TRANSITIONING TO THE MODERN GRID WORKSHOP

THE CENTER FOR BUILDING PERFORMANCE AND DIAGNOSTICS
CARNEGIE MELLON UNIVERSITY

JANUARY 18 & 19 2007

PROVIDED BY VOLKER HARTKOPF AND FRED BETZ
CBPD

Transitioning to the Modern Grid Workshop

Minutes of Transitioning to the Modern Grid Workshop
At the Center for Building Performance and Diagnostics (CBP&D)
Carnegie Mellon University, 18, 19 January 2007

Provided by Volker Hartkopf and Fred Betz
Executive Summary

The two day workshop, “Transitioning to the Modern Grid” is summarized in the following pages. Here, in the executive summary, we want to provide only the highest level overview and focus on the most important opportunities.

1) Carnegie Mellon University should work in concert with Illinois Institute of Technology to compare both universities’ best practices and fully understand the opportunities generated by the strategic cooperation between IIT, Commonwealth Edison, The Galvin Foundation and EPRI. At IIT the president, the board of trustees’ chairman (CEO of Commonwealth Edison), and Mr. Galvin, a graduate of IIT cooperate strategically to transition to the modern grid by engaging IIT as a microcosm for this effort.

Furthermore, the University of Calgary in Calgary, Alberta, Canada, has formed a strategic partnership with an ESCO (Energy Services Company) to bring the campus energy conservation to maximum potential. Simultaneously, energy savings are utilized to create new department chairs and new knowledge domains, which also support student scholarships. (Jay Apt of the CMU Electricity Industry Center is very knowledgeable on this subject.)

Smart metering and instant feedback decision making algorithm show a lot of promise both educationally and for energy conservation. Techniques deployed in River Quest (see Dan Siewiorek’s presentation) are very promising in this regard.

2) Since the workshop, Volker Hartkopf had discussions with leading faculty and administrators of Bucknell University following his lecture on Monday the fifth of February. Consequently, Bucknell has shown great interest to cooperate within this context. Additionally, faculty members from Penn State showed interest in this potential collaboration and through our colleges at Tsinghua University, Prof. Jiang Yi and Wei Qingpeng, who already work with University of Pennsylvania, we could put together a Pennsylvania based university cooperation that could include UPenn. Steve Lee will have, in early March, a discussion with the DEP of PA Deputy Secretary, Dan Desmond, in Harrisburg, PA and will bring up the subject. Additionally, Volker Hartkopf will be able to address, during the annual Wege Foundation meeting in Ann Arbor, MI, on March 27, Michigan based institutions of higher learning to explore cooperation in this regard. The chairman of the foundation, Peter Wege, is very much in support of this.

3) Currently we work on a proposal to the German Marshall Fund. This proposal, due March 1, asks for support of a formative conference to create the base for a transatlantic cooperation towards best building practices, to be pursued at cooperating institutions in Europe and North America, as well as China and India. Volker has had and continues to have high-level meetings with the German Chancellor’s, President’s offices as well as Deutsche Bank and key industries. These meetings focus on the creation of a transatlantic bridge to enable long term cooperation through a commensurate funding of a foundation. The next meeting will be in Berlin on March 9th, 2007.

4) We will certainly follow through with researching the opportunity regarding a hybrid plug-in/PV on the Forbes street garage (see text)

5) During the workshop another major opportunity surfaced, namely the desirability to dedicate one bay of the Robert L. Preger Intelligent Workplace (5 x 10 meters) to install a PV array, battery

storage, power computers and lights, thereby monitoring, assessing and demonstrating a DC to DC power concept. We would work with major computer manufacturers, possibly Google, as well as battery companies. This opportunity we will discuss further with Dr. Nicholas Pietrangelo, an industry leader and workshop participant.

6) The ITEST (Information Technology Enabled Sustainability Test-bed) project in the Robert L Preger Intelligent Workplace, serving as a living and lived-in prototype of a total systems concept, is to incubate integrated hardware and software solutions to enable intelligent operations to result in simultaneous occupant satisfaction, health, and productivity; organizational effectiveness; technological adaptability; energy and environmental sustainability. **(See also the CBP&D work on BIDS, Building Investment Decision Support tool lead by Vivian Loftness.)**

Thereby, the IW functions as a total incubator, which can also include the exploration of technologies for remote management of facilities. We expect to have a specific focus on education, as well as, ultimately applications at CMU's campuses, as a whole, in Pittsburgh, the West Coast, Australia, and Qatar.

With appropriate high level planning, we expect to work with Joel Smith, Vice Provost for Computing Services at CMU, to strategically pursue this revolutionary concept.

7) The Bellefield cogeneration opportunities are worth considerable additional discussions. Unfortunately, there exists an immense time pressure. However, the opportunities to work with “Clean Coal Technologies”, cogeneration systems, as well as carbon sequestration in large green houses are considerable and should not be lost.

8) 20,000 megawatts sit idle, except for a couple of days per year during peak demand and in turn are responsible for 10% of the total electric utility costs. Here CHP technologies, smart metering, as well renewable energies and demand side control, all play a major role in reducing this cost, and would enable the consumers to book major savings. Electricite de France (EDF)is working with EPRI on this issue as well, and Clark Gelling at EPRI is a key professional regarding these issues. This where the Building as Power Plant at CMU could play a major role.

9) CMU has, on Forbes Avenue, a garage of 50m by 140m. On top of this garage a 7000m^2 a solar PV array of approximately 860 kW could be installed. This in turn could produce 1,000 MWh per year. CMU could work with plug-in hybrid car manufacturers and battery companies to make the first PV/battery/plug-in hybrid project happen. Faculty that would want to participate might be given free parking for one year and free electricity in turn for being part of the study. It could be imagined that the participating vehicles would require no fuel for that entire year, provided their daily distances to and from work would not exceed 50 miles round trip. We should discuss this opportunity with Conergy (see text “call-in from DEP”.)

LIST OF PARTICIPANTS:

Transitioning to a Modern Grid, Opportunities for Universities, Kurt Yeager, President Emeritus, EPRI, Galvin Foundation, January 18. 2007

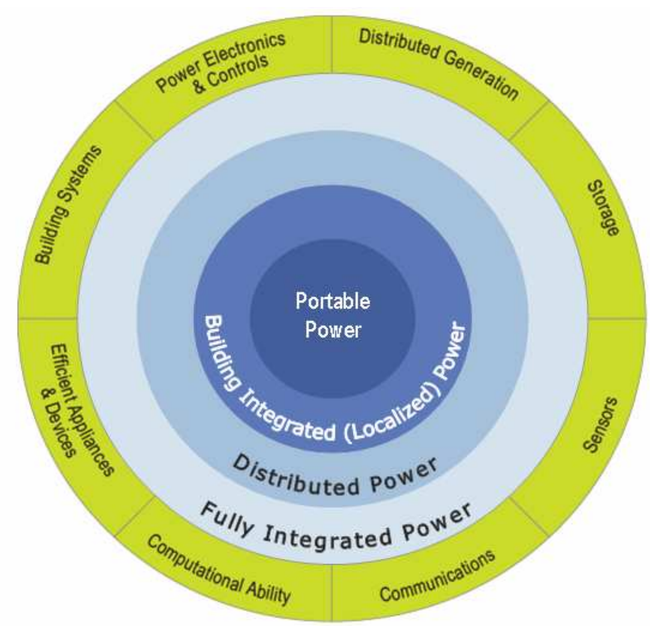
Key Points

The electricity network is the greatest 20th century achievement, according to the National Academy of Sciences. It must remain the backbone of the quality of life and industry, however, it is designed and built in the first half of the 20th century. Major mismatches dominate the system. 45 years of stalled investments and institutional structures of the past define the system, and the perspective is all demand based.

