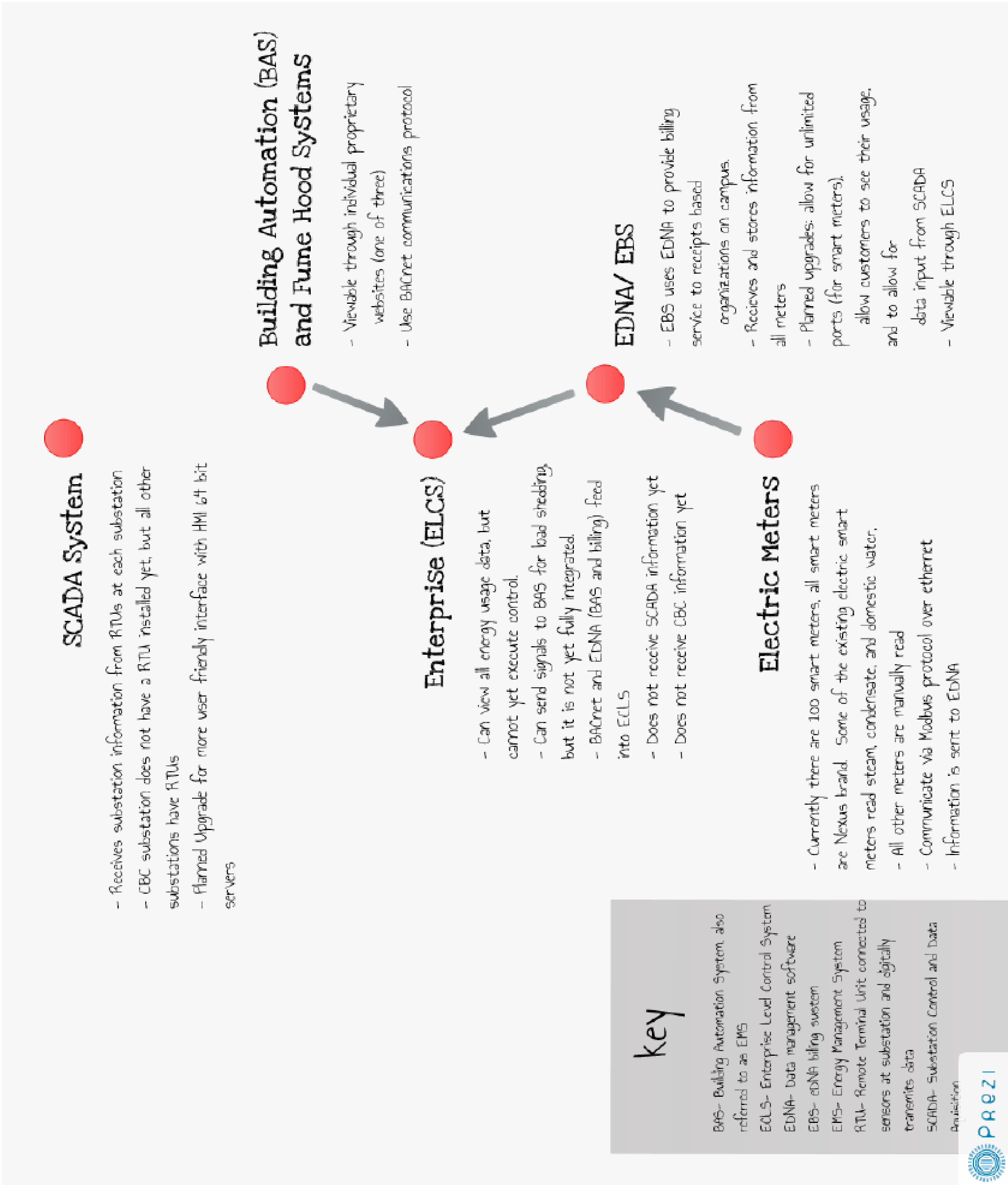
Note: All buildings have both Fiber and Wireless connections.

- Appropriated
- Self Liquidating
- Combination
- Non NCSU Buildings
- Steam
- Chilled Water
- Progress Energy

BAS
- Schneider Site Net
- Johnson Controls Metasys
- Schneider Inet 7
- Smart Meters
- Substation (15MW)
- EV Charging Site
- Solar



Appendix F: ELCS Diagram



Appendix G: Centennial Campus Energy Usage

One analysis tool is a tree map which compares energy usage by building to determine energy hogs and priority buildings. Figure 2 is a tree map that shows total kWh for one year, for buildings on campus. It shows that the four biggest electrical users on Centennial Campus are: Monteith Engineering Research Center, College of Textiles, Engineering Building I, and Engineering Building III.

