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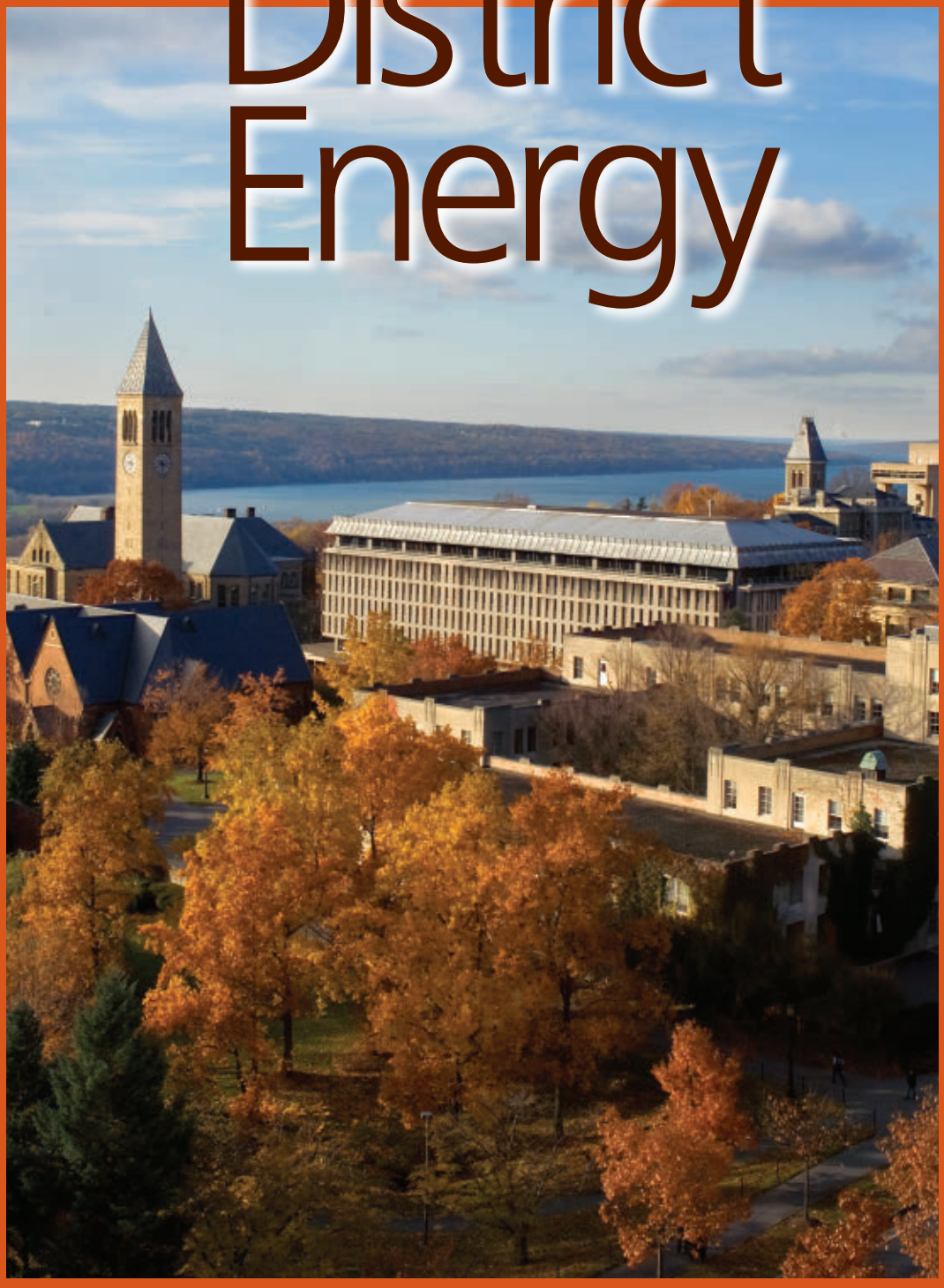

THIRD QUARTER 2010

Cornell's Quest for Climate Neutrality

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Cover Story

Making Climate Neutrality a Reality:

Cornell expands renewable energy supply

James R. Adams, Director of Utilities, Cornell University; Jerrold A. Schuett, PE, Infrastructure Practice Leader, Affiliated Engineers, Inc.; Mike Walters, PE, LEED AP, Sustainability Practice Leader, Affiliated Engineers, Inc.