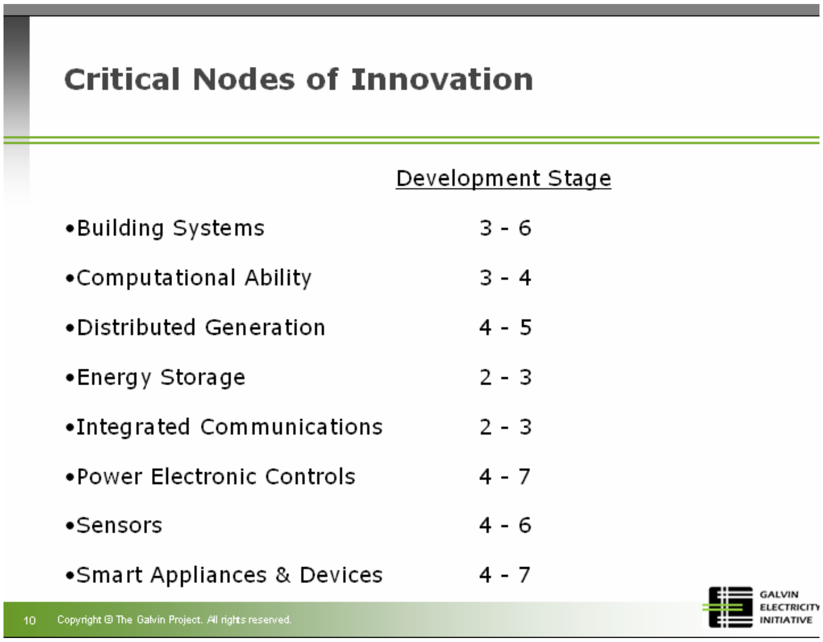
Bob Galvin, author of Six Sigma, former CEO of Motorola, chaired the EPRI Technology Roadmap effort. The report is titled “Cities in Gridlock, Networks of Transportation and Infrastructure Issues”. The report cites, for instance, that outages of less than 3 minutes are not registered. Kurt leads “The Perfect Power System of the Future” effort at the Galvin Foundation.

A big issue for the future is value based electronic control. Consumers should not be seen as hostages. Smart metering and real time communication and decision making should be enabled. A big opportunity lies in how much value could be added from each electron, especially in relation to energy and the environment, leading to smart initiatives including CHP microgrids. Another major issue is that up to 60% of the costs of computers are caused by going from AC to DC. The microgrid concept starts with the devices and building systems on all levels and understands opportunities in generation, distribution and end use which would lead to fully integrated power systems (See image).

Galvin focuses on portable integrated distributed power systems. See diagram.

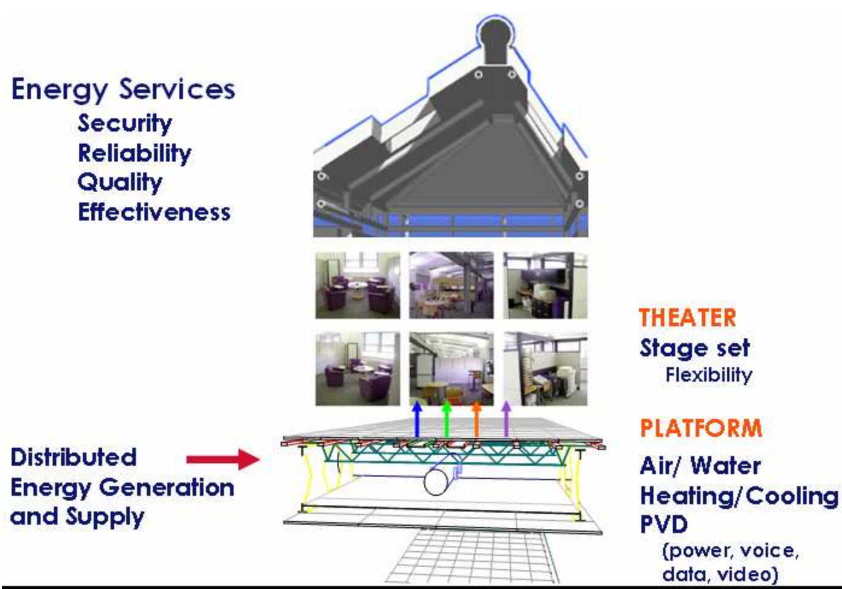


Presently, the unreliability of the grid costs annually 1 to 2 % of US GDP. If this cost were calculated, each dollar of the electricity bill would have to carry an additional $0.75 to account for the unreliability. Unfortunately, only 10% of the total sales volume is invested in the system as a whole per year. Kurt identified critical nodes in the electrical infrastructure.



Some universities address these issues, for instance, the University of Minnesota and North Carolina State have management schools which focus on operational quality management. Very important: in the future, utilities will be selling services instead of power to customers.

This service concept corresponds well to the Building as Power Plant concept pursued by the Center for Building and Performance at CMU, pictured below.



Phase 3 of the Galvin Foundation initiative is to implement the distributed utility path. One wants to work with key utilities, building owners, developers, and end users. According to Kurt, MUST BE BUILDING SYSTEMS APPLICATION ORIENTED. This is Kurt's key interest as far as the CBPD at CMU is concerned.

Illinois Institute of Technology (IIT) President John Rowe is committed to convert the IIT campus into a state of the art microgrid. The board of trustees, faculty, and staff, as well

as the local utility, are all committed to meet this objective (it helps that Galvin is a graduate of IIT, on the board of the institution, and Commonwealth Edison's CEO chairs the board).

Another major application is the Majestic Realty Casino Complex in Las Vegas, Nevada where power quality is the essence for gambling and systems and operational costs are critical.

Furthermore, the developer Forest City is involved in a major development which includes 100 megawatts of solar power in Albuquerque, NM. According to Galvin, **heretical thinkers are needed; the time of conventional thinkers is past.**

20,000 megawatts sit idle, except for a couple of days per year during peak demand and in turn are responsible for 10% of the total electric utility costs. Here CHP technologies, smart metering, as well renewable energies and demand side control, all play a major role in reducing this cost, and would enable the consumers to book major savings. Electricite de France (EDF)is working with EPRI on this issue as well, and Clark Gelling at EPRI is a key professional regarding these issues.

The use of intermittent (non-dispatchable) distributed generation (solar, wind) is limited not only by the availability of these resources, but by the ability of the grid to handle the power fluctuations. Converting the grid controls from mechanical systems, which take minutes to switch, to electronic controls, which take milliseconds to switch, would increase the capacity of the grid for intermittent distributed generation from 10% to 20%.