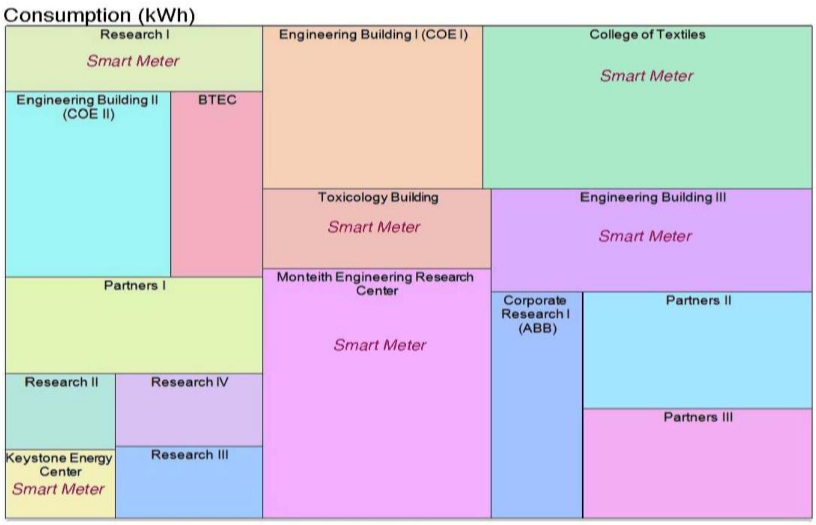


Figure 2 - Centennial Campus Electrical Consumption by Building Tree Map

Another metric which is useful in comparing buildings is kWh/gross square foot (GSF). Figure 3 compares centennial campus building using this metric. The four biggest electrical users per GSF are Research I, Research III, Partners II, and Montieth Engineering Research center.

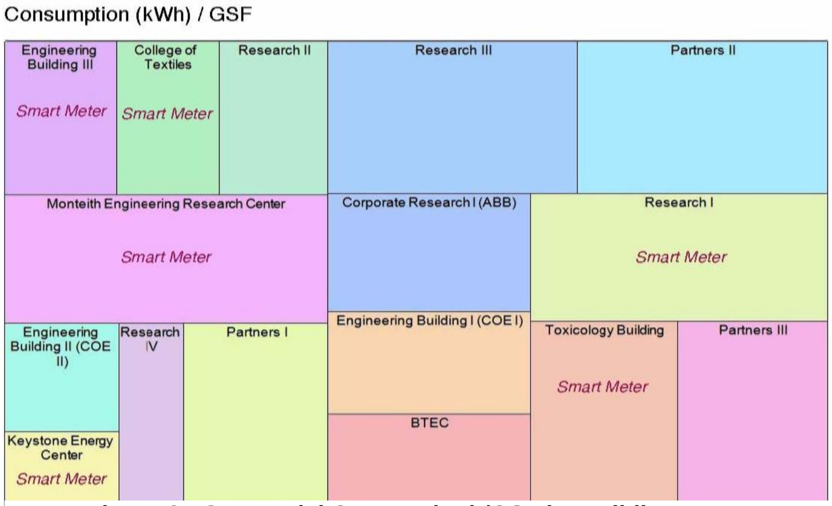


Figure 3 - Centennial Campus kWh/GSF by Building Tree Map

The location of Smart Meters on Centennial Campus is also indicated on the tree maps. Examinig these tree maps indicates that the next buildings which should receive smart meters, are: Engineering Building I, Research III, and Partners II, and that some initial smart grid efforts should focus on Montieth Engineering research center.

To get an understanding of the energy use at Centennial Campus the Team compared three charts, all generated using data collected by Progress Energy and made available through their website.

Figure 4 is a two year view of energy use generated using daily energy usage readings. From this chart the general pattern of energy usage emerges in a sinusoidal shape which is much higher in the winter than the summer, consistent with the fact that Centennial campus is cooled primarily by electricity, but is heated by natural gas fired boilers. This chart also shows the base load of campus to be 6,000 kWh per day, meaning that even in the winter on weekends when very few people are on campus, it still consumes 6,000 kWh. Smart grid offers ways to reduce this base load, for example, robust BAS can help campus operators ensure that during off times, such as nights, weekends, and holidays, everything expect essential systems are shut down.