"The challenges facing our world are great. The time to address and ameliorate them is short. The opportunity for action is now. And the agent of positive change – perhaps more than ever before in our history – can be Cornell."

When Cornell University President David Skorton spoke these words in his fall 2007 State of the University address, he was expressing Cornell's commitment to fostering a sustainable future – not just for the institution, but for all.

The Ithaca, N.Y., university has long been a leader in energy sustainability – at least as far back as the 1880s when it first harnessed the waters of Fall Creek to generate hydroelectricity for campus use. Nearly 120 years later, in 2009, Cornell marked one of its most significant sustainability milestones yet: the release of a Climate Action Plan to reduce campus greenhouse gas emissions to net zero by 2050.

While encompassing a wide range of measures, the plan recognizes that Cornell's greatest opportunity to lower its carbon footprint exists in the area of on-site combustion – in reducing the fossil fuel burned to meet the university's heating and electric needs. A new combined heat and power plant, which has been up and running on campus since January 2010, is already bringing the university much closer to its net zero goal. Plans are also under way to develop and incorporate a variety of renewable energy sources – including innovative geothermal and bioenergy technologies – into the campus fuel mix.

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A Head Start on Sustainability

Cornell's current focus on developing renewable fuels is part of the latest chapter in its history of sustainability, including sustainable energy production. It began with on-campus hydroelectric generation in the 1880s (Cornell remains the only U.S. college campus producing its own hydroelectric power) and continues today with district energy and combined heat and power systems that have been steadily improved over the decades (see System Snapshot).

The heating source for campus is the natural gas-fired combustion turbine CHP plant with heat recovery steam generators and

Photo Jon Reis.

Cornell's new CHP plant opened in January 2010 at the Central Heating Plant, built in 1922. The university first installed a central steam system to serve the Ithaca campus in the late 1880s.

supplemental boilers feeding backpressure steam turbines. Cooling is accomplished via Cornell's innovative lake source cooling system, which uses the deep waters of a nearby lake to cool campus chilled water. More than 85 percent of the electricity needed for campus is supplied by the cogeneration systems, with the balance being taken from the electric grid via a Cornell-owned 115,000-volt substation. These utilities are supplied by distribution networks that cover the 900-acre campus.

Cornell's sustainability initiatives also extend far beyond its energy infrastructure. The university's environmental course offerings – begun in 1875 with arboretum and conservatory botany classes – today exceed more than 150 courses related to climate change and sustainability. In 2007, the university also established the Cornell Center for a Sustainable Future, which awards on-campus grants to groups researching topics directly applicable to carbon reduction.

In April 2010, the university announced creation of the President's Sustainable Campus Committee to oversee all aspects of sustainability in campus operations and facilities. This includes the Energy and Sustainability Department responsible for, among other things, the production and distribution of steam, chilled water and electricity. These systems are run similarly to a private, for-profit utility, with the exception that no profit is made – an approach that helps the department operate efficiently and at the same time maintain its competitiveness with external or distributed energy options. With a campuswide energy management and building operations system, all steam, chilled-water and electric loads are metered by building, quantifying improvement opportunities with absolute metrics. (This capability was very useful in tallying Cornell's greenhouse gas inventory – the first step to implementing the Climate Action Plan and subsequently prioritizing carbon dioxide reduction by emission source.)

Committing to Net Zero

While Cornell has long been a regional and national leader in sustainability and matters of environmental concern, President Skorton has pledged to do more. In 2007, he was a charter signatory of the American College and University Presidents Climate Commitment (ACUPCC). Member institutions signing the ACUPCC commit to pursuing climate neutrality, defined as

Courtesy University Photography.

President David Skorton spoke to students at a gathering celebrating the first anniversary of his pledge to reduce Cornell's energy footprint.

"no annual net emissions of global warming gases to the atmosphere from buildings, transportation, travel, land use and processes under the entity's control."

In September 2008, Cornell assembled a consultant team to draft a Climate Action Plan that would become its blueprint for achieving climate neutrality by 2050. Affiliated Engineers, Inc. (AEI) served as Cornell's technical consultants and project team leader in developing the plan over the next year. Joining AEI were Energy Strategies LLC and transportation consultants Martin/Alexiou/Bryson PC. The plan was funded in part by a grant from the New York State Energy Research and Development Authority (NYSERDA).