Result: Yeager is interested in pursuing the potential of a CMU – IIT collaboration with a potential involvement of the University Calgary, Canada and Tsinghua University in Beijing, China (Prof. Wei Qingpeng was here to pursue such opportunities.). Chris Gabriel of the Heinz Endowment showed interest as well.

Call-in from David Althoff, Chief, and Malcolm Furman, Team Leader, Division of Energy Policy and Deployment, Commonwealth of Pennsylvania Clean Coal Initiatives in the Department of Environmental Protection (DEP). January 18. 2007

Althoff extended greetings from Secretary Katie McGinty and her deputy Dan Desmond. The Governor's initiatives focus on Health, Highways, and Energy. The office of Energy Policy and Deployment focuses within this set to the subject of energy. It is expected that the funding for both the Pennsylvania Energy Development Authority (PEDA) and Energy Harvest of DEP will increase substantially in next year's budget. Major goals are: R&D support to enable first adopters of energy generation, waste coal utilization as part of Tier 2 Group (energy performance standards) efforts, cogeneration and demand reduction, and Integrated Generation Combined Cycle (IGCC) flexibility, as well as carbon sequestration.

Furthermore, alternative energy options and the maximization of fuels' opportunity effectiveness are important. The DEP wants to showcase replicable projects that work, and learn from the successes. Pennsylvania wants to be on the forefront of these major issues and create jobs.

Malcolm Furman focused on opportunities stemming from Coal Gasification and cogeneration, including IGCC by monitoring and documenting national, as well as international efforts and successes. IGCC power plants are a major focus, especially considering multiple inputs and outputs. Energy inputs (sources) such as waste and low ranked coal, biomass, and municipal waste can be gasified to generate syngas (CO +H2). However, syngas has only 1/3 of the heating value of natural gas; a major project is the WMPI in Gilberton, PA a waste coal to liquid fuel (diesel) and 41 megawatts of electricity project.

Several industrial <u>large-scale</u> Case Studies (completed)

- **Coal-SNG Large-Scale Industrial Park (on-going)**
- **Marshall County, WV Industry-Cluster Study (scoping efforts underway)-740MWe (equivalent)**
  - Identify Combined Power, Steam, and Natural Gas Consumption of Industry Cluster
  - Review Power Plant Case Studies
  - Develop Technical and Economic Analysis
- **Industrial Sector Applications of Gasification Technologies (new-potential)**
- **Syn-Gas as an Alternative to Natural Gas-Technology and Policy related issues (new-potential)**
  - Modeling based assessment

The Bellefield project could be seen as an opportunity in this regard.

Consol Energy mine methane drives turbines. Recent test results are promising. (See 11 January, 2007 News Release from Consol Energy) (Comment: Volker will call on Maureen McFall's husband). According to Furman, 100,000 pounds per hour of syngas feed a 10-14 megawatt combined cycle turbine to match the load.

Marty Altschul emphasized the importance of regulatory support in this area, and Furman seconded that. **VH asked, "Would you support efforts to bring partners to our project's table? Particularly in relation to coal gasification and opportunities." The answer was yes.**

The potential of involving the Department of Community and Economic Development (DCED) in future projects was emphasized.

In-Depth Presentations and Discussions

Bellefield Steam Generation Plant and Future Plans Status, Challenge and Potential Solutions, Martin Altschul, January 18. 2007

First operational in 1903, the Bellefield steam generating plant supplies steam to a number of institutions in the area including; the Carnegie Museums – Library, Phipps Conservatory, University of Pittsburgh, UPMC, and CMU. An operating committee is responsible for decisions in maintenance and operation and potential renovations of Bellefield. The Carnegie Museums and Library have four votes on the committee, whereas CMU has 2, U Pitt has 1 and UPMC has 1. Phipps Conservatory has 0.

This year the facility will be out of compliance as far as EPA is concerned and major initiatives are currently being discussed and evaluated, including the opportunities for cogeneration. Major challenges are presented by the requirement to match seasonally fluctuating needs for steam (which is used for heating and might be used for cooling) with electric loads. **See PowerPoint presentation.**

Marty Altschul emphasized the very short timetable and the need for rapid decision making and he felt that far reaching plans, such as the ones proposed by Dr. Archer might be hard, if not impossible to be realized under these constraints.

Coal Gasification, Distributed Electric Energy Generation presentation by Donald Bonk with Robert Romanosky of the National Energy Technology Laboratory (NETL) followed by a brief presentation by Dr. David Archer. January 18. 2007

Donald Bonk of NETL provided a detailed overview of various coal gasification and power generation processes that are of interest to NETL.

Donald Bonk, Robert Romanosky, and David Archer to please fill in here for final version.

River Quest & People Tracking, Dan Siewiorek January 18. 2007

Dan Siewiorek first spoke to the subject of River Quest, which is an educational boat on the Pittsburgh Rivers, providing experimental and experiential settings for school children of all ages. River Quest serves schools in Allegheny, Armstrong, Beaver, Butler, Erie, Fayette, Greene, Indiana, Somerset, Washington, and Westmoreland counties in Pennsylvania, and plans in the next year to include Ohio and West Virginia.

River Quest is the world's first green passenger vessel propelled by

- a hybrid diesel-electric propulsion system and a power plant designed for the future addition of solar, wind or fuel cells.

It also includes:

- Large battery banks for zero emission operations - charged at the dock or underway.
- Generator engine waste heat recovery.
- Excellent thermal insulation system.
- Low volatile organic coatings.
- Highly efficient interior and exterior lighting systems.
- Water efficiency and zero wastewater discharge.
- Energy management and control system.

Furthermore, all passengers can see where the energy comes from at any point in time through an interactive display. Beyond being great fun, the educational impact is considerable (Send this section to Christine Mondor, Volker wants you to include this in the informal learning proposal.). The Heinz Endowment provided major funding, industry donated materials and services, and several Pittsburgh architectural firms donated design and engineering capabilities.

People Tracking

The Human Computer Interaction Institute (HCII) conducted a study with faculty and students tracking their movements across campus via their laptops and PDAs communication activities. This combined with GPS applications could provide major opportunities for operating buildings and their equipment interactively. As a result, the CBPD team will pursue the potential of an integration of these technologies into ITEST (Information Technology Enabled Sustainability Test-bed), an activity for Khee Poh Lam and Volker Hartkopf.

CO2 Sequestration: Are Large Greenhouses an Option? Valentin Kefeli, Slippery Rock Watershed Coalition, January 18. 2007

Valentin Kefeli gave an inspiring and very quick animated presentation by using the white board distinguishing between different plant types, their interaction within greenhouses and CO2 digestion and release.

Key points:

1, Growth of plants will stop if the CO2 level decreases below 150 ppm and increases remarkably at 500-1000 ppm.

2. Density of crop is very important and depends on light quality, intensity and type of variety. In general, the growing area for each tomato plant is 0.4qv.m. Consequently, total plant density should be 24.710 plants per ha. CO2 concentration for raising seedlings of tomatoes is 800 p.m. and for adult plants- 1000-13000 p.m.