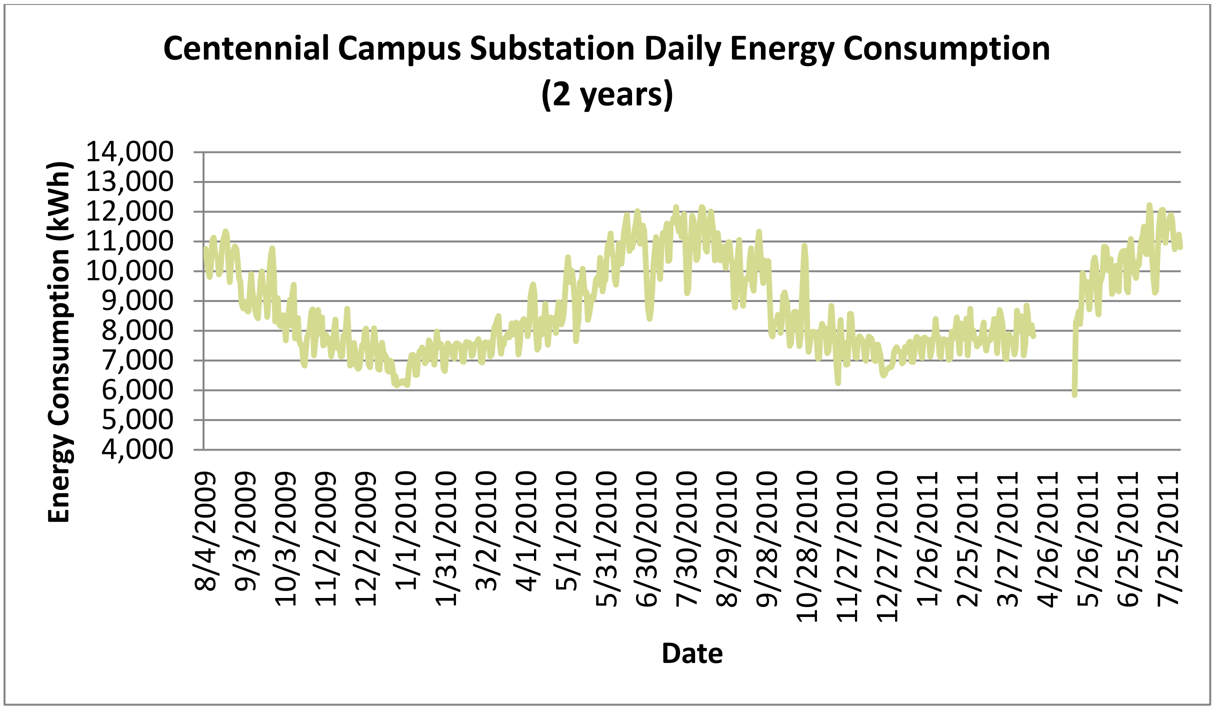


Figure 4 - Centennial Campus Two year Energy Consumption

Figure 5 and Figure 6 are monthly demand charts for July 2011 and January 2010 respectively. Demand charges make up almost half of the University's monthly electrical bill and are the area where smart grid has the potential to realize the most savings. The demand, or load, profile is dramatically different in the winter than in the summer, so it is necessary to consider them separately.

