GREENHOUSE GAS EMISSION
REDUCTION STUDY

Prepared for:

EAST TENNESSEE STATE UNIVERSITY
JOHNSON CITY, TN

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EXECUTIVE SUMMARY

URS Corporation was requested by East Tennessee State University (ETSU) to assist with the campus Master Plan's commitment to reduce greenhouse gas emissions 17% by 2020, based on 2005 values. The University is also working on reducing pollution by addressing transportation and fleet issues, but the objective of this study is to focus on decreasing emissions by reducing facility energy consumption. The product is this report which examines the current energy use on campus and identifies several potential energy conservation projects and, when applicable, indicates an opinion of estimated implementation costs and expected savings. A portion of the tuition paid by every student at ETSU is earmarked to be used specifically for making the University "greener". This study is being funded by this account, therefore it is intended to emphasize concepts which will be visible to the students, have attractive payback periods, and require capital investments within the means of this fund, specifically below $300,000. Projects which would increase current operations costs were not to be analyzed in depth. Based on this criteria, projects such as green roofs were not analyzed in depth because they typically require a large investment, have a very small effect on energy usage and greenhouse gas emissions (energy usage may actually increase if additional lighting and irrigation pumping is considered), and operating and maintenance costs always increase. Green roofs are generally more beneficial in large cities where they help decrease the heat-island effect and also provide a natural environment for occupants which doesn't exist in the surrounding area.

ETSU has completed or is in the process of implementing several energy conservation projects which are described in more detail below. An analysis of the energy usage and costs for the Main Campus over the last five fiscal years indicates that ETSU is performing very well relative to other universities across the country, but total energy usage has still increased steadily and energy use per-square-foot also appears to be increasing.

Following are brief descriptions and conclusions for several proposed energy conservation projects. Details of the analysis of each can be found in the *Proposed Projects* section below. The first two are highly recommended because they meet all of the Green Committee's requests for involving the students, reducing emissions, good economics, and relatively low estimated implementation costs. The remaining projects would all still reduce energy usage and/or greenhouse gas emissions, but are either not visible to the students, have long paybacks, increase operational costs and/or are outside of the funding limits.

Recommended Projects

1. Computer Power Management:
   Implement a program to activate power management features on all University and student computers to reduce direct electrical usage as well as space cooling energy. The estimated cost may be up to $150,000 depending on the number of computers and method used. The estimated potential savings are up to $341,000 per year. Estimated emission reduction potential is up to 5,540 metric tons (MT) per year or 11.7% of 2005 levels.

2.   Student Housing Utility Metering:
Install digital meters on all utilities at housing facilities and initiate competition among students to reduce usage. The estimated cost is up to $240,000 which should result in estimated savings of up to $137,000 per year. The potential emission reduction is up to 1,140 MT per year or 2.5% of 2005 levels.

Attractive Projects Worth Additional Consideration

3.   Daylight Optimization Lighting Controls:
Install light level and occupancy sensors in areas with extensive windows to reduce electric lighting when natural light and/or occupancy allows. The estimated cost is typically $200-$250 per light fixture and the payback is expected to be 10 years or more. A more detailed study is required to accurately model and simulate HVAC savings and greenhouse gas emission reductions.

4.   Occupancy Sensor Control of Lighting and HVAC Setback:
Install occupancy sensors in intermittently occupied spaces to automatically turn off lights and reduce HVAC usage when not required. Costs will vary greatly depending on the space schedule and HVAC system type, but typically paybacks are on the order of 10-15 years. Additional analysis and calculations are required to accurately determine HVAC savings and greenhouse gas emission reductions.

5.   Retro-Commissioning:
Implement a retro-commissioning program to verify that existing systems, specifically older HVAC systems, are performing as intended. Several specific problems with chilled water systems would be prime candidates. Costs, savings, paybacks and emission reductions would vary extensively, but would be estimated by the commissioning team on a system-by-system or building-by-building basis.

6.   Light Emitting Diode (LED) Outdoor Lighting:
Replace existing metal-halide parking and pedestrian lighting with LED lighting and/or require LED for all future outdoor lighting projects. In general, LED lighting has many benefits, including reduced energy and maintenance costs, but right now high installation costs are driving the payback period up to at least 15 years. LED technology is improving very rapidly so this concept should be reevaluated in the future.

Renewable Energy Projects

7. <u>Wind Power:</u>
Install turbine(s) to provide electricity from wind. This kind of project would be very visible to students, but in general it does not appear to meet the financial needs of the Green Committee. A small installation should provide a financial payback in 18-20 years, but the greenhouse gas reduction potential relative to the whole campus would be less than 1%.

8. <u>Biomass Boilers:</u>
Install a boiler which burns a renewable fuel source such as wood or farm waste instead of fossil fuels. This type of project would not actually reduce greenhouse gas emissions, they would just be from a "renewable" source instead of fossil fuels. Fuel and operational costs would probably increase, meaning there would be no economic payback.

9. <u>Solar Energy – Photovoltaics:</u>
Install a solar array to provide electricity from sunlight. A small array would be very visible to the students, depending on the location, and should have an economic payback of about 30 years. Electricity usage and corresponding emissions could be reduced approximately 0.2% from 2005 values.

10. <u>Solar Energy – Domestic Water Heating:</u>
Install a solar water heating system which will pre-heat domestic hot water utilizing sunlight. New solar water heating panels could be made visible to the students but have a very long payback period of approximately 190 years. Greenhouse gas reductions are so small they should be considered negligible.

OVERVIEW

East Tennessee State University was founded in 1911 as the East Tennessee Normal School, and today consists of over three-million gross square feet of floor space and has an enrollment exceeding 15,000. This report focused on the Main Campus and does not include the Veterans Affairs Medical Center campus or the facilities located in Kingsport, Bristol, or Elizabethton. The Main Campus includes a large variety of facilities, including classroom, laboratory, athletic, administrative, service/support, retail, medical, and housing spaces. The buildings range in age from 1 to 100 years old, with most of the larger buildings being built in the 1960s and 1970s.

This report is based upon URS' meeting with key members of the University Green Committee, which includes students, faculty, and staff, a review of historical energy usage documentation, and also our observations of the existing central cooling and heating plants as well as several representative buildings. These observations included input from engineering and maintenance personnel but were limited to a brief visual survey of existing conditions and are not to be considered a statement of the exact conditions or remaining life and/or verification of required repairs of the facilities inspected.

ETSU has successfully implemented several very effective energy conservation projects over the last few years. Approximately 95% of the indoor lighting has been upgraded to more efficient fixtures which not only reduce the electricity required for lighting but also reduce the heat produced by the fixtures thereby reducing the amount of air-conditioning required. Single-pane windows have been upgraded to double-pane in most of the older facilities. Many HVAC retrofit projects have been completed and more are in progress or planned which reduce energy usage by providing more efficient systems. The University has been gradually replacing the HVAC controls across campus with new digital controls that are connected to a central system. This will provide maintenance and engineering personnel the ability to recognize and diagnose energy wasting problems more effectively. Looking towards the future, ETSU has adopted the *Sustainable Design Guidelines* published by the State of Tennessee as a requirement for all new buildings in an effort to make all upcoming construction on campus as energy efficient as feasible.