When Cornell first signed on to the ACUPCC, popular perceptions of carbon reduction were occupied with energy conservation behaviors and technologies, including more efficient HVAC systems, lighting upgrades and retrofits, improved building energy use standards and user conservation outreach. A year later, however, the price of a gallon of gas exceeded four dollars – a bellwether number in a period of widespread commodity fuel cost volatility. Aware of the challenges posed to institutions by dependence on uncontrollable resources, Cornell's climate action planning team understood the need to address campus energy and carbon issues for the long term. Like the sustainability movement as a whole, the team enlarged its focus beyond reducing energy consumption to include more aggressive carbon-lowering measures on the energy supply side.

Cornell's first step toward developing the Climate Action Plan was to complete an inventory of campus greenhouse gas emissions. This inventory considered the on-site combustion of fossil fuels; purchased electricity consumption; institution-funded air travel; and the commuting of students, faculty and staff. As the base inventory for the Climate Action Plan, Cornell's fiscal year 2008 carbon footprint was estimated at 319,000 metric tons of CO_2-equivalent (CO_2e) emissions associated with fossil fuel consumption, including CO_2, nitrous oxide and methane. Air travel accounted for 8 percent of the total; commuting, 9 percent; and purchased energy, 27 percent. (This assumed that purchased energy was converted to fossil fuel consumption at the grid power plant source and rolled into the carbon footprint.)

Meanwhile, on-site combustion accounted for 56 percent of Cornell's greenhouse gas emissions, equivalent to that produced by 3,000 truckloads of coal. Indeed, coal has been the primary fossil fuel used to generate steam for heating most Cornell buildings. In 2008, the Ithaca campus burned more than 65,000 tons of coal with an associated carbon footprint of 154,000 metric tons. The other significant fuel used, natural gas, had a carbon footprint of 19,000 metric tons. The remainder of on-site combustion was comprised of gas, diesel, miscellaneous oil and propane fuels, with an associated carbon footprint of 5,000 metric tons.

Armed with Cornell's greenhouse gas inventory data, the team embarked on developing the Climate Action Plan in September 2008 using a year-long, five-stage process (see sidebar). It was a comprehensive effort that engaged external consultants, community members, subject matter experts and a broad spectrum of Cornell stakeholders. The resulting plan, approved by Cornell's board of trustees in September 2009, called for action in five major categories:

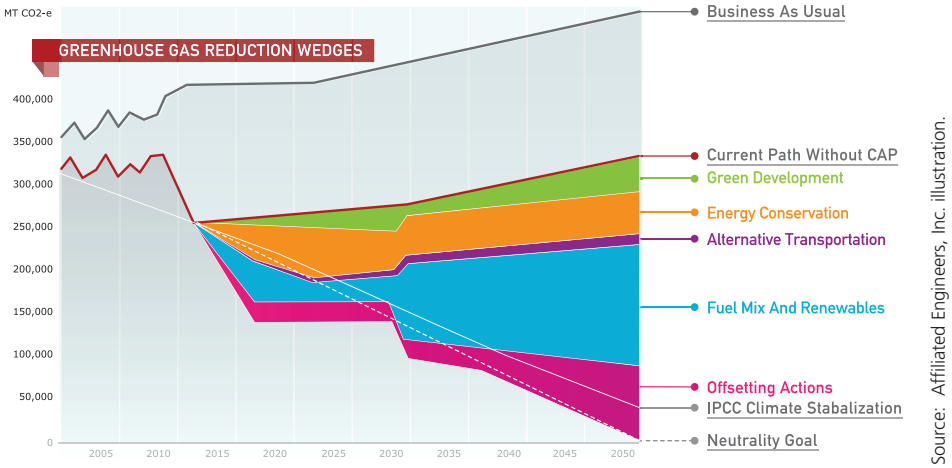
- **Green development** – Improved land use, more effective use of building space and higher energy standards for new construction.
- **Energy conservation** – Renovations of lighting, heating and air-conditioning systems; education of campus users about conservation practices; and development of a smart grid that will improve campus electrical load management.
- **Transportation** – Promotion of mass transportation, reduction of single-occupancy vehicle use for commuting and business travel, and the establishment of higher fuel-efficiency standards for fleet vehicles.
- **Carbon offsetting** – Converting idle university-owned pastures to mature-growth forests and the subsequent management of forest growth to enhance carbon sequestration.
- **Fuel mix and renewable energy** – Converting from coal to natural gas use through startup of Cornell's new CHP plant and continued renewable energy initiatives.