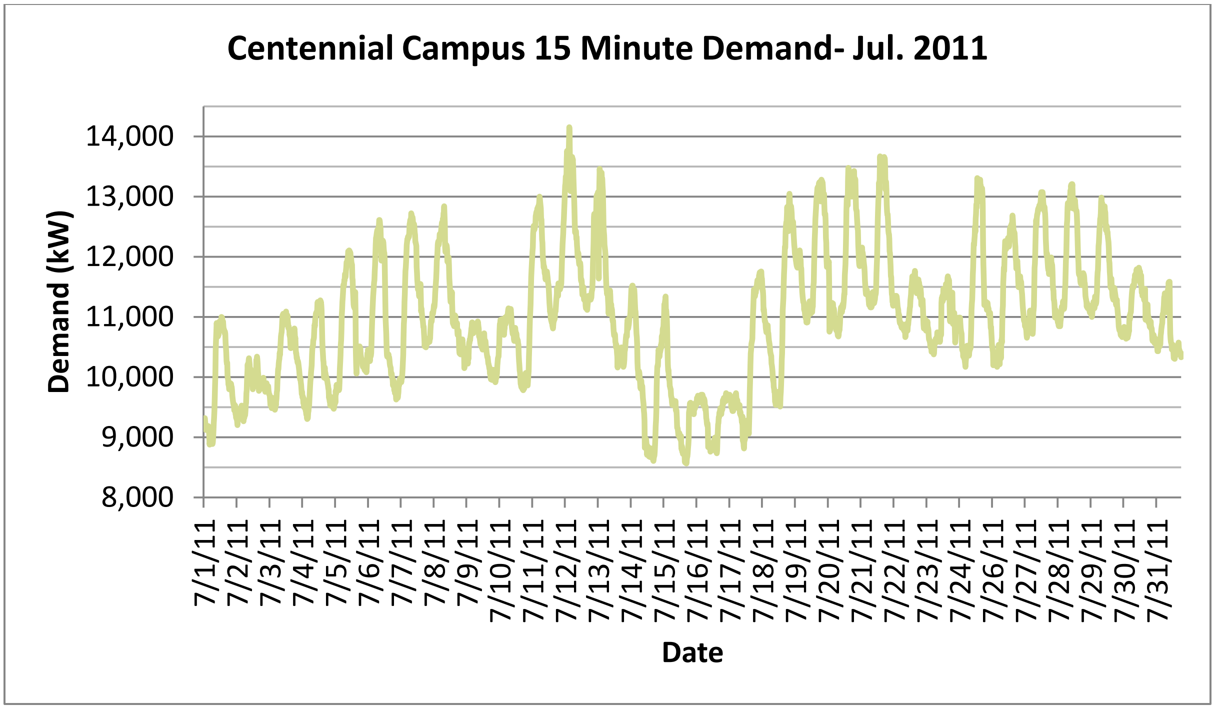


Figure 5 - Centennial Campus 15 Minute Demand, Jul. 2011

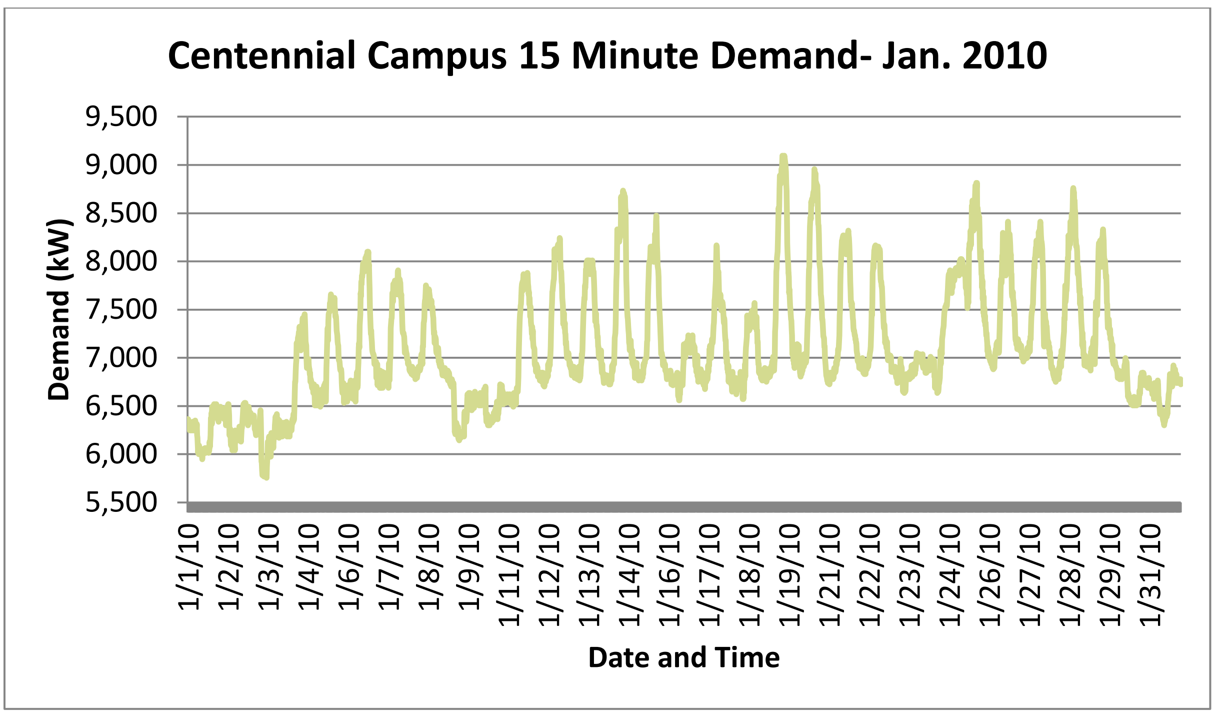


Figure 6 - Centennial Campus 15 Minute Demand, Jan. 2011

Appendix H: NC State Stakeholders Interviewed

Name	Title	Department	Phone	E-mail
Jack Colby	Asst. VC for Facilities Operations	Facilities	919.515.2967	jack_colby@ncsu.edu
Ralph Recchie	Director Real Estate	Real Estate Office	919.515.2018	ralph_recchie@ncsu.edu
Bill Winner	Professor	Env. Science & Natural Resources	919.515.5780	wewinner@ncsu.edu
Mike Harwood	Vice Chancellor for CC Development	Centennial Campus Development Office	919.513.7961	michael_harwood@ncsu.edu
Ewan Pritchard	Program Manager (ATEC) and Director of Industry and Innovation (FREEDM)	FREEDM Systems Center	919.513.4176	ewpritch@ncsu.edu
Paul McConocha	Energy Management Program Manager	Utilities & Engineering Services	919.513.3646	paul_mcconocha@ncsu.edu
Eric Dean	Power Systems Engineer	Power Systems	919.513.7178	ec_dean@ncsu.edu
Alan Daeke	Director for Utilities Services	Utilities & Engineering Services	919.513.5081	alan_daeke@ncsu.edu
Jeff Hightower	Director of Utilities Planning	Facilities Operations	919.513.0028	jeff_hightower@ncsu.edu
George Smith	Building Automation Engineer	Building Maintenance and Operations	919.513.8149	gismith@ncsu.edu
Dr. Marc Hoit	Chief Information Officer and VC Information Technology	Office of Information Technology	919.515.0141	Marc_Hoit@ncsu.edu

Appendix I: Stakeholder Smart Grid Concerns and Benefits

Stakeholder Concerns

Identified Universal Concerns:

- Project cost
- Project leadership
- Energy savings
- First steps in project implementation
- Interoperability of devices
- End goals of project

Other Concerns

- Alignment with the Sustainability Master Plan, Centennial Campus Master Plan, Strategic Energy Management Plan, and Climate Action Plan
- Actual benefits of project
- Responsibility for equipment
- Security and privacy
- Reliability risk of new technology
- Lack of education and knowledge