Central Heating Plant: Heat is provided for most of the large buildings by a central boiler plant and underground steam distribution piping. The central plant consists of two gas-fired Cleaver-Brooks boilers, one with 62,000 and the other with 33,000 lb/hr capacity, and three Babcock-Wilcox coal-fired boilers with approximately 30,000 lb/hr capacity each. The coal boilers have recently been equipped with new controls. The smaller gas boiler is equipped with a stack economizer which allows hot water to be made from the hot combustion gases. The order that the boilers are scheduled on is prioritized by fuel costs, so typically the coal boilers are used to handle the base heating load and a gas boiler is modulated to meet the exact steam requirements.

Saturated steam is distributed to the campus at approximately 95 psi, primarily through direct-buried pre-fabricated insulated piping and through tunnels in some areas. Each building typically utilizes a heat exchanger to produce heating hot water which is then circulated through the individual buildings by

electric pumps. Condensate is typically pumped back to the boiler plant from the buildings by packaged duplex electric condensate pumps.

Central Cooling Plant: A central chiller plant provides cooling water for the majority of buildings on campus. The plant consists of four water-cooled electric chillers, one Trane 2000 ton centrifugal machine, two Trane 1000 ton centrifugal machines, and a 1000 ton dual-compressor McQuay screw machine that primarily serves as an emergency back-up. All of the chillers are between 6 and 10 years old. Grade mounted cooling towers with variable speed fans provide condenser water for the chillers. There are two 4-cell towers that are original from 1974 and two newer, smaller 2-cell towers. The University is currently in the process of installing new horizontal split-case condenser water pumps.

Chilled water is circulated to the campus at approximately 45° F, primarily through direct-buried pre-fabricated insulated piping and through tunnels in some areas. The buildings are typically equipped with electric pumps which circulate the water directly to air-handling units and/or fan-coil units for space cooling. Currently the chilled water distribution system is operating at a much higher pressure than would typically be expected in order to maintain circulation in a few buildings.

Individual Building HVAC: Most of the buildings on campus utilize either variable-air-volume (VAV) air-handling units with terminal boxes or 4-pipe fan-coil units and dedicated outside air systems to provide ventilation and control space temperature and humidity. Some of the older buildings still utilize inefficient HVAC systems, most notably the Administration Building which is heated and cooled by a dual-duct system. When the existing HVAC systems in each building require replacement, the University has been making a concerted effort to upgrade to energy efficient systems and to provide sophisticated digital controls that allow for central monitoring and adjustment. New dedicated outside air systems are provided with heat recovery capabilities which allow energy to be recovered from exhaust or relief air thereby reducing the heating or cooling required to condition the outside air. High-efficiency variable refrigerant flow systems have also been installed in several buildings. New air handling units and exhaust fans and chilled and hot water pumps are typically equipped with variable speed drives (VFDs) and digital sensors which allow the electric motors on these machines to only work as hard as necessary rather than operating at a constant full speed.

Lighting: Indoor lighting is primarily accomplished with ceiling mounted fluorescent tube fixtures. As indicated above, nearly all of the existing lighting has been upgraded from T12 lamps with magnetic ballasts to more efficient T8s with electronic ballasts. The upgraded fixtures require less electricity to provide the same amount of light and also give off less heat which reduces the amount of air-conditioning required. The new lights may increase the amount of space heating required, but typically this only affects perimeter spaces and is still significantly offset by the other savings. Notable exceptions to the lighting upgrades include the chiller plant, Brooks Hall, and the Center for Physical Activity which still utilize inefficient metal-halide or high-pressure-sodium fixtures. Outdoor lighting is predominantly metal-halide.

Utility Metering: The buildings on campus are not typically individually metered for electricity, chilled water, steam, gas, or domestic water usage, however, these meters have been installed in a few facilities and an ongoing project is installing them in 13 more in the near future.

HVAC Controls: Almost all of the buildings on campus are equipped with direct digital controls (DDC) and are tied into a central Johnson Controls Metasys system which allows for monitoring and limited control from a central location. Typically the controls are upgraded in each building as the HVAC systems are upgraded. The central chiller plant is controlled by a Tec-Worx digital system which is also tied into the Metasys system.

RECENT ENERGY USAGE

The tables and graphs on the following pages summarize the utility usage and costs for the Main Campus over the last five fiscal years, including electricity, natural gas, coal, water and sewer. Some fuel oil was also consumed by the University, but it was generally less than 0.5% of the total usage so it is not included. There are energy consumption and greenhouse gas emission factors related to water and sewer services, but they are typically unavoidable and difficult to estimate so the graphs only include the three primary energy components of the utilities. Electrical demand charges have remained relatively constant over the last five years so they are directly added to the electrical consumption charges and represented as a combined rate. All of the rates are weighted averages over each year.

The total energy consumption has increased gradually over the five year period by a total of about 27%. During that time, electricity usage has remained relatively constant, varying by only about 8%, while the rate increased by 34% from '06 to '09 then dropped by about 10% over the past year. The relatively flat electrical usage reflects the University's efforts to reduce consumption being balanced out by adding facilities such as Governor's Hall and Centennial Hall. In general the total energy used for heating has gradually increased, accounting for almost all of the 27% total energy increase. Coal and natural gas usage and rates have varied widely over the period analyzed. Either can be used to generate the steam needed for campus heating, so the consumption was adjusted by the University to utilize the best rates available. The natural gas rate has been decreasing gradually but steadily over the last five years. Coal rates have been relatively steady, other than a significant jump in '08-'09 after which it returned to near its typical value. Typically coal has been less expensive than gas, other than in '08-'09 when they were nearly equal.

For the latest fiscal year, 2009-2010, the campus *energy use intensity* (EUI), also sometimes called *energy use index*, was 107 MMBtu/sq. ft./yr. The average EUI value for a typical university is around 150. This indicates that ETSU is performing very well in its energy conservation efforts relative to its peers. It also indicates that there is probably less potential for large energy savings.