3. Sources of CO2 may be used for plants feeding only during day time. CO2 generators should be located throughout the greenhouse. CO2 should be free from impurities: C0 and ethylene.

4. In order to reach the optimal level of CO2 it is necessary to add 0.37 kg CO2/100m2

5. CO2 consumption is estimated to be between 0.12-0.24kg/hr/100m2

Carbon dioxide-photosynthesis-growth-productivity : Introduction

Leaves and stems of plants are able to develop their body thanks to main gas exchange processes like Photosynthesis and Respiration. Leaves are the centers of biosynthesis of plant monomers (glucose, phenol acids and alcohols, amino-acids, nitrogen bases) from carbon dioxide of the air.

Monomers - blocks of plant polymers, which construct the body of the plant.

Polymers of plant origin- proteins, starch, cellulose, and lignin. Thanks to polymers, the self-developing construction of the plant body plants grow and became more resistant to the environmental factors.

Conducting vessels in the bark and wood of the plants are the transporting arteries for the movement of monomers and polymers from leaves and roots. The pipes and tubes in the plant structure are also a real network (armature) of the plant body. The centers of the regulation of plant activity: plant hormones and inhibitors-growth regulating substances are mostly located in the growing points of stems and roots.

Growing points- apexes are the centers for the regulation of the growth and self-reproduction activity.

Compartmentalization (location in special compartments) of the processes of the biosynthesis and the deposit of the storage substances is a result of the transport of substances over long distances. All these processes are based on the photosynthesis, growth and regeneration of plant organs- rhythms of activity and dormancy. The formation of the yield (plant productivity) is a result of this complex machinery function.

Plants could be considered as Phyto-Architecton, the self-developing architectural model with the centers of body formation, operation of the activity, conducting vessels and the deposit of the accumulated products.

The Phyto-Architecton is based on formations of cellular and organ blocks, which use, for their formation, renewable forms of the energy. In the same time Phyto-Archtecton controls its body building, thanks to light and geo sensors, as well as to hormones and biosynthesis which direct the nutrition flows to the proper compartments.

Carbon dioxide-CO2 and photosynthesis
Carbon dioxide is one of three main components which combine to produce the products necessary for plant development; the amount of carbon dioxide in the air is only 0.003%. This compares to 78% of nitrogen, 21% oxygen, 0.97% of trace gazes. Plants will stop growing when CO2 decreases below 150 ppm. The higher CO2 concentration (400-500 ppm) increased the rate of formation of dirt plant matter.

C-3 and C-4 plants
Carbon dioxide /oxygen relations are based on two global processes-photosynthesis and respiration. There are 3 main types of plants in their relation to respiration:
C-3 plants, which during the night evaluate carbon dioxide during the respiration: cucumbers, tomatoes, carnations,
C-4 plants, which conserve metabolic carbon dioxide in organic forms mostly acids of the respiration cycle). The main C-4 plants are bamboo, rice, corn, sugar cane, millet, orchids CAM-plants crassula, other type of carbon dioxide conservation. C-4 plants possess higher productivity of biomass and do not produce much of carbon dioxide as the product of glucose splitting

CO2 in the green house
Usually the level of CO2 in the green house is a limiting factor for plant growth and harvest. CO2 concentration in the center part of green house is lower than near the outer walls. The lack of adequate CO2 levels lowers the average plant yield quality and market value. Growers using CO2 in the concentration 50% higher in the green house increased crop production without costly methods of stimulating plant growth.

Crop spacing
A rule of thumb for soil and bag culture is that each plant needs 0.4 sq.meter growing area and that total plant density should be 24.710 plants per ha. Generally tomatoes in plant bag culture are set out in double rows.

Germination rate for greenhouse tomatoes is generally at least 80%, so only one seed need to be planted per container. Plant shape depends of branching intensity and growth, which are controlled by genetics and selection properties. Dwarf and semi dwarf plants have retarded growth and higher productivity. Thus choosing of plant varieties is an important factor of green house plant productivity (green mass of leaves and stems) plus harvest of (fruits).

CMU Electricity Center Distributed Resources, Granger Morgan, EPP January 18. 2007

Granger Morgan gladly acknowledged the support of EPRI, and Kurt Yeager in particular, in the launch of the Electricity Industry Center at CMU.

The electricity industry in the United States accounts for $250 billion in sales, and demand for electricity is increasing. The industry faces issues which make meeting that demand difficult. These issues include slow rates of technology adoption, a transmission system designed for an earlier era, a hybrid of regulated and deregulated jurisdictions, and incomplete markets.

The problems of the electricity industry are inherently interdisciplinary, and the Carnegie Mellon Electricity Industry Center (CEIC) has merged engineering, economics, risk analysis, decision science to study problems such as these current areas of research:

- Electricity Markets and Investment
- Distributed Energy Resources
- Advanced Generation, Transmission, and Environmental Issues
- Reliability and Security of the Electricity Infrastructure
- Demand Estimation and Demand Response

The center is frequently called upon to testify before Congress. Through its faculty's and PhD. student's research such as Doug King's dissertation on microgrids, Hishan Zerriffi's on failure rates of the electrical grid, and Inês Azevedo's work on small source power supplies, the center has become an internationally recognized leader. The center has been instrumental in providing guidance to draft state legislation to facilitate the growth of microgrids. As 20% of all electricity is used in lighting, the future of energy efficient lighting is very important.

(On that issue, Volker cautioned that much of the lighting demand is during day, particularly in commercial buildings, which could be avoided through daylighting. Presently, only about 6% of the energy entering a power plant ends up as electric light (70% loss at the plant on average, 10% loss in transmission and distribution, and 20% loss in conversion to light). LED's promise twice as many lumens as fluorescent light sources in the future. This would increase the efficiency to 10-12%, however as Prof. Wei Qingpeng has monitored, as much as half the energy demand of many commercial buildings is caused by lighting a very considerable side effect is an increased cooling demand caused by that artificial lighting.)

Granger also referenced the Living Planet Report 2006 from the World Wildlife Fund (WWF) calling for urgent action. http://wpweb2.tepper.cmu.edu/ceic/

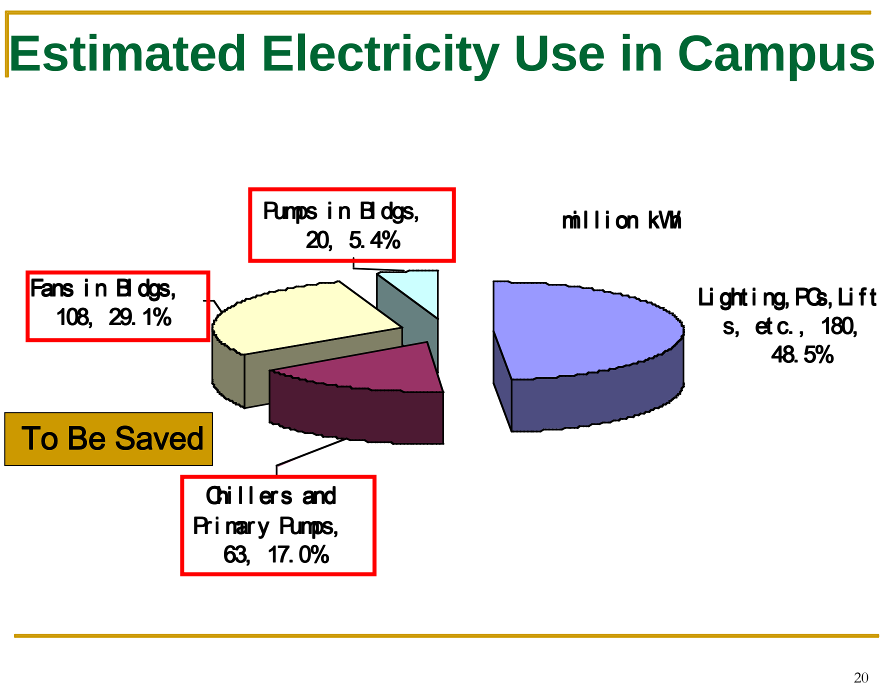
Before departing, Kurt Yeager complimented Granger and his colleagues' work and emphasized how happy he was in having a role in creating the center.