Stakeholder Benefits

Momentum

- Federal government support and national publicity
- Existing infrastructure on campus
- Access to FREEDM Systems Center industry members for support in development, design and funding
- Opportunity to be a first mover and keep NC State a technology leader
- Support and excitement of corporate partners
- Possibility of donations
- Flexibility in defining a pilot project
- Leverage FREEDM Systems Center Green Energy Hub, ABB Smart Grid Center of Excellence and Duke Energy Envision Center

Control & Savings

- Promise of energy savings
- Increased energy independence
- Load control
- Better control of system
- More data

Students

- Potential of drawing more students, partners and visitors to campus
- Students want NC State to be a leader in sustainability
- Allows for research opportunities in "real world" scenarios
- Student participation

Appendix J: Legislative and Regulatory Status

Federal Level

Current Legislation

The federal government has enacted several pieces of legislation that support the development, study and implementation of smart grid technologies. Below are four key pieces of legislation with notable smart grid highlights.

- The Energy Independence and Security Act (EISA) of 2007 included a statement of policy on the modernization of the electricity grid, development of a smart grid advisory committee and smart grid task force, smart grid technology research, development, and demonstration, federal matching funds among other items.
- The American Recovery and Reinvestment Act (ARRA) of 2009 provided financial support to smart grid regional initiatives, establishment of a smart grid information clearing house, increased federal reimbursement match for smart grid investments and rewards innovation and early adaptation.
- The Energy and Water Development and Related Agencies Appropriations Act, 2010 includes the purchase of plant and capital equipment, development of a national cyber security organization, and financial support for further smart grid projects.
- The FERC Smart Grid Policy provides guidance for the development of a national smart grid system that focuses on key standards to achieve interoperability and functionality.

http://www.sgiclearinghouse.org/Legislation

Pending Legislation

In 2009, FERC adopted a smart grid policy with rules about recovering costs through rate increases.

The Storage Technology for Renewable and Green Energy Act of 2011 (STORAGE Act) proposes a 20% investment tax credit for large scale electrical grid storage systems and 30% tax credit for individuals and businesses to encourage more large-scale electric storage projects.
http://www.smartgridnews.com/artman/publish/Technologies_Storage/U-S-could-lead-the-charge-in-grid-storage-if-Congress-plays-along-4254.html

State Level

HB 872, a pending NC smart grid bill, would provide a job creation tax credit for researching modern electric grid technologies. Qualifying expenses are full-time employment expenses, but the bill also allows for 20% of the tax credit to be applied to a higher education institution working in collaboration with a tax paying entity. At the time of this writing, this bill is in the Finance Committee.

Smart grid companies have come to North Carolina and started businesses here without tax credits, but this bill could help retain these companies in the state in the future. Smart grid and renewable companies sometimes move headquarters and jobs to states with better incentives. In 2011, the demand response company Consert moved to San Antonio,TX, a deregulated utility market, to work with the local utility showcasing smart grid implementation and will create more than 150 new jobs in the city over the next few years.

In a regulated market, there is limited ability to recover costs by selling distributed energy. Current NC law only allows a utility to sell power to customers and this limits smart grid activities. NCSEA is advocating for the ability for market competition via direct sales of renewable energy. The clean energy project size could be limited to 2 megawatts or up to 120 percent of the customer's annual peak load. The project would be need to located on the customer’s property.

The House Third Party Sale of Electricity Committee will examine these and other issues in the early months of 2012 and can make recommendations for legislative action by the full General Assembly during the 2012 short session, which begins in May.

Appendix K: Utility System Communication Protocols

Modbus (RTU & TCP/IP)

The Modbus RTU communication protocol was introduced by Schneider Electric, then Modicon, in 1979. Modbus is widely used because it is openly published and free of charge. Modbus is compatible with many manufactures and therefore promotes interoperability of devices with in a system.

Modbus TCP/IP (Transmission Control Protocol/Internet Protocol) was developed in 1999 in order to allow Modbus protocol to be used communicate via the Internet and Ethernet. Some benefits of this are that the TCP/IP protocol takes advantage of an existing infrastructure, it also allows the data to be accessed by an authorized person from any computer with an Internet connection.

Some down falls of the Modbus TCP/IP protocol is that its performance depends on the network and hardware. If it is run over the Internet than responses times cannot exceed typical Internet response times on a given network.

DNP 3.0

DNP is a SCADA protocol that was created in 1990 and updated in 1993 to become DNP3 designed to optimize the transition of data and control commands. DNP3 defines the protocol stack, integrates status monitoring into IED's, assigns priorities to data items and supports time synchronization, among other capabilities.

DNP3 is a protocol that utilizes a simplified 4-layer setup proposed by the International Electrotechnical Commission (IEC), as opposed to the standard 7-layer protocol utilized by the Open System Connection (OSC), in order to more easily integrate basic implementations. These four layers are the physical layer, data link layer, pseudo-transport layer, and the application layer.[22] Although DNP3 is an open protocol that can be accessed for free, there are continued challenges with the protocol, the most significant of which are interoperability between IED's and other protocols and its ability to adapt as future technologies emerge.