2005-2006 Annual Utility Consumption							
	Usage		Normalized MMBtu	Cost	Rate		Normalized Rate $/MMBtu
	qty	unit					
Electricity	46,454,990.0	kWh	158,504.4	$2,837,906	0.061	$/kWh	$17.90
Coal	4,441.0	tons	88,820.0	$364,374	82.048	$/tons	$4.10
Natural Gas	35,974.0	MCF	37,197.1	$498,148	13.847	$/MCF	$13.39
Sewer	98,526.0	kgal		$189,536	1.924	$/kgal	-
Water	116,936.0	kgal	-	$190,139	1.626	$/kgal	
Totals			*284,521.5*	*$4,080,103*			

2006-2007 Annual Utility Consumption							
	Usage		Normalized				Normalized Rate
	qty	unit	MMBtu	Cost	Rate		$/MMBtu
Electricity	45,841,490.0	kWh	156,411.2	$2,963,371	0.065	$/kWh	$18.95
Coal	5,012.0	tons	100,240.0	$410,282	81.860	$/tons	$4.09
Natural Gas	32,922.0	MCF	34,041.3	$432,915	13.150	$/MCF	$12.72
Sewer	79,737.0	kgal		$181,930	2.282	$/kgal	-
Water	108,312.0	kgal	-	$152,839	1.411	$/kgal	
Totals			**290,692.5**	**$4,141,337**			

2007-2008 Annual Utility Consumption							
	Usage		Normalized				Normalized Rate
	qty	unit	MMBtu	Cost	Rate		$/MMBtu
Electricity	49,481,344.0	kWh	168,830.3	$3,371,683	0.068	$/kWh	$19.97
Coal	5,926.0	tons	118,520.0	$465,544	78.560	$/tons	$3.93
Natural Gas	43,834.0	MCF	45,324.4	$475,127	10.839	$/MCF	$10.48
Sewer	74,142.0	kgal		$192,756	2.600	$/kgal	-
Water	117,278.0	kgal	-	$168,870	1.440	$/kgal	
Totals			**332,674.7**	**$4,673,980**			

2008-2009 Annual Utility Consumption							
	Usage		Normalized				Normalized Rate
	qty	unit	MMBtu	Cost	Rate		$/MMBtu
Electricity	47,084,125.0	kWh	160,651.0	$3,873,965	0.082	$/kWh	$24.11
Coal	2,479.0	tons	49,580.0	$377,688	152.355	$/tons	$7.62
Natural Gas	114,462.0	MCF	118,353.7	$956,282	8.355	$/MCF	$8.08
Sewer	98,473.7	kgal		$305,809	3.105	$/kgal	-
Water	158,043.6	kgal	-	$212,235	1.343	$/kgal	
Totals			**328,584.7**	**$5,725,979**			

2009-2010 Annual Utility Consumption							
	Usage		Normalized				Normalized Rate
	qty	unit	MMBtu	Cost	Rate		$/MMBtu
Electricity	48,703,604.0	kWh	166,176.7	$3,614,652	0.074	$/kWh	$21.75
Coal	1,227.0	tons	24,540.0	$111,400	90.791	$/tons	$4.54
Natural Gas	164,761.0	MCF	170,362.9	$1,155,173	7.011	$/MCF	$6.78
Sewer	79,512.3	kgal		$355,895	4.476	$/kgal	-
Water	138,696.1	kgal	-	$233,740	1.685	$/kgal	
Totals			**361,079.6**	**$5,470,860**			

ETSU Annual Energy Usage

ETSU Annual Energy Cost
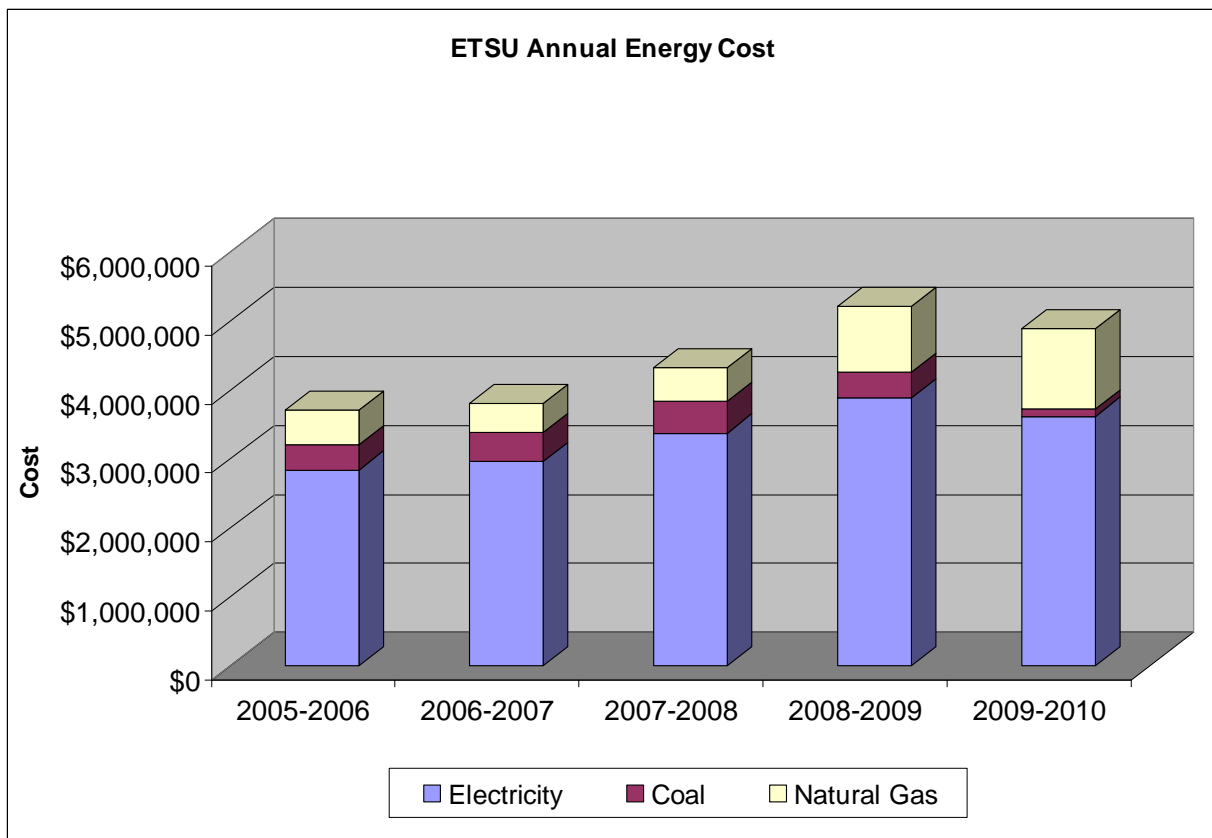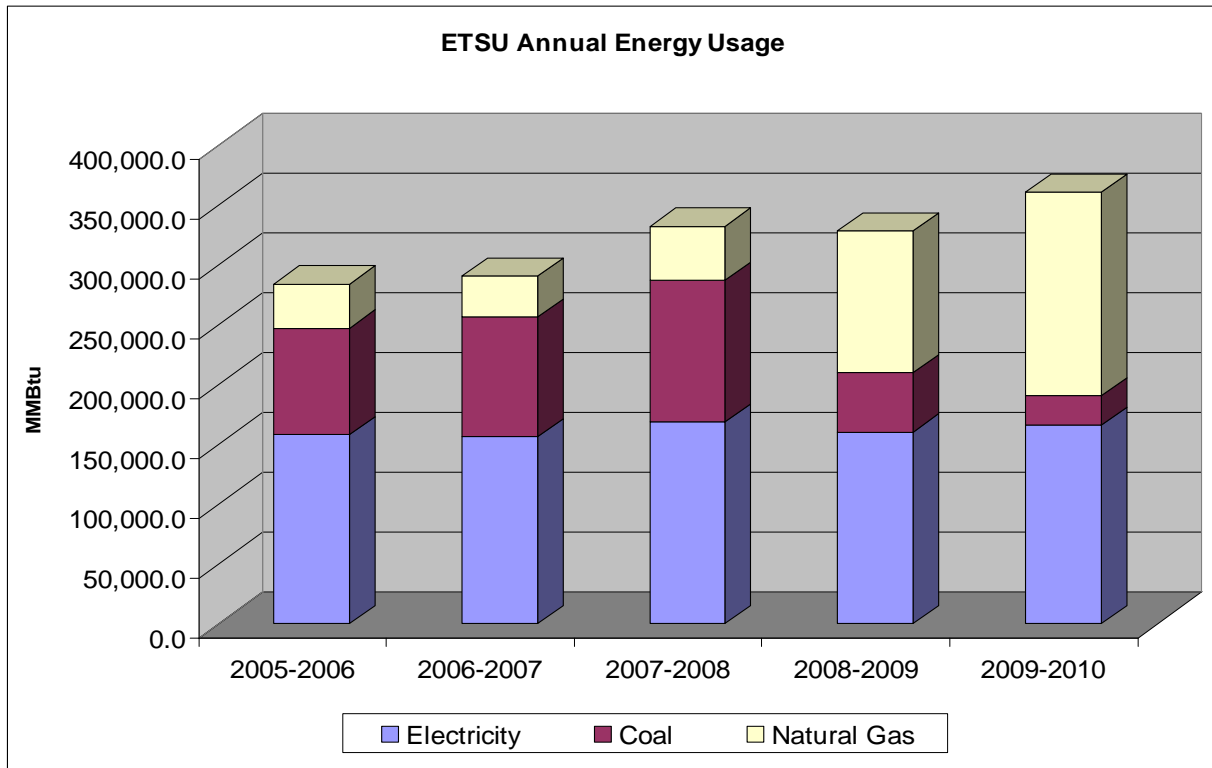
PROPOSED ENERGY CONSERVATION PROJECTS