Wei, Qingpeng, Professor, Tsinghua University, China, Control Systems and Energy Use, January 18. 2007

Professor Wei made an insightful presentation regarding a study at a major university on the east coast with a total population of 36,000, a total built up area of 1,320 km^2 and a total energy bill of $67 million.

Two buildings were studied in depth and their electricity, steam, and cooling requirements compared with the statistics of the overall campus. The major pattern that emerged can be described as follows:

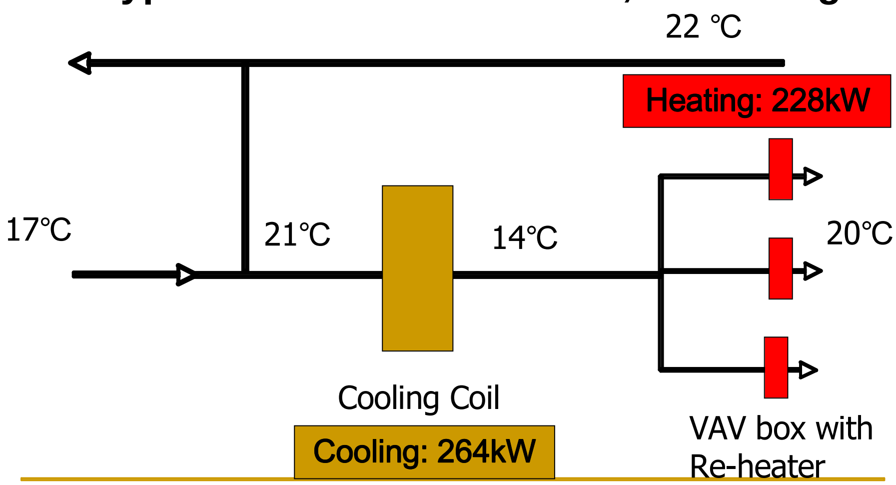
First, half of the loads are for lighting and electricity use for equipment. This load in turn generates the majority of the cooling requirement, which in turn generates a large demand for electricity, because of fans and pumps and relatively small (17%) electricity requirement for chillers which operate at an average COP of almost 6.0. It has been observed that all systems work very well, in terms of their individual performances. However, the way the overall system was designed and is being operated gives rise to questionable practices.



For instance, in the swing periods (Spring and Fall), when outside conditions would be appropriate to ventilate, heat and cool the buildings naturally, the building demands simultaneous heating and cooling. This is because the envelopes are fixed and do not allow for natural ventilation, daylighting, passive heating and cooling. Furthermore, the artificial ventilation, heating and cooling systems are operated to maintain constant temperatures and humidities despite greatly varying occupancies during the day and night. The HVAC systems end units combining ventilation, heating and cooling consist of VAV (variable air volume) diffusers and terminal reheat units. At night, in order to maintain constant conditions, the lighting, people and equipment loads are substituted by steam. Furthermore, when the outside temperatures are appropriate for natural ventilation, but the CO_2 sensors indicate no need for ventilation, the outside air dampers are closed and the recirculated air is being cooled, supposedly to reduce humidity and then reheated. In October (or Spring) the outside temperature might be at 17°C and the desired inside temperature is 21°C. The system first cools the air down to 14°C (supposedly to remove often non-existent humidity), and then reheats it at the terminal end units.

Energy Issues Findings 1

- **A typical situation in October, S Building**



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Studying the overall energy consumption in steam and electricity, the authors concluded that maintaining the existing system, providing intelligent sub metering and reprogramming the control system would save the university up to 20% of the energy with minimal investment.

Friday, January 19, 2007

ITEST: Volker Hartkopf

Involving: Aircuity, Air Advice, Bosch, Cisco, LTG, Retro-Solar, Siemens, Somfy, and CMU IT we developed a key concept: **IT Enabled Sustainability Test-bed (ITEST).** With this concept, we mean the opportunity before us to employ IT hardware and software technologies to intelligently design, engineer, build, and most importantly, operate sustainable built environments. Thereby, in addition to enabling and managing voice, data, and video operations, the IT infrastructure could also serve building operational needs including HVAC, lighting, security, elevators, etc. and be the key to building intelligence towards sustainability. This builds on the concept of Cisco Connected Real Estate, and provides a vision with important consequences.

ITEST can build on the companies' corporate citizenship objectives, going beyond product social responsibility, namely, how companies' products are environmentally responsibly manufactured, distributed, utilized, and ultimately, recycled.

Beyond product social responsibility, ITEST in the Intelligent Workplace, serving as a living and lived-in prototype of a total systems concept, to incubating integrated hardware and software solutions to enable intelligent operations are to result in simultaneous occupant satisfaction, health, and productivity; organizational effectiveness; technological adaptability; energy and environmental sustainability. **(See also the CBP&D work on BIDS, Building Investment Decision Support tool lead by Vivian Loftness.)**

Thereby, the IW functions as a total incubator, which can also include the exploration of technologies for remote management of facilities. We expect to have a specific focus on education, as well as, ultimately applications at CMU's campuses, as a whole, in Pittsburgh, the West Coast, Australia, and Qatar.

With appropriate high level planning, we expect to work with Joel Smith, Vice Provost for Computing Services at CMU, to strategically pursue this revolutionary concept.

At this time ITEST focuses on occupant sensing through the analyses enabled by Aircuity Indoor Air Quality, Bosch Sensors, LonWorks CO2 Sensing, and Siemens fan coil sensors, actuators, and controllers.

The ultimate objective is to operate the IW occupant and weather/climate interdependently while using renewable energies (day-lighting, passive/active heating/cooling) to the greatest extent possible before utilizing multi-modal HVAC and lighting components powered by biodiesel generators and only as a last resort, by non-renewable resources.