The planning team produced a forecast of Cornell's annual greenhouse gas emissions through 2050, using a 'wedge' diagram to illustrate multiple scenarios (fig. 1): "Business as Usual," had the university not invested in significant campus infrastructure and energy conservation upgrades leading up to the Climate Action Plan; "The Current Path Without Climate Action Plan," indicating the emissions profile before any additional reduction efforts; and the level of additional greenhouse gas reduction possible through a variety of measures called for in each of the Climate Action Plan's five key categories.

The Lion's Share

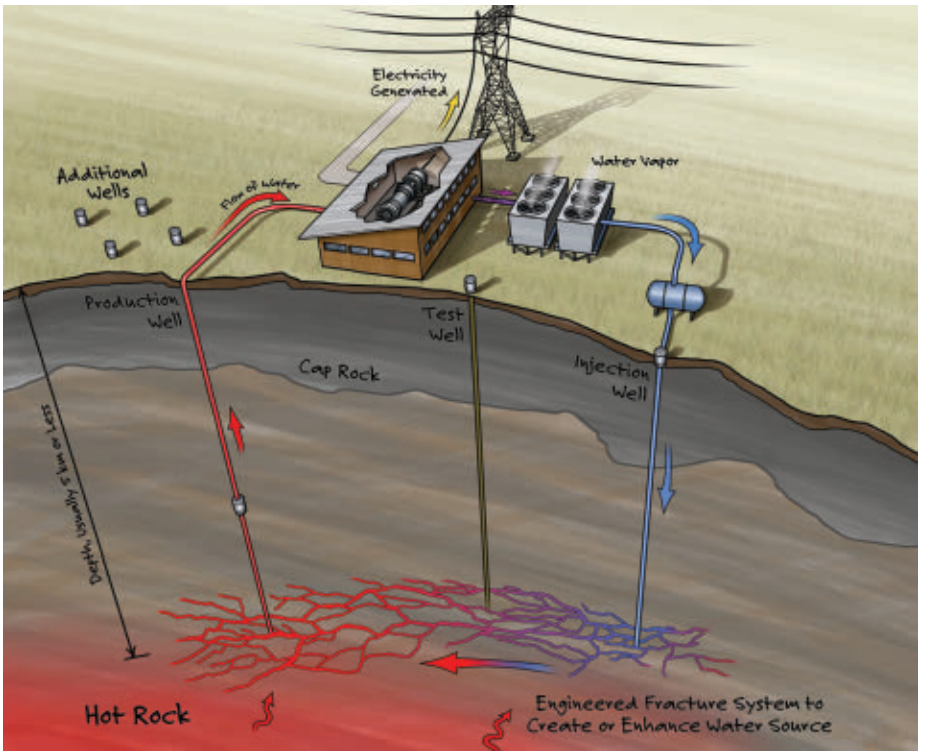
Considering that 56 percent of Cornell's greenhouse gas inventory derives from on-site combustion, the greatest opportunity for carbon emission reductions – as well as exposure to commodity fuel price volatility – exists in the fuel mix and renewable category of actions. In figure 1, the sharp descent from 2009 to 2010 of the "Current Path Without Climate Action Plan" line reflects the initial operations of Cornell's CHP plant, which was projected to generate between 70 and 85 percent of the electricity needed for the campus. By switching fuel sources from coal to natural gas, and producing heat and electricity together, the facility alone reduces campus coal use by 80 percent and associated carbon emissions by 20 percent. (The plant's Solar Titan 130 combustion turbines can run on either natural gas or fuel oil and, in the future, perhaps liquid biofuels.)

Figure 1. Cornell University Climate Action Plan: Greenhouse Gas Reduction Forecasts.



Source: Affiliated Engineers, Inc. illustration.

Figure 2. Conceptual depiction of a full Engineered Geothermal System, including electrical energy production. Cornell's plans call for EGS that focuses solely on the production of thermal energy.



Source: Affiliated Engineers, Inc. illustration.