1. Computer Power Management: Implementing a campus wide computer power management program would enable the hibernate power management feature on all University owned computers to automatically power down the central processing unit and monitor when the computer is not being used. This program should also educate and encourage students to utilize the power management features of their personal computers to minimize power consumption. Also, all new computers purchased by the University should be energy star compliant notebooks.

    Approximately 85% of the 8,760 hours in a given year computers are inactive as illustrated in the table below. This represents a tremendous energy conservation opportunity for computers that are continuously plugged in without enabling their power management features. For computers with a LCD monitor, the CPU consumes the majority of power when a computer is inactive. For computers with a CRT monitor the power consumed is approximately equal for the CPU and the CRT. Therefore it is important that both the CPU and the monitor are included in a computer power management system. Power Management features, which are standard in Windows and Macintosh operating systems, place monitors and computers (CPU, hard drive, etc.) into a low-power "standby mode" after a period of inactivity. Touching the mouse or keyboard "wakes" the computer and monitor, typically within seconds.

    Estimated Computer Utilization

Time Period	Hours	% of Time Computers are Active			Active Hours
		8am-3pm	**3pm-10pm**	**10pm-8am**	
School in Session M-F	3936	70%	20%	0%	1180.8
School in Session Sat	792	15%	0%	0%	39.6
School in Session Sun	792	15%	0%	0%	39.6
Summer & Breaks	3240	5%	0%	0%	54
Total	**8760**				**1314**

<div align="right">Overall % of Time Computers are Active   **15%**</div>

    To maximize power savings, the EPA recommends setting computers to enter system standby or hibernate after 30 to 60 minutes of inactivity and monitors to enter sleep mode after 5 to 20 minutes of inactivity. Note that laptops typically need to activate these settings in the AC power profile as well as the DC (battery power) profile.

    Enabling hibernate option is very important from a power management perspective since the power consumed by the computer during the hibernate mode is effectively zero, as compared to the sleep mode where typical power consumption is 3 watts for a laptop and 5 watts for a desktop. The hibernate mode conserves power by copying system data from RAM to non-volatile storage, typically a reserved area on the hard drive, and then completely turning off the computer. When the computer exits hibernate mode, it returns to the same operating state it was in before entering the hibernate mode, so that most programs can continue executing as if nothing happened. In addition to higher

energy savings, the hibernate mode is preferable to the sleep mode since system data is saved in the event of a loss of power.

Several institutions have successfully implemented computer management schemes, resulting in an average annual energy cost savings of $25-$75/computer. Several case studies can be found on the following Energy Star website link: http://www.energystar.gov/index.cfm?c=power_mgt.pr_power_management

Though not as significant as power management, additional energy savings can be realized by utilizing computers with LCD monitors instead of CRT; utilizing laptops instead of desktops and by purchasing Energy Star labeled computers and accessories. LCD monitors typically consume 75% less power than CRT's; while laptops typically consume 50% less power than a similarly equipped desktop and energy star labeled computers use significantly less power than non labeled computers. Note that the savings from these measures will be realized only while a computer is active, which will be approximately 15% of the time if a power management system is in place.

The potential energy savings from implementing a power scheme that turns off the monitor and hard drive and places the computer's CPU in the hibernate mode after a predetermined period of inactivity is illustrated below. Values used are from manufacturers for typical desktop and laptop machines. Please note that the energy savings includes the reduction in HVAC cooling load due to reduced computer heat production. The number of computers and other assumptions are to be verified with the University prior to the final report being issued.

Potential Estimated Energy Reduction – ETSU Owned Computers

Number of ETSU Owned PCs / Laptops	5,000	
Percentage that are Laptops	15%	
Percentage of time computers are inactive	85%	
Current percentage with monitor shut-down active	75%	
Current percentage with hibernate mode active	0%	
Idle hours per year	7,446	hrs/year
Annual kWh per laptop consumed while idle	276	kWh/year/laptop
Annual kWh per PC consumed while idle	624	kWh/year/PC
Total annual kWh per year consumed by laptops while idle	206,627	kWh/year
Total annual kWh per year consumed by PCs while idle	2,650,311	kWh/year
Cooling MMBtu per year consumed by laptops while idle	705	MMBtu
Cooling MMBtu per year consumed by PCs while idle	9,046	MMBtu
Total Annual Electric Power Reduction	2,856,937	kWh/year
Total Annual Cooling Load Reduction	9,751	MMBtu
Potential Total Annual Energy Reduction	***19,501***	***MMBtu/year***
Potential Reduction in Campus Energy Cost at 2010 Rates	***$212,486***	***$/year***
Potential Reduction in Greenhouse Gas Emissions	***4,103***	***Metric Tons/year***
Potential Reduction in Energy Consumption from 2005 Levels	***6.9%***	
Potential Reduction in Facility GGE from 2005 Levels	***8.8%***	

The potential energy savings from implementing a power management system to place the student owned computers in hibernate mode after a predetermined period of inactivity is illustrated below.