IEC 61850

IEC 61850 is a software-based substation automation system and unifying global communication standard that both IEC and ANSI (American National Standards Institute) support. It allows for the integration of the DNP3 protocol and others in one system.

IEC 61850 is broadly recognized as an international standard for power system communication and its related standards have been adopted for use in substations, hydro power plants, wind energy networks and distributed energy resources, due mostly to its superior interoperability capacity. This protocol, with ever improving enhancements on security and communications, is perfectly suited for smart grid developments across the world.

[22] http://www.trianglemicroworks.com/documents/DNP3_Overview.pdf

The key elements of IEC 61850, initially published in 2004, are interoperability, global architecture and future-proofing. Interoperability in the standard allows for IEDs from different suppliers to easily integrate different protocols without human interaction or costly converters. Global architecture means that the standard can interpret and support a multitude of functions from utilities around the world and support various system architectures. To avoid stifling innovation and further the creation of potentially cost-saving technologies, IEC 61850 has been developed to handle the integration of new components and keep costs low.

IEC 61850 includes a number of Ethernet-based communications protocols, along with standardized naming and object modeling. It also includes an XML-based substation configuration language (SCL), which allows for the exchange of configuration data between tools. SCL is used to design, document, and exchange both device level and substation level configurations. IEC 61850 is a more comprehensive approach than previous efforts in substation integration and uses advanced communications techniques to address data management and simplify integration of applications.[23] It has been shown that IEC 61850 provides a unified approach to system engineering and can reduce overall costs. IEC 61850 also supports the Generic Object Oriented Substation Events (GOOSE) concept, which allows vast reductions in inter-device wiring and the support of the copper-free substation. In fact, GOOSE is often touted as the major outcome of the IEC 61850 standard.[24]

DNP3 is designed to focus on inexpensive endpoints and low-bandwidth communication channels, while IEC 61850 is designed for high-bandwidth communication channels with a richer, wider range of features. Both protocols must accommodate for increasingly loud calls for flexibility and interoperability. IEC 61850 is already the leading protocol in Europe and India, and experts predict that it probably will win over North America, as well.[25]

Appendix L: Project Goals

1. **Collaboration**
    - Collaboration between different university departments (i.e. Utilities and engineering, FREEDM, OIT, Academics) to achieve smart grid goals
    - Collaborate with other smart grid entities and universities
    - Collaboration with FREEDM Green Energy Hub Micro grid
    - Collaboration with City of Raleigh smart grid project

2. **Educated utility decision making**
    - Anticipate and respond to changes in utility pricing structures
    - Increase power purchasing options
    - Optimize the NC State Co-generation plant
    - Support the development of an Enterprise Billing system at NC State.

3. **Align with existing goals**
    - Support NC State plans

[23] http://www.kalkitech.com/offerings/solutions-iec_61850_offerings-iec_61850__overview/
[24] http://www.elp.com/index/display/article-display/361183/articles/utility-automation-engineering-td/volume-14/issue-5/features/dnp-vs-iec-skirmish-in-the-substation.html
[25] http://www.elp.com/index/display/article-display/361183/articles/utility-automation-engineering-td/volume-14/issue-5/features/dnp-vs-iec-skirmish-in-the-substation.html

- *Sustainability Master Plan*
  - *Strategic Energy Management Plan*
  - *Climate Action Plan*
  - *Centennial Campus Development Plan*
- Create energy saving
  - Support the intersession setback program
- Reduce Greenhouse gas emissions and campus carbon foot print
- Reduce overall power bills
  - Reduce demand costs through demand control

4. Development and Leasing

- Increase growth on centennial campus
- Encourage development

5. Distributive Generation and Storage

- Allow for easy integration of additional renewable power sources on campus
- Create the ability to support Plug in electric vehicle infrastructure
- Increase energy storage and generation capacity on campus

6. Data Acquisition and Control

- Increased reliability of data
- Robust understanding and control of campus energy use
- Smart meters on all campus buildings
  - Sub meter tenant space where appropriate
- Fully automated and integrated BAS

7. Funding

- Secure grant money
- Secure equipment donations

8. Academics and Research

- Develop new certificate and degree programs relating to smart grid
- Support campus as a classroom
- Create and inform research opportunities and projects

9. Outreach

- Encourage consumer change
- Educate students, faculty, and staff about:
  - Their energy use
  - Smart grid
  - Energy conservation strategies
- Promote NCSU as a leader in new technology

10. Increased reliability of distribution system

11. Make the best use of the current infrastructure

Appendix M: Advisory Board Roles & Responsibilities

[DRAFT]

NC State University Smart Grid
Advisory Board Roles & Responsibilities

Members:

- Key NC State University Stakeholders and decision makers. (Facilities Operations, Centennial Campus, IT, Engineering, FREEDM Systems Center)

General Roles & Responsibilities:

Objective:
The advisory board will give guidance and develop recommendations on the implementation of Smart Grid on the NC State University campus.