Subsequent to publishing the Climate Action Plan in September 2009, Cornell made the bold decision to discontinue all use of coal as a heating fuel by July 2011. The university will accomplish this by greater utilization of the CHP facility and the use of existing gas/oil boilers when peak loads require it. Eliminating all coal will further reduce emissions by approximately 64,000 metric tons of CO_2e per year, an additional 20 percent.

Additional fuel mix and renewable energy actions (not including the new CHP system) will account for the majority of carbon abatement in the Climate Action Plan, eliminating approximately 137,000 metric tons of CO_2e annually. These combined measures would achieve a dramatic shift using renewable energy initiatives focused on regional and global research priorities, jobs creation and available local resources. These initiatives include installing eight 1.4 MW wind turbines with a 30,500 MWh annual output; upgrading the hydroelectric plant to improve efficiency and output; and replacing an existing 1,810 kW single-stage turbine at the Central Heating Plant with a newer multistage steam turbine generator rated at 2,360 kW.

Two additional – and possibly eventually interrelated – renewable energy action items include researching and developing campus biomass energy resources through the Cornell University Renewable Energy Initiative (CURBI) and developing a hybrid engineered geothermal system (EGS) that could ultimately be combined with a campus biomass-to-biogas system to feed district energy system boilers.

The CURBI program is currently studying how best to convert 57 campus waste streams and other university-owned biomass resources through cutting-edge conversion technologies for use in the Cornell CHP plant. Several options are under consideration, including direct combustion, anaerobic digestion and pyrolysis/gasification, all of which could potentially be used to offset the use of natural gas for campus steam production. Initially these biomass energy resources may be used to heat greenhouses and other energy-intensive facilities, with eventual connection to the district energy system as it expands to serve more square footage.

Commonly referred to as "deep hot rock," EGS is an emerging technology that proposes to utilize heat energy beneath the earth's surface to generate district heat and electricity (fig. 2). Cornell's Ithaca campus sits atop more shallow geothermal resources (2-4 miles below the earth's surface) than are found elsewhere in the northeastern United States. According to Jefferson Tester, Cornell's Croll Professor of Sustainable Energy Systems in the College of Engineering and an expert in EGS, a two-well binary

geothermal system could produce up to 600,000 MMBtu per year – equating to about half Cornell's current annual thermal demand.

Ultimately the EGS installation could be expanded, converting the entire campus steam system to hot water heat distribution, with EGS meeting the majority of campus heating needs. Rather than overbuild the EGS to meet peak heating season loads, a hybrid system would link the EGS to a biomass-to-biogas system to provide additional hot water. The particular design of this biomass gasification system would depend on the results of the current CURBI feasibility study.

Converting biomass to biogas would open up the possibility of combusting biogas in existing boilers or combustion turbine duct burners providing electricity and steam for campus. Fully implemented, this innovative marriage of EGS and biomass gasification alone could eliminate nearly 113,000 metric tons of CO_2e annually, or 35 percent of the university's total greenhouse gas reductions needed to reach climate neutrality.

All told, Cornell's proposed renewable energy initiatives could reduce the university's energy and carbon compliance costs by millions of dollars over the next 40 years and eliminate approximately 170,000 metric tons of CO_2e on an average annual basis. At the same time, these actions would advance Cornell as a premier renewable energy research institution.

All told, Cornell's renewable energy initiatives could eliminate approximately 170,000 metric tons of CO_2e on an average annual basis.

As Cornell develops and incorporates more renewable energy sources into its fuel mix, one challenge it will face is to match generation capacity to campus needs, balancing 'as-supplied' energy resources (wind, solar and conventional hydropower) with 'on-demand' energy (geothermal and stored biomass). In part, this is being facilitated by Cornell's ongoing investment in electrical transformers and switchgear

System Snapshot: Cornell University
System Owner/Operator: Cornell University
Location: Cornell University, Ithaca, N.Y.