Potential Estimated Energy Reduction – Student Owned Computers

Number of Student Owned PCs / Laptops	10,000	
Percentage of Students that live on campus	20%	
Percentage of dorm rooms that are air conditioned	75%	
Percentage of Laptops	75%	
Percentage of time computers are inactive	40%	
Hours commuting students are on campus	6	hrs/day
Number of days per year class is in session	250	days/year
Percentage of the time computers are inactive for commuting students	40%	
Current percentage with monitor shut-down active	20%	
Current percentage with hibernate mode active	0%	
Idle Hours per year	4,104	hrs/year
Annual kWh per laptop consumed while idle	173	kWh/year/laptop
Annual kWh per PC consumed while idle	406	kWh/year/PC
Annual kWh per year consumed by laptops while idle	1,298,808	kWh/year
Annual kWh per year consumed by PCs while idle	432,936	kWh/year
Cooling MMBtu per year consumed by laptops while idle	4,433	MMBtu
Cooling MMBtu per year consumed by PCs while idle	1,478	MMBtu
Total Annual Electric Power Reduction	1,731,744	kWh/year
Total Annual Cooling Load Reduction	4,433	MMBtu
Potential Total Annual Energy Reduction	***6,354***	***MMBtu***
Potential Reduction in Campus Energy Cost at 2010 Rates	***$128,637***	
Potential Reduction in Greenhouse Gas Emissions	***1,337***	***Metric Tons***
Potential Reduction in Energy Consumption from 2005 Levels	***2.2%***	
Potential Reduction in Facility GGE from 2005 Levels	***2.9%***	

Given the number of University owned computers on campus and the need to periodically install updates, a computer by computer power management approach may not be practical, so a central computer power management scheme could be implemented. There are several network management software packages that incorporate central computer power management schemes. This allows for standardized power management settings across all managed desktops/servers. Links to two companies that offer network software packages with central power management schemes: http://www.mspcenterplus.com/ and http://www.bigfix.com/.

EZ GPO at http://www.terranovum.com/projects/energystar/ez_gpo.html is a free tool developed by Terra Novum for the US EPA Energy Star Program to centrally manage computer power settings. EZ GPO was developed for network administrators who run Windows Active Directory and manage client workstations using Group Policy Objects (GPOs). EZ GPO provides Group Policy Objects for centrally configuring power management settings, as they are not native in Windows 2000 or XP

EZ GPO does not work on Widows Vista Systems, since unlike Windows XP, power management in Vista can be controlled through Group Policy. Windows Server 2008 can enable Group Policy for

Vista PCs. Additionally, Windows Server 2000 or 2003 can enable Group Policy on Vista domains with a few simple steps, but must be managed from a Vista Workstation by a user logged in with administrative rights to the domain.

The cost to implement a computer management scheme will depend on what path the University chooses for implementation. The cost of a third party network management software ranges between $10 to $30 per device and varies based on vendor and features offered.

We believe this would be an ideal project for the University's Green Committee as it requires involvement from both the University and the students. Motivation could be provided for the students, staff, and/or faculty by offering some kind of recognition indicating that they are participating in the program. Another possibility would be adding a signature line to university email addresses indicating support of the initiative while at the same time spreading the information about the program.

2. <u>Student Housing Utility Metering:</u> The University is in the process of installing digital meters on all of the utilities serving many of the individual academic and administrative buildings on campus. These meters could also be installed at each student housing facility and a competition could be initiated between the buildings to see which can reduce their energy usage the most. Once the meters are installed, a full year of data should be collected to set a baseline before the competition is started. The new meters could be tied into the central building automation system (BAS) to track the data and a web site could be set up to allow anyone to see the day-to-day progress. Chilled water, steam, electricity and water usage could all be monitored. Some factors would have to be considered, such as actual occupancy versus the baseline occupancy and energy use per-square-foot. A monthly reward of some kind could be offered to the residents of the most improved facilities compared to the previous year.

   The estimated cost to install meters is about $20,000 per facility. Assuming there are 12 residence halls and that they account for 25% of the total energy and water usage, the current annual energy usage is about 90 MMBtu per year and annual costs for energy and water are about $1,368.000. If consumption can be reduced by an average of just 10%, the estimated potential annual savings of $136,800 per year would pay for the investment in less than 2 years. The estimated reduction in greenhouse gas emissions would be 1,140 MT or a 2.5% reduction from 2005 levels.

3. <u>Daylight Optimization Lighting Controls:</u> The University engineering and maintenance staff have been investigating options to provide lighting controls in spaces where daylight could be utilized more effectively. Implementation of this type of system would include replacing the existing light fixture ballasts with digital dimming ballasts, installing light sensors and occupancy sensors, and providing a control system which would automatically dim the electric lights when the natural light from windows is sufficient to maintain acceptable lighting levels when the spaces are occupied. Light levels would be dimmed or brightened gradually so that the lights are not actually being turned on and off. The goal is that occupants are not even aware that the lights are being adjusted.

Occupancy sensors could be integrated into the system to allow the lighting levels to be reduced further if the spaces are unoccupied. As mentioned above, not only does this reduce the electricity used directly for lighting, it also reduces the heat load in the spaces so that less air-conditioning is required. Occasionally the reduction in heat from the lights can result in more heating required, but this heat is provided by coal and/or natural gas which are significantly less expensive than the electricity which provides cooling.

Prime candidates for this type of retrofit would be the main library and the Center for Physical Activity which both have a lot of windows. Preliminary calculations indicate that, assuming 75% of the fixtures can be dimmed by 75%, the simple payback including cooling savings is around 8 to 10 years. A more detailed study involving a full energy model would refine this number by including a more detailed simulation of the savings in cooling energy.

4. <u>Occupancy Sensor Control of Lighting and HVAC Setback:</u> Another type of control system would be applicable to the various classroom, lecture halls, conference rooms, and offices around campus. This type of system automatically turns off lights in unoccupied spaces and sets the HVAC systems to the unoccupied mode. After a predetermined time, the lights shall be de-energized and the room HVAC system shall change the following set points to the unoccupied mode:
   - Room temperature.
   - Minimum supply air set point.
   - Ventilation set point.