Intelligent Workplace Energy Supply System (IWESS)
Friday, January 19, 2007

Dr. Archer and team introduced each of the IWESS projects:

- Solar thermal heat supply with hot water driven chiller, (storage) - Ming Qu

- Biodiesel engine generator with heat recovery equipment for steam and hot water – Fred Betz
- Steam driven absorption chiller – Hongxi - Yin
- ($ Solid oxide fuel cell with heat recovery at high temperature $) – To expensive at the moment.
- Fan coil cooling/heating units with advanced controls – Yun Gu and Viraj Srivastava
- Radiant cooling/heating units: mullions, radiant panels – Gary Gong, TAMU
- Ventilation system with enthalpy recovery, (heat pump air cooling and heating), solid desiccant dehumidification - Chaoqin Zhai

and how those projects fit in with the overall IWESS project.

Next, the program steps were discussed:

- component selection, modeling
- preliminary system design: loads, flow diagram, material and energy balances, instrumentation diagram, equipment specifications/descriptions, operational description, layout
- procurement
- detailed design
- installation
- component test, data evaluation, performance analysis
- component integration into the IW, with other components, test, systems annual performance analysis
- advanced control: optimization, diagnostics
- system design guidelines, procedures, tools, economics, applications
- component redesign, optimization, integration

Then Dr. Archer indicated the status each project as well as the costs.

Component	Leaders	Selected	Preliminary Design	Procurement	Detailed Design	Installation	Test, Evaluation	Integration, Operation	Optimization, Diagnostics	Cost
Solar thermal cooling, heating	**Ming Qu, Sophie Masson**	■	■	■	■	■				$387 k
BioDiesel engine generator, heat recovery	**Fred Betz**	■	■	■	■					$844 k
Steam driven absorption chiller	**Hongxi Yin**	■	■	■	■	■	■			$219 k
High temperature fuel cell with heat recovery		▒	▒							
Fan coils with advanced control system	**Yun Gu, Viraj Srivastava**	■	■	■						$314 k
Radiant cooling/heating: mullions, panels	**Gary Gong**	■	■	■	■	■	▒			
Ventilation, conditioned air supply system	**Chaoqin Zhai**	■	■	■	■	■	▒			$74 k
										$1,838 k
Thanks to David Claridge, Christopher Damm, John Wiss, John Fisher, Wike Doorse	**Hans Werner Roth, Gerhard Zimmermann**									

Next the goals of IWESS were listed:

- combine components and IW: determine performance, effectiveness, efficiency, over a day, season, year: Trnsys-Comis modeling platform
  - solar receivers, chiller, fan coils, IW: space cooling/ heating: operational strategies, storage, insulation: annual energy use. Extend to economics, environment, storage alternatives

- operable windows: cooling, ventilation: strategies, energy use. Extend strategies, economics, environmental

and future studies were briefly discussed.

- solar reflectors, blinds, IW: annual energy loads: operational strategies
- radiant cooling/heating, ventilation, IW: annual energy use: benefits of dehumidification, comparison radiant, convective cooling/heating
- fan coil (operational and control models) cooling/heating, ventilation, IW, single and multizone: considering temperatures, humidities, occupancy: operational and control strategies: annual energy use
- engine generator with heat recovery equipment, chiller, fan coils, ventilator: strategies: annual effectiveness, energy use

Dr. Archer discussed the next steps to completing the IWESS project.

- complete component installation, test, evaluation
- integrate operation with the IW, with other components
- develop operation, control, optimization, diagnostic strategies
- develop system guidelines, design procedures, tools: component characterization; system synthesis; technical, economic performance evaluation
- component adaptation, integration for performance improvement, cost reduction
- EDUCATE

Finally, Dr. Archer discussed the future requirements of the project.

- another generation of capable graduate students: six students/four years, $1.2 million
- faculty/staff guidance: four persons/four years, $1.2 million
- equipment: fuel cell, modified existing components, $0.8 million

Call-in by the Department of Environmental Protection of PA (DEP) Friday, January 19, 2007

Deputy Secretary of the DEP, Dan Desmond, called in to the meeting. He was pleased to hear that his colleagues Althoff, and Furman made valuable contributions to our discussions. Dan emphasized the importance of green technology and sustainable practices that Governor Rendell is pursuing, as reflected in the forthcoming budgets and the activities of the commonwealth to support employment growth and reduce environmental burdens. Dan suggested that far reaching opportunities with significant employment implications should involve beyond DEP, the

Pennsylvania Department of Community and Economic Development (DCED), Secretary Dennis Yablonsky.

In the ensuing discussions, examples of collaboration between DEP and CMU, as well as Industry could include our quest to attract innovative façade component manufacturing, such as the Retro-Solar and Retro-Lux daylighting glare control and light redirection internal blinds. Somfy, the world's largest actuator manufacturer for windows, doors, blinds, and ventilation devices, is ready to cooperate with Retro-Solar/Retro-Lux to setup component assembly lines in Pittsburgh. In addition, Volker Hartkopf mentioned the opportunity could be realized in the PNC tower currently under final design and early construction. In addition to greatly reduce the electric demand (and there by reducing cooling loads, see Wei Qingpeng presentation) the project could be a catalyst to attract Somfy and partners to Pittsburgh. Pittsburgh in turn could then be a hub of production for the entire United States. Volker said he would discuss this opportunity with Rebecca Flora of the Green Building Alliance in relation to the GBA Green Building Products initiative funded by the Ben Franklin Partnership. (This discussion took place and Rebecca is pursuing the opportunity jointly with the center.)

(Furthermore, through the good offices of Pat Branch of Astorino Architects and Engineers, Volker Hartkopf met with Gary Sailson, the PNC VP for facilities regarding this opportunity. Gary is willing to have the blinds installed in his office for evaluation and to possibly use them for their prototypical Branch Bank project, with the potential to deploy the blinds subsequently in 100 branch bank buildings.)

Another major opportunity that was discussed at the workshop with Dan Desmond concerns a potential collaboration with Conergy and EnerCON, global players in renewable energy design, engineering, construction, operation, and maintenance. Governor Rendell and his administration were successful to attract
Conergy to set up their US headquarters in Philadelphia.

CMU has, on Forbes Avenue, a garage of 50m by 140m. On top of this garage a 7000m^2 a solar PV array of approximately 860 kW could be installed. This in turn could produce 1,000 MWh per year. CMU could work with plug-in hybrid car manufacturers and battery companies to make the first PV/battery/plug-in hybrid project happen. Faculty that would want to participate might be given free parking for one year and free electricity in turn for being part of the study. It could be imagined that the participating vehicles would require no fuel for that entire year, provided their daily distances to and from work would not exceed 50 miles round trip.

http://www.conergy.com/

Campus Energy and Electricity Use, Bradley Hochberg with Martin Altschul and Barbara Kviz, January 19, 2007

Bradley Hochberg with the support of Barbara Kviz and Martin Altschul discussed how CMU consumes energy and what it is doing to reduce environmental impacts.

Brad started off by showing the movie, “Climate: A Crisis Averted 2055”, which then led into his slide show.