Steam/Cogeneration System	Chilled-Water System	
Startup Year	1922	1963
Number of Buildings Served	300	80
Total Square Footage Served	14 million sq ft	7 million sq ft
Central Plant	Combined Heat and Power Plant	Lake Source Cooling Facility
Plant Type backpressure steam turbines	Gas turbine cogen with two loop via heat exchangers, separate peaking chillers	Open lake water loop connected to closed campus
Central Plant Capacity 37.5 MW electric	680,000 lb/hr steam	25,450 tons chilled water
Satellite Plant Capacity	N/A	N/A
Number of Boilers/Chillers	6	3
Annual Energy Delivered	2,100,000 MMBtu	500,000 MMBtu
Fuel Types	Natural gas, No. 2 ULSD	N/A
Length of Distribution Network 12.4 miles of condensate line 165 underground vaults	13.4 miles of steam line	12,000 ft supply, 12,000 ft return
Primary Piping Type	Concrete shallow trench	Welded steel with coating and cathodic protection
Piping Diameter Range	1-18 inches	4-42 inches welded steel
System Pressure	35-110 psig	up to 250 psig
System Temperatures	200 F condensate return Campus loop supply: 42-45 F	Lake water supply: 39-41 F
System Water Volume	N/A	8 million gal
Thermal storage	N/A	4.4 million gal

Source: Cornell University.

– and research in smart grid technology – allowing campus energy managers to track and eventually control energy supply and demand in real time. Monitoring all energy and distribution sources as well as energy demand, and modulating utility production to match system need, will enable wind, solar and hydropower to be more effectively utilized.

A Larger Vision, a Broader Mission

As New York state's land-grant university, Cornell helps turn knowledge into practical actions and contributes to the economic prosperity of the public realm. The university's programs in energy, environment and economic development involve more than 30 on-campus centers, 300 faculty and 60 state extension agents in initiatives at local, national and international levels. The Climate Action Plan itself was granted funding from NYSERDA so that the planning processes and tools created to develop it can be used by other institutions and municipalities. The practical answers that Cornell's Climate Action Plan will yield on questions of environmental sustainability are indeed answers that, as President Skorton envisioned, will belong to us all.

Authors' Note: *The authors wish to thank Peter Strupp, director of communications, Affiliated Engineers, Inc., for his contributions to the writing of this article.*

James R. Adams, Cornell University's director of utilities since 2000, manages campus production and distribution of steam, chilled water, electricity and potable water. He participated actively in the development of the Climate Action Plan, leading the fuel mix and renewable 'wedge' and defining carbon offsetting activities on behalf of the university. In the energy industry since 1980, Adams currently serves on IDEA's board of directors. He may be reached at jra4@cornell.edu.

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Mike Walters, PE, LEED AP, is sustainability practice leader for Affiliated Engineers, Inc. He directed overall development of Cornell's Climate Action Plan. His consulting projects have included work for the National Institutes of Health and King Abdullah University of Science and Technology in Saudi Arabia. A frequent industry speaker, Walters has taught the sustainable building design and LEED course at the University of Wisconsin-Madison. He can be contacted at mwalters@aeieng.com.

The Planning Process

The year-long development of Cornell University's Climate Action Plan, led by consultants Affiliated Engineers, Inc., proceeded in five stages:

1. **Discovery** – During this stage, the planning team established base case metrics against which all Climate Action Plan options would be assessed. These included estimates of campus growth, projected energy supply and demand by energy type, and costs associated with future greenhouse gas regulations.
2. **Ideation** – Next, methods and strategies for carbon reduction were solicited from the entire Cornell and Ithaca communities, ultimately generating 706 ideas that were grouped with like concepts and either advanced or identified for research, future consideration or elimination.
3. **Analysis** – In this phase, the 706 ideas were grouped according to 114 themes and were assessed relating to scale of implementation, carbon abatement potential, first cost, operating cost and qualitative review of environmental (beyond carbon), economic, social and institutional considerations ('triple bottom line plus'). Actions advanced from analysis were considered together as an interrelated investment portfolio, and 19 actions were endorsed for the next stage.
4. **Plan Creation** – This stage was comprised of near-term actions for immediate implementation, recommended mid-term actions subject to periodic review and long-term opportunities that should be monitored and assessed over time.
5. **Execution** – The final stage, executing the plan, is now under way, consisting of feasibility studies, grant proposals and project development.

Cornell's Climate Action Plan is not a static document, but a dynamic tool and an evolving initiative, in keeping with opportunities that will surely emerge with new technologies and changing cultural and economic circumstances over the next 40 years. Accordingly, the principle objectives of the plan are profiled, and their progress will be reported on Cornell's dedicated Climate Action Plan Web site.

To learn more about Cornell's Climate Action Plan, visit www.sustainablecampus.cornell.edu/climate.