   In order to reduce the amount of heat and reheat required when the lights are turned off it is important to allow the supply and ventilation air volume set points to go to zero and for the summer space temperature set point to increase and the winter space temperature set point to decrease. Without setting back the room HVAC, much of the energy reduction achieved by turning the lights off during normal building operating hours is lost through increase in space heating and reheating of 55°F supply air to prevent over-cooling.

   Implementation of this ECM requires the following prerequisites:
   - Rooms to be controlled need to have independent thermostatic control via dedicated variable volume terminal unit (VAV box), fan coil unit, heat pump or similar equipment dedicated to serve only that room or zone.
   - Room HVAC equipment needs to be equipped with programmable DDC controls to allow for utilization of set back modes of control.
   - If the room is served by central air handing units then the unit needs to be variable volume in order to allow room to go to unoccupied mode while the air handler is operating.

   Note: ASHRAE 90.1-2004 requires occupancy sensors for lighting control for most spaces in most buildings, therefore controlling the HVAC through occupancy sensors could and should be incorporated into all new construction and major renovation projects.

5. <u>Retro-Commissioning:</u> Ideally all new buildings go through some level of commissioning before they are turned over from the Contractor to the Owner. This is a process by which all of the systems, primarily HVAC, are verified to be operating as designed and intended to meet the needs of the Owner and occupants. Some buildings may not have been through this process and, even if they have, over time building functions change, system performance degrades, and complex control systems may not be optimally applied. In some cases commissioning an existing building is necessary. Primary indicators that a building or system needs to be retro-commissioned are excessive energy usage, maintenance calls, and occupant complaints. The Energy Star Building Manual has an excellent description of the benefits of retro-commissioning at:
 http://www.energystar.gov/ia/business/EPA_BUM_CH5_RetroComm.pdf.

The implementation of a campus-wide retro-commissioning program could be outsourced or performed in-house by University maintenance staff. Retro-commissioning can be utilized as a continuous advanced training tool to educate maintenance staff on various control strategies and the logic behind them as well as educating them in identifying energy conservation opportunities. The energy savings from retro-commissioning programs varies widely and the total operational and maintenance cost savings can be difficult to quantify but retro-commissioning typically reduces energy consumption by at least 3-5% where implemented.

A comprehensive retro-commissioning program includes:
- Testing communication and proper operation of all control points (e.g. OA dampers are closed during morning warm up mode, air handlers shut off during normally unoccupied hours, variable speed drives modulate in response to VAV boxes opening/closing).
- Repair / replacement of software and hardware as appropriate.
- Implementation of energy efficient control strategies including demand control ventilation, expanded set back control, occupancy strategies and potential lighting integration.
- Sub metering of all incoming building utilities and comparison to the previous years consumption on at least a monthly basis to identify potential maintenance / operational issues.
- Expanded training program for maintenance staff.

Retro-commissioning benefits include:
- Energy savings through efficiency gains from new control systems and strategies
- Energy and Comfort improvements from existing renovated control system
- Improved building comfort
- Maintenance savings from removal of obsolete controls
- Proactive identification of equipment in need of replacement, reducing emergency replacement of failed equipment and associated cost and disruption
- Training to increase utilization of advanced control strategies and monitoring

The University engineering and maintenance staff is aware of one specific problem which may call for a retro-commissioning effort. The central chilled water distribution system is forced to operate at

about 120 psi at the furthest points in order to maintain minimum performance in a few specific buildings. This is much higher than would normally be expected. As a result, because of what may be correctable problems at a few buildings, the entire campus system has to work harder than necessary. A retro-commissioning program at the offending facilities should eventually lead to significant savings, both at the buildings themselves, and also at the central plant. It is impossible to accurately predict the costs of the program until the commissioning process is complete, because modifications may be as simple as replacing a control sensor or valve or as complicated as replacing a defective pumping system, but once the solution is found the payback will almost always be attractive.

6. LED Outdoor Lighting: As mentioned above, outdoor lighting such as parking lots and pedestrian walkways is typically currently provided by metal-halide (MH) fixtures on campus. Maintenance personnel indicated that they would like to move to light-emitting diode (LED) lighting in the future for several reasons. The primary benefits of LEDs compared to MHs are that they typically claim to last at least five times longer, the quality of light they produce should not degrade as much with time, they do not contain any mercury so they don't require special disposal programs, and they use less energy to produce the same amount of light. The most notable detriment is that they cost significantly more to install and, because they are relatively new, there is some unpredictability in long term performance.

The fact that the lamps last longer can greatly reduce labor and replacement costs. In general LED lamp replacements can cost 2-3 times as much to purchase, but should only be required once every 10-12 years instead of every 1-2 years. Obviously, labor should also be reduced considerably. On a 1-for-1 basis, an LED area light is going to cost 2-3 times as much to install as a metal halide fixture which gives off the same amount of light while using 50-75% as much energy. This means that the basic payback is going to be on the order of 30 years. If you include maintenance labor and replacement costs that number may fall to about 15 years.

7. Wind Power: Unfortunately the area around ETSU does not hold very much potential to utilize wind energy as a power resource. Even the best nearby locations, which are typically mountaintops, fall into the "Marginal" range. See Appendix A for a Wind Resource map of the United States published by the National Renewable Energy Laboratory (NREL).

Wind turbines are available in many sizes, from a 10kW residential type up to an over 2MW utility type. Costs vary from $2-$3/Watt for large installations up to $3-$5/W for smaller ones. As an example, a 75 kW turbine could be provided for approximately $300,000. Assuming an optimistic 50% efficiency due to the wind potential of the area, this would provide about 0.5% of ETSU's current maximum demand of 7.5MW. Including current federal incentives of $0.021/kWh, potential savings would be approximately $23,000 per year in electrical costs and an emission reduction of 167 MT per year or 0.4% of 2005 levels. Increased operational costs such as insurance, regular maintenance, repair, spare parts and administration are difficult to predict, but assuming they are 2% of the installed cost per year, about $6,000 per year could be required. The resulting payback period is about 18 years. Larger installations generally have better payback periods.

TVA does have incentive programs through which they will pay a premium for power provided back to the grid, but this would only be feasible if a new installation produced more power than the University consumes.

8. Biomass Boilers: Similarly to wind power, renewable biomass resources are not readily available near the University. See Appendix A for a Biomass Resource map. It should be noted that biomass fuels typically emit at least as much greenhouse gas as fossil fuels do, but they emit the same amount of carbon as they consume while growing as plants, creating what is sometimes called a "closed carbon cycle". Carbon emitted by burning fossil fuels would have theoretically remained stored underground indefinitely. Biofuels are attractive because they are renewable and reduce dependence on foreign fossil fuel sources. However, many environmentalists contest that it takes years or possibly decades for the plants to absorb the carbon which is released in seconds when burned, so they believe that the net effect is far from balanced.