General Responsibilities:

- Governance
  - Oversee the development of a plan for a Smart Grid concept on campus in accordance with the campus master Planning Process
  - Evaluate and implement the approved plan
  - Formulate agreed upon priorities and vision
  - Review and monitor success of the implementation plan
  - Develop subcommittees as needed
- Leadership
  - In partnership with Office of Research, Innovation, and Economic Development and Office of Finance & Business, guide the mission and direction of a Smart Grid project in relation to NC State University, Strategic Sustainability Plan Centennial Campus Master Plan, Strategic Energy Management Plan, and Climate Action Plan
  - Assist with strategic planning and decision making
- Stewardship
  - Promote Smart Grid project and awareness to the campus community (general communications, formal presentations)
  - Be an advocate for the project
- Accountability
  - Attend board meetings, distribute meeting minutes and agendas, and other documentation as necessary
  - Keep stakeholders informed of progress
- Budgeting and Funding
  - Assist in developing a comprehensive and practical budget for the project
  - Look for various avenues of funding (departmental budgets, grants, donations, etc)
  - Support grant writing and reporting efforts
- Meeting Frequency
  - Bi-monthly

Appendix N: Advisory Board Draft Invitation Letter

Dear [**Recipient Name**]:

Thank you for your interest in becoming part of NC State University's Smart Grid Advisory Board. Your knowledge, expertise, and presence are extremely valuable.

The objectives of the board are:

1. Develop and guide a campus-wide smart grid vision
2. Assist with strategic planning and ensure alignment with the Strategic Sustainability Plan, Strategic Energy Management Plan, Climate Action Plan, and other relevant campus master plans
3. Assist in developing a budget and identifying funding opportunities
4. Oversee, monitor, and communicate smart grid deployments on campus

As identified by the Centennial Campus Smart Grid Feasibility Study team, NC State University is currently using elements of smart grid and a more unified deployment can support plans already in place such as the Strategic Sustainability Plan, Strategic Energy Management Plan and the Climate Action Plan. Momentum for smart grid deployment is growing nationally and NC State University is continuously approached by businesses, students, staff and government agencies to establish smart grid projects. The NC State University Smart Grid Advisory Board will create a cohesive vision, set priorities, and establish guidelines to direct the growth and adoption of smart grid projects.

Please view the attached draft roles and responsibilities document for details on expectations of advisory board members. At the first meeting of the advisory board, this roles and responsibilities document will be edited by the Board and a presentation defining the current status of smart grid on NC State will be given.

Please notify us of your availability for the initial Smart Grid Advisory Board Meeting.

Sincerely,

[**Your Name**]
[**Title**]

Enclosures: Draft Smart Grid Advisory Board Roles and Responsibilities, Smart Grid Advisory Board Members (Invited), Centennial Campus Smart Grid Feasibility Study Presentation

Appendix O: Preliminary Advisory Board Member List

First Name	Last Name	Title	Department	Phone	e-mail
Forrest	Allen	Associate Director/SAAO	University Development	919.513.0484	forrest_allen@ncsu.edu
Alan	Daeke	Director	Utilities & Engineering Services	919.513.5081	alan_daeke@ncsu.edu
Mike	Harwood	Associate Vice Chancellor	Centennial Campus Development	919.513.7961	michael_harwood@ncsu.edu
Jeff	Hightower	Director Utility Infrastructure Planning	Facilities-Directors Office	919.513.0028	jeff_hightower@ncsu.edu
Lisa	Johnson	University Architect	University Architects Office	919.515.6258	lisa_johnson@ncsu.edu
Dennis	Kekas	Assoc. Vice Chancellor	College of Engineering - Dean's Office	919.515.7036	kekas@ncsu.edu
Kevin	MacNaughton	Assoc. Vice Chancellor	Facilities Division	919.515.2732	kevin_macnaughton@ncsu.edu
Paul	McConocha	Energy Program Manager	Energy Management	919.513.3646	paul_mcconocha@ncsu.edu
Ewan	Pritchard	Director, Industry, Collaboration and Innovation	FREEDM Systems Center	919.515.2194	egpritch@ncsu.edu
George	Smith	Mechanical Engr. Control Shop Supervisor	Bldg. Maintenance & Operations-Central Shops	919.513.8149	gismith@ncsu.edu
Bill	Winner	Professor	Environmental Science & Natural Resources	919.515.5780	wewinner@ncsu.edu
Representative			Office of Information Technology		
Research representative			College of Engineering		