Annual Campus Energy Use

FY' 06 utility costs

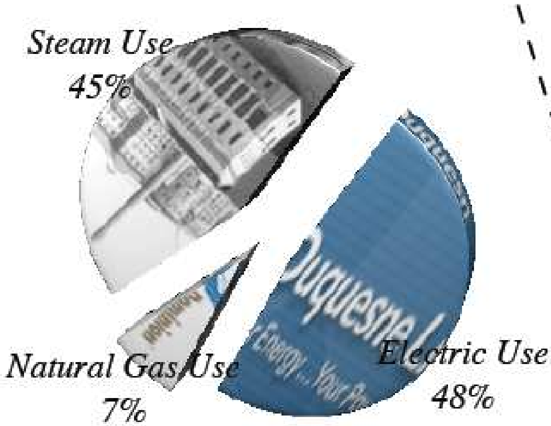
Approx. $14.1M

FY' 07 budget $14.7M
FY' 08 forecast $19.2M
FY' 09 forecast $20.3M
FY' 10 forecast $20.7M

FY' 06 utility data:

- *Electricity use is ~100,000,000 kWh*
- *Natural Gas use is ~53,000 Mcf*
- *Steam use is ~321,000 Mlb*
- *Total energy use is ~718,000 MMBtu*
- *EUI (energy utilization index) is 169,000 Btu/gsf*
- *ECI (energy cost index) is 3.30 $/gsf*

Total utility by Btus:



Each utility per gsf served by that utility:

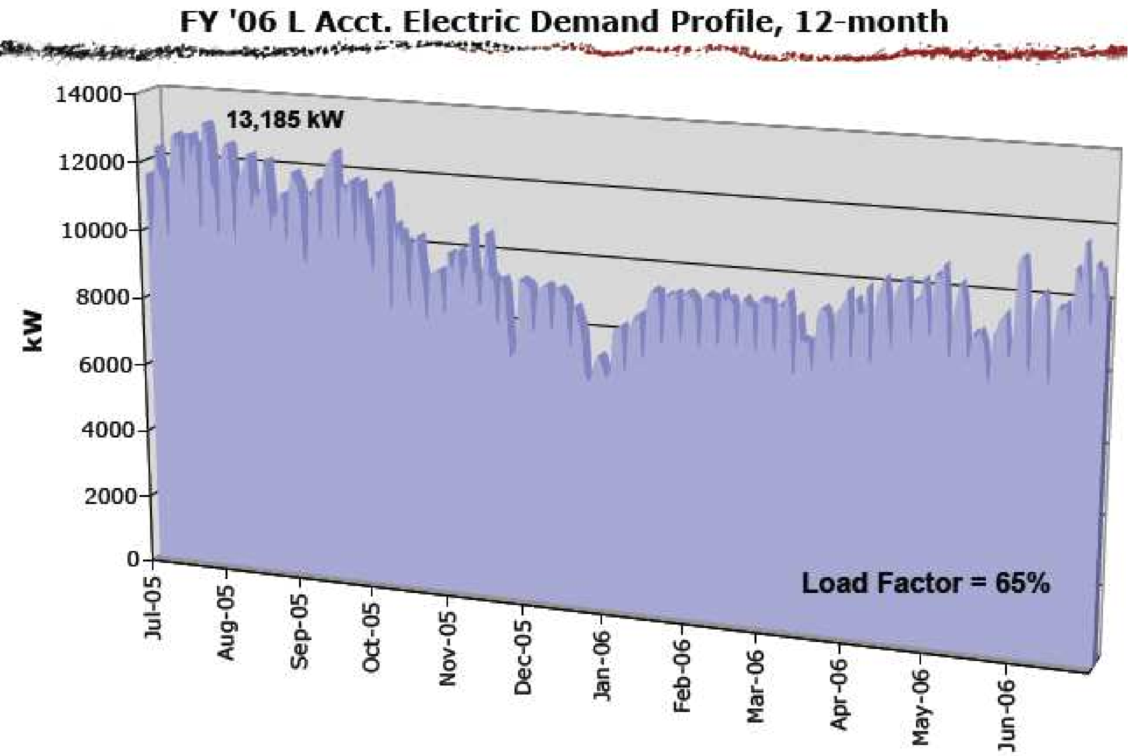
- *FY' 06 Electricity use is ~80,000 Btu/gsf*
- *FY' 06 Natural Gas use is ~59,000 Btu/gsf*
- *FY' 06 Steam use is ~93,000 Btu/gsf*

Normalization Factors

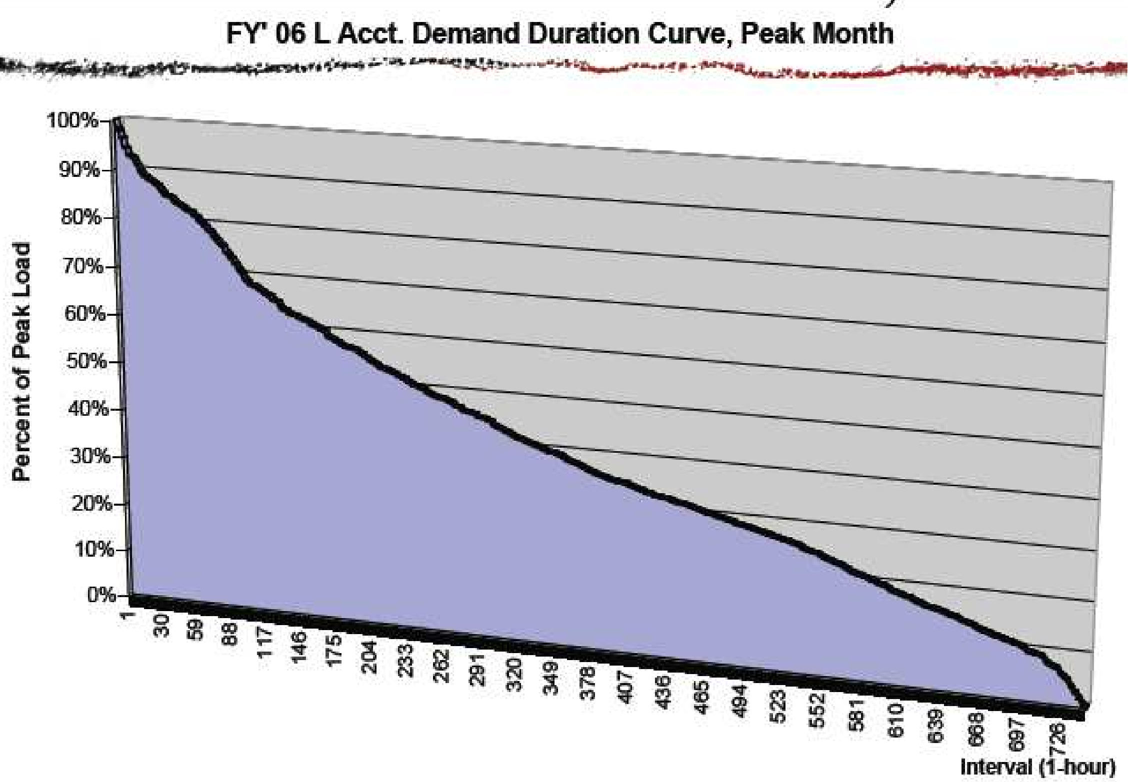
FY' 06 parameters:

- *Gross square feet (university paid utilities only) 4,281,413*
- *Number of students (total, from 2006 factbook) 9,731*
- *Number of students (fte, from 2006 factbook) 8,898*
- *Number of employees (from 2006 factbook) 4,021*
- *HDD/ CDD (from NOAA local climatological data) 5,385/848*
- *University Factbook, www.cmu.edu/ira/index.htm*
- *Space data maintained by Property Accounting Services*

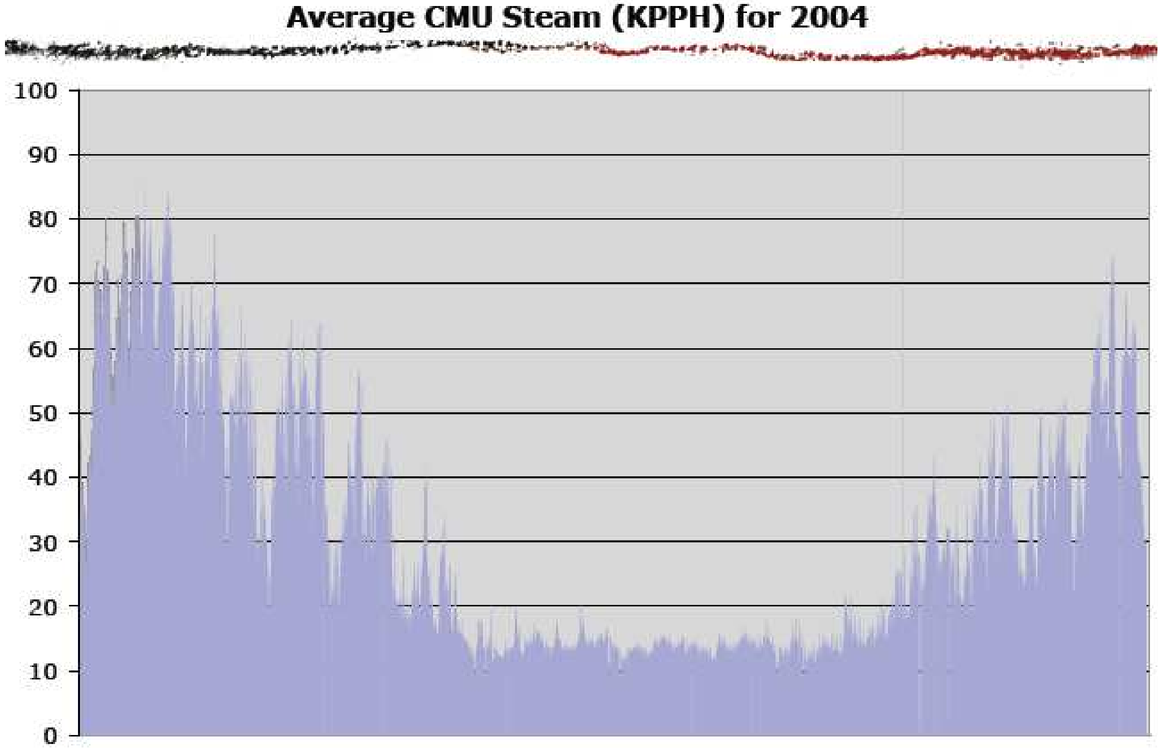
Main Electric Acct Profile



Main Electric Acct Profile, cont.



Steam Profile



Campus Fleet Fuel Consumption

Annual consumption for 73 over-the-road vehicles and 19 off-road campus vehicles:

- *Gasoline, ~30,000 gallons*
- *Diesel, ~ 16,000 gallons*

Brad mentioned that CMU is not interested in generating its own biofuels. They are interested in supporting others by switching their fleet over to biodiesel (buses and heavy trucks), E85 ethanol (light cars and trucks), and electric vehicles (small campus maintenance vehicles).

Initial Wind-power Purchase

Carnegie Mellon made this initial investment to: (1) demonstrate the university's recognition of the importance of development of renewable, less environmentally damaging sources of energy; (2) provide educational opportunities for students, faculty and staff; and (3) help support the development of wind power generation in Western PA.

Emissions

Air emissions produced through campus energy use, at the source:

- *CO_2 (short tons) 160,000*
- *SO_2 (short tons) 300*
- *NO_x (short tons) 300*

Conservation Opportunities

a. Technology change

b. Individual behavioral change

c. Institutional change

Potential energy reduction from a&b, ~30%*

- *Technology upgrades, ~20%*
- *O&M best practices, ~5%*
- *User awareness, ~5%*

Capital Projects

- *LEED (greener bldg) certified new construction*
- *Laboratories for the 21st Century*
- *Energy savings performance contract*
- *Metering/ sub-metering of building utility use*
- *Web access to building utility data, EEMS*
- *Many others*

Institutional Change

Remove disconnect between utility expense & capital investment,

Improve equity and transparency in utility expense allocation,

Write and adopt university energy conservation policy, or

Create an university-wide Sustainable Development Policy,

Establish energy budget for new construction (e.g., kW/sf),

Fund energy conservation line-item in annual budget,

Increase and enforce use of life-cycle costing for procurement,

Enhance and enforce greenness of FMS Design Guidelines.

Design Review of HVAC Controls of the Gates Building, Dr. Wei Qingpeng January 19, 2007

Positives

- One of the best documented projects
- Well metered
- Control Strategy
  - Occupied / unoccupied model
  - Free cooling prior to CO_2 DCV
  - VAV box with operable windows

Opportunity to Improve

- Meter
  - From metered data to useful information
- Design
  - LEED oriented design?
  - Zoning reconsideration?
- Control Sequence
  - Pumps VFD Control: Didn't see it
  - VAV Fan VFD control: SPC to TAVC?
  - Air Handling Process during partial load: reset Ta,su or use steam?
    - Partial use of space;
    - In spring and falls
  - Faults detect and diagnosis?

Metered Data to Information

- Gather real time data and transfer to IW for on-line consulting analysis
  - Metering more equipment (subentry metering)
    - Fans and Pumps
  - Transfer data to IW via wired / wireless network
  - Energy use modeling and analysis tool based on real time metered data
  - Continuous consulting to the owner
- Reconsider the enthalpy recovery wheel
  - Small AHU equipped ERW (1/7 of total air volume) but not bigger ones, get LEED score?
  - Annual hourly simulation to prove how much of energy they could recover
  - Fault detect of the dampers opening and position related to the ERW
- Zoning of VAV System
  - Internal zone and perimeter zone?
  - For different oriented zones
    - If some need cooling, some needs heating, but the system can only offer ONE Supply Air Temp., the reheat will do the job?
  - The minimum air volume of VAV BOX?

Control Sequence

- VFD Fans in VAV systems
  - 2/3 location of SP control strategy, not so good from energy point view
    - Improved by floating pressure control
  - Total Air Volume Control was proved in practical projects
    - Depending on opening of VAV BOX

- Partial load control
  - Even energy consumed than peak load time
  - Not very clear documented
    - Unoccupied mode
    - Free cooling mode

    - DAT Reset Schedule
  - Cooling and Heating
    - Use reheat to offset cooling

- Faults detect and diagnosis
  - Damper position / opening
  - Valve opening / leakage
  - VAV BOX control
    - Senor faults
    - Unsatisfied ratio evaluation
    - Calling for cooling or heating