Converting existing coal boilers to biomass boilers is still a relatively new concept and the first prototype projects are still in the planning stages so accurately estimating costs and results for this type of upgrade is very difficult. On the other hand, new biomass boilers are becoming more common. As an example similar to the one above for wind energy, a new wood-fuel biomass boiler with about 2000 lb/hr capacity could be provided for approximately $300,000. If installed, this could replace about 6.7% of the capacity of one of the existing coal-fired boilers. The price per Btu of coal and natural gas is generally lower than high quality wood so fuel costs would probably increase. Additional analysis would be required to evaluate alternative fuels such as farm waste. Because it would be a separate installation there would also be additional operational costs. It does not appear that there would be any economic payback. As indicated above, actual greenhouse gas emissions would also be equal or slightly higher, although they would be from a "renewable" source.

Typically this kind of installation would not be very visible to the students, but attention could be drawn to it by various means such as signage or a public meter indicating the amount of steam being provided to "replace" fossil fuel steam generation.

9. Solar Energy – Photovoltaics: East Tennessee is not an ideal location for solar power, as can be seen on the Photovoltaic Solar Resource map in Appendix A. The primary reason for this is simply average cloud cover during daylight hours.

A typical small solar array installation tied into the central campus electric system costs approximately $3000 per square meter. Again using a $300,000 initial investment, an approximately 100 square meter array could be provided. Per the map referenced above, an array installed in the area around ETSU can be expected to provide an average of 3.5 kWh per square meter per day, or 350 kWh per day equating to approximately 128,000 kWh per year. This would be about 0.2% of the annual campus electrical usage and should save approximately $9,500 per year in utility costs, resulting in an expected payback of about 32 years. Additional operational costs should be minimal,

although some maintenance would be required. Greenhouse gas emissions could be reduced by about 87 MT which is less than 1% of 2005 values.

Depending on the location, the array of solar panels could be very visible to the students. Again, a public meter could indicate savings in both costs and emissions. Also, similarly to the LED discussion above, photovoltaic technology is evolving very rapidly so the economics may change in the near future.

10. <u>Solar Energy – Domestic Water Heating:</u> The same general drawbacks apply to solar water heating as to solar electricity generation discussed above.

Domestic hot water is currently provided by heat exchangers utilizing steam from the central boiler plant. A solar water heater installed in the ETSU area can be expected to generate an average of approximately 185,000 Btu of heat per square foot of collector per year. Systems cost about $200 per square foot, so for an installation cost of $300,000 approximately 1500 square feet could be installed, including the collectors and required accessories such as a heat exchangers and pumps. Based on these assumptions, about 278 MMBtu per year could be provided, which could potentially save the university about $1575 per year using an average of the coal and natural gas fuel costs. This results in an estimated payback period of about 190 years. This evaluation assumes an indirect type of heater which heats a heat transfer fluid in either a flat-plate or evacuated-tube type collector then transfers that heat through a heat exchanger to a domestic water tank. This type of system allows the heater to be utilized during freezing weather when a direct water heater would have to be drained to prevent freezing. The estimated capacity takes into account the heat losses due to the cold surrounding air during winter months. Additional operational costs should be minimal, but some maintenance on the system or systems would be required. Greenhouse gas emissions could be reduced by approximately 9 MT which is less than 0.1% of 2005 values.

CONCLUSIONS

East Tennessee State University has proven to be very conscious of reducing energy usage in their facilities in many ways. Extensive lighting, HVAC, and building envelope upgrade projects in existing facilities combined with strict requirements for all new construction projects have established ETSU as a leader in energy efficiency and sustainability.

The proposed computer power management and housing utility monitoring projects appear to meet all of the criteria of the Green Committee for viable projects, most notably active participation by the students. URS has seen similar projects succeed and in some cases exceed expectations at other universities, so we confidently recommend these two projects.

The installation of automatic controls for lighting and HVAC systems, the retro-commissioning program, and LED outdoor lighting are also historically successful at reducing energy usage, and could be scaled to fit into the Committee's budget, but the paybacks are not overwhelming and they mostly involve improvements that are "behind-the-scenes", meaning that most students would probably have no idea that they are being implemented. Based on the given criteria, URS does not recommend these projects.

The more extravagant projects involving renewable energy sources could be very visible to the students and would generally reduce greenhouse gas emissions, but appear to be beyond the means of the funding available and are not economically viable in the short-term.

APPENDIX A

U.S. Wind Resource (50m)
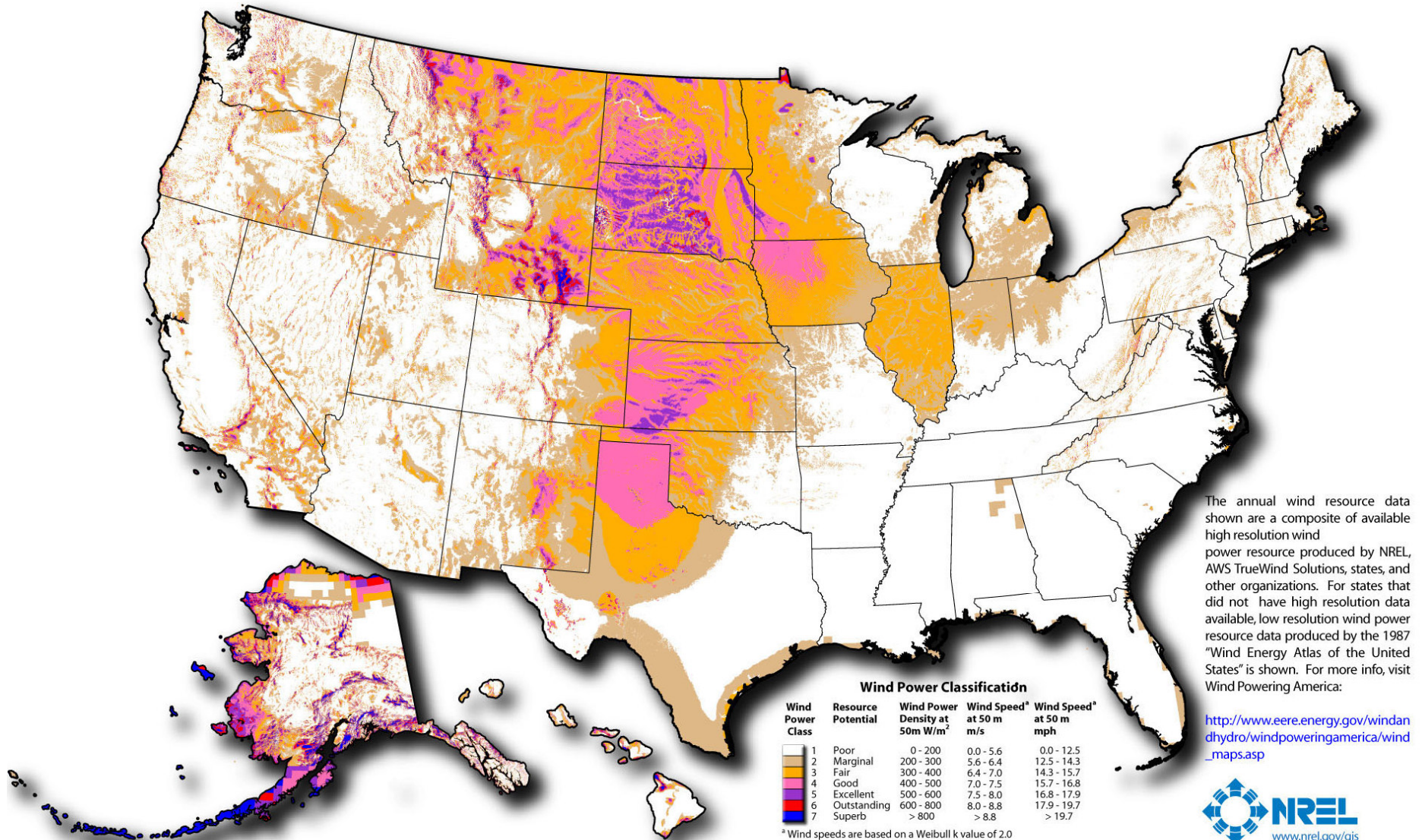
The annual wind resource data shown are a composite of available high resolution wind power resource produced by NREL, AWS TrueWind Solutions, states, and other organizations. For states that did not have high resolution data available, low resolution wind power resource data produced by the 1987 "Wind Energy Atlas of the United States" is shown. For more info, visit Wind Powering America:

http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	> 800	> 8.8	> 19.7

[a] Wind speeds are based on a Weibull k value of 2.0

Author: Billy Roberts - December 12, 2008

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.

NREL
www.nrel.gov/gis

U.S. Biomass Resource

This study estimates the annual technical biomass resources currently available in the United States by county. It includes the following feedstock categories:

- Agricultural residues (crops and animal manure);

- Wood residues (forest, primary mill, secondary mill, and urban wood);

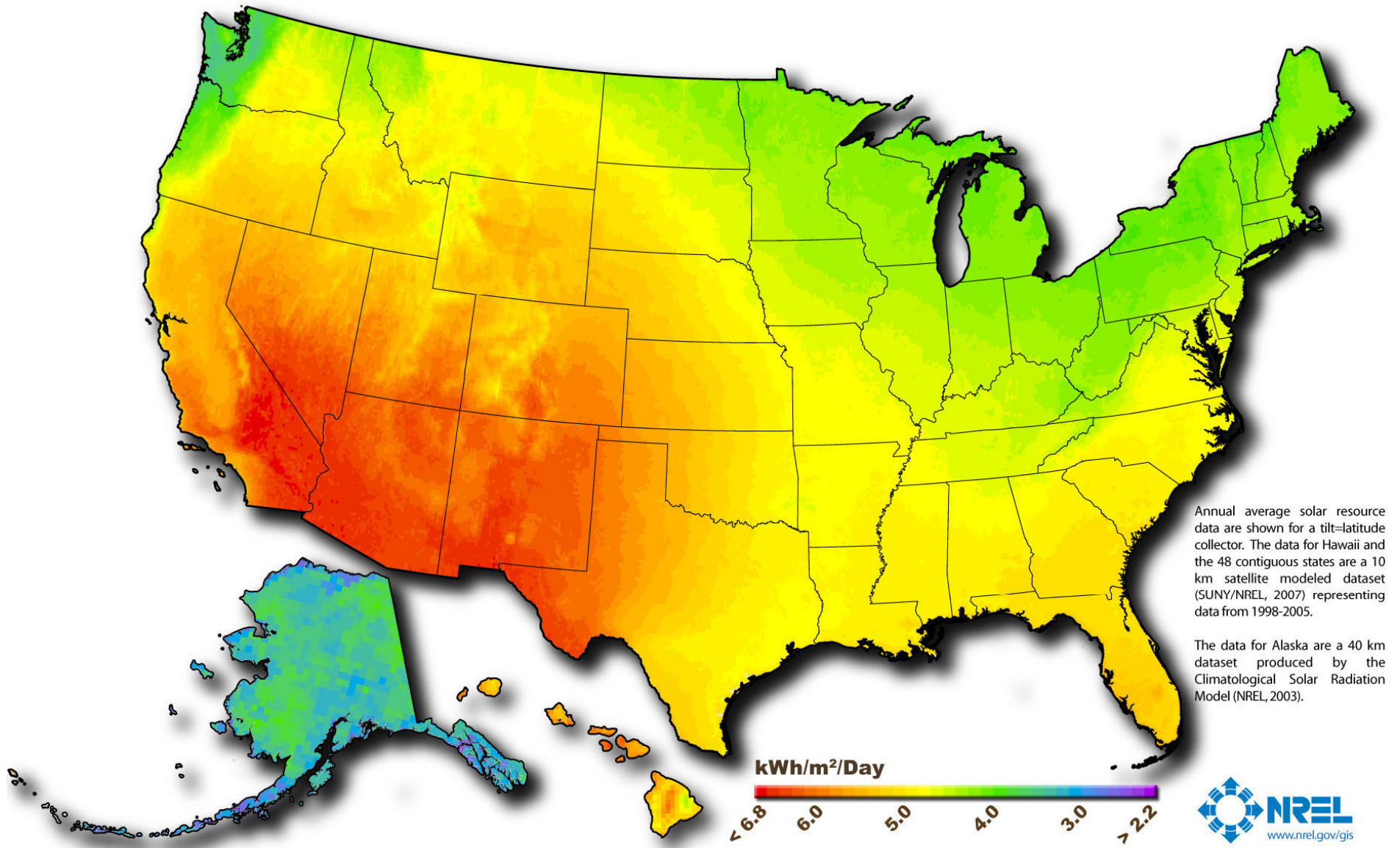- Municipal discards (methane emissions from landfills and domestic wastewater treatment);

- Dedicated energy crops and switchgrass on Conservation Reserve Program lands).

Thousand Tonnes/Year
Above 500
250 - 500
150 - 250
100 - 150
50 - 100
Less than 50

NREL
www.nrel.gov/gis

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
See additional documentation for more information at http://www.nrel.gov/docs/fy06osti/39181.pdf

Author : Billy Roberts - October 20, 2008

U.S. Photovoltaic Solar Resource

Annual average solar resource data are shown for a tilt=latitude collector. The data for Hawaii and the 48 contiguous states are a 10 km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005.

The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).

kWh/m²/Day

< 6.8   6.0   5.0   4.0   3.0   > 2.2

NREL
www.nrel.gov/gis

Author: Billy Roberts - October 20, 2008

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.