Table 4-Preliminary Advisory Board Members

Appendix P: Suggested Smart Grid Collaborators

First Name	Last Name	Title	Department/Company/Organization	Phone	E-mail
NC State University					
Forrest	Allen	Associate Director/SAAO	University Development	919.513.0484	forrest_allen@ncsu.edu
Allen	Boyette	Director	Building Maintenance & Operation	919.513.0181	allen_boyette@ncsu.edu
Jack	Colby	Asst. Vice Chancellor for Facilities Operations	Facilities - Directors Office	919.515.2967	jack_colby@ncsu.edu
Alan	Daeke	Director	Utilities & Engineering Services	919.513.5081	alan_daeke@ncsu.edu
Bill	Davis	Architect, Project Manager	Capital Project Management	919.513.7492	bill_davis@ncsu.edu
Eric	Dean	Power Systems Engineer	Power Systems	919.513.7178	ec_dean@ncsu.edu
Tracy	Dixon	Director	University Sustainability Office	919.513.0211	tracy_dixon@ncsu.edu
Pete	Fraccaroli	Engineer	University Housing-Facilities	919.830.0064	pete_fraccaroli@ncsu.edu
Wade	Fulgham	Assistant Director, Economic Development Partnership	Office of Research, Innovation, and Economic Development	919.513.2710	wade_fulghum@ncsu.edu
Mike	Harwood	Associate Vice Chancellor	Centennial Campus Development	919.513.7961	michael_harwood@ncsu.edu
Jeff	Hightower	Director Utility Infrastructure Planning	Facilities-Directors Office	919.513.0028	jeff_hightower@ncsu.edu
Marc	Hoit	Vice Chancellor	Office of Information Technology	919.515.0141	marc_hoit@ncsu.edu

Alex	Huang	Executive Director	FREEDM Systems Center	919.513.7387	aqhuang@ncsu.edu
Lisa	Johnson	University Architect	University Architects Office	919.515.6258	lisa_johnson@ncsu.edu
Brian	Jones	Project Manager - Architect	Capital Project Management	919.515.8005	brian_jones@ncsu.edu
Dennis	Kekas	Assoc. Vice Chancellor	College of Engineering - Dean's Office	919.515.7036	kekas@ncsu.edu
Kevin	MacNaughton	Assoc. Vice Chancellor	Facilities Division	919.515.2732	kevin_macnaughton@ncsu.edu
Paul	McConocha	Energy Program Manager	Energy Management	919.513.3646	paul_mcconocha@ncsu.edu
Barry	Olson	Director of Business Administration	University Housing - AVC Operations	919.515.4402	barry_olson@ncsu.edu
Ewan	Pritchard	Director, Industry, Collaboration and Innovation	FREEDM Systems Center	919.515.2194	egpritch@ncsu.edu
Ralph	Recchie	Director Real Estate	Real Estate Office	919.515.2018	ralph_recchie@ncsu.edu
George	Smith	Mechanical Engr. Control Shop Supervisor	Bldg. Maintenance & Operations-Central Shops	919.513.8149	gismith@ncsu.edu
Bill	Winner	Professor	Environmental Science & Natural Resources	919.515.5780	wewinner@ncsu.edu
Industry Collaborators					
Bobby	Compton		Eaton	919.878.2326	BobbyLCompton@eaton.com
David	Davidson	Manager, Business Development and Solutions	Eaton	803.316.5384	davidldavidson@eaton.com
Paul	Gregory		Green Energy Corporation	919.967.1130	pcgregory@greenenergycorp.com

Steve	Kunsman	VP & General Manager, Substation Automation	ABB, Inc	610.392.8371	steven.a.kunsman@us.abb.com
Tom	Underhill		Progress Energy		
Vythahavya	Vadlamani	Lead Protection & Control Engineer	ABB, Inc	919.856.3845	vythahavya.vadlamani@us.abb.com
Carl	Wilkins		Quanta Technologies	919.334.3093	cwilkins@quanta-technology.com
Hank	Wright	PE	McKim & Creed	919.233.8091	hwright@mckimcreed.com
Other Universities					
See Appendix C for a complete list of university contacts					
Other Contacts					
Jeff	Barghout	Electric Transportation Director	Advanced Energy	919.857.9006	jbarghout@advancedenergy.org
Bo	Carson	Information Services	Research Triangle Regional Partnership	919.830.7372	bcarson@researchtriangle.org
Michael	Haley	Project Manager	Wake County Economic Development	919.664.7042	mhaley@raleighchamber.org
Robert	Hinson	Renewable Energy Coordinator/Project Manager	City of Raleigh	919.996.3840	Robert.Hinson@raleighnc.gov
Ivan	Urlaub	Executive Director	NC Sustainable Energy Assocation	919.832.7601	ivan@energync.org
Mike	Ligett		Former Progress Energy Staff		mike.ligett@gmail.com
Lee Ann	Nance	Senior VP Strategic Iniatives	Research Triangle Regional Partnership	919.830.7372	lnance@researchtriangle.org
Julian	Prosser	Assistant City Manager	City of Raleigh	919.996.4282	julian.prosser@ci.raleigh.nc.us

Julie	Robinson	Director of Government Affairs	NC Sustainable Energy Association	919.832.7601	julie@energync.org
Chuck	Sathrum	Smart Grid Specialist	NC Energy Office	919.896.1465	csathrum@nccommerce.com
James	Sauls	Director	Raleigh Chamber of Commerce	919.664.7049	jsauls@raleighchamber.org
Peter	Squire	Consultant	Formerly of NC State Energy Management	919.302.2376	psquire07@gmail.com
Garrett	Wyckoff, Jr.	Economic Development Representative	NC Department of Commerce	919.733.1437	qwyckoff@nccommerce.com