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Greening MIT

As the Institute publicly declares the need to curb greenhouse-gas emissions, it faces the daunting challenge of reducing energy use on campus.

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Steven Amanti spent a good chunk of his senior year at MIT spying on his fellow students and researchers. From November 2005 to April 2006, during the day and at odd hours of the night, he made innumerable visits to Building 18, which houses 40 chemistry labs. He peered into those labs, took time-lapse photographs, and jotted down notes, recording behavior he would later characterize as excessive, irresponsible, and even dangerous.

As part of his thesis for a bachelor's degree in mechanical engineering, Amanti was documenting the ways energy was being wasted in the building, one of the biggest energy consumers on campus. On the basis of his observations, he estimated that MIT was squandering as much as $350,000 a year on heating, cooling, and electricity it didn't need--just for that one building. And, he said, the Institute could stop this waste by taking steps that would cost almost nothing.

Amanti's investigations happened to coincide with the beginning of the MIT Energy Initiative (MITEI), a major effort to promote energy research and education at the Institute. When President Susan Hockfield discussed the initiative in November 2005, she said that in addition to spawning innovative, eco-friendly energy technologies, itwas also meant to inspire change in the way the Institute itself uses resources: "I very much hope that we will also lead by example and ... model sustainable energy practices on our campus."

Since then, MIT has taken steps to make this happen. New buildings going up on campus were designed to be more energy efficient than conventional buildings. And faculty, staff, and students working on several different projects have uncovered energy-wasting equipment and practices across campus that could add up to millions of dollars a year. A group of students from the Sloan School of Management, for example, worked with the facilities department to identify energy-saving projects costing $14 million that could pay for themselves in less than three years. Already, a $765,000 investment in a two-year project is saving the Institute about $800,000 a year.

To get projects like these off the ground, last year MIT's executive vice president and treasurer, Theresa Stone, set up a new MIT Energy Conservation Investment Fund with seed money of $500,000. Alumni have since pitched in an additional $1.5 million to the MITEI Campus Energy Task Force Fund, including a $1 million gift from Jeffrey Silverman '68 establishing the Silverman Evergreen Energy Fund. The money saved through the projects paid for by these funds will be reinvested in other conservation projects.

But operating a research institute sustainably is no easy task. Labs consume far more energy than offices or residences, largely by necessity. What's more, plenty of "green" companies are eager to sell solutions that might not really work. "One of the institutional obstacles to doing something about energy efficiency is the perceived uncertainty about costs and savings," says Steven Lanou, MCP '98, deputy director for environmental sustainability in MIT's Environment, Health, and Safety Headquarters Office and a member of the MIT Energy Initiative's Campus Energy Task Force. "There's often skepticism about promises of conservation. What's the bang for my buck really going to be?"

Energy Hogs

Amanti's time-lapse photos showed Building 18's lights glowing constantly day and night. Light-sensor readings revealed that the building was twice as bright inside as others on campus. But the lights, Amanti calculated, accounted for only 5 percent of the electricity used. The main problem--the reason this building consumed more energy per square foot than any other MIT building but one--was that it had 200 fume hoods, and researchers were leaving them open when they weren't in use.

Fume hoods are "one of the greatest energy hogs on campus," says Stone, who cochairs the Campus Energy Task Force. These cabinetlike devices use fans to pull air away from the confined environment of the laboratory, carrying traces of toxic chemicals outside so that researchers don't breathe them in while doing experiments. But in so doing, they're constantly pulling heated or cooled air out of the building. "It's like leaving your front door and your back door open all day," says Peter Cooper '70, manager of sustainable engineering and utility planning at MIT's facilities department. By one estimate, he says, a single fume hood typically accounts for as much annual energy use as two homes--and there are more than a thousand on campus.

Conventional fume hoods pump air at the same rate whether their glass doors are open or closed. The hoods in Building 18, however, had been selected because the airflow drops by two-thirds when the doors are closed, potentially making them much less wasteful. But the researchers were defeating the purpose. Amanti found that some had even disabled alarms designed to sound whenever the hoods were using more energy than necessary, "jamming the mute button with scraps of paper," he wrote.

Lab heads had little incentive to get researchers to close the hoods. Individual departments and researchers don't pay their own energy bills, Cooper says; the Institute as a whole picks up the tab. Requiring each lab to pay for the energy it uses might motivate researchers to save, he says, but the current policy is unlikely to change--for good reason. At MIT, it's easy for, say, a biologist and an electrical engineer to form a lab together. Although getting space allocated can sometimes be a challenge, "they don't have to worry about the biology department and the electrical-engineering department combining their budgets," he says. "When we compare ourselves to other research universities, a lot of our success is because we have interconnecting corridors and a common financial system."

As it turns out, people can be persuaded to change even without a financial incentive. After the head of the chemistry department, Tim Swager, learned how energy hungry his building was, he decided to do something about it, and went looking for a way to reveal the most wasteful labs. Each fume hood is equipped with sensors that record how far open the doors are and relay that information to a system that controls the airflow. Swager found $12,000 to develop a program to convert the data into reports that compare all the labs, identifying the best performers and exposing the worst offenders.

The reports prompted researchers to close the hoods more often; that saved the Institute about $24,000 a year and reduced carbon dioxide emissions by 93 tons in Building 18 alone, according to an analysis done by Dan Wesolowski, PhD '08. Even though the chemistry department itself didn't save any money, Cooper says, "just giving them information changed behavior."

Other efforts to change behavior are under way. Wesolowski, along with other students, also studied the use of revolving doors in the MIT Medical building (E25). "On average eight times as much air is exchanged when a swing door is opened as opposed to a revolving door. That's eight times as much air that needs to be heated or cooled," the students wrote. They concluded that if everyone used the revolving doors in E25, MIT would save almost $7,500 in natural gas each year--enough to heat five houses--and eliminate nearly 15 tons of carbon dioxide emissions. Their study also found that many people avoid the revolving doors because they're hard to push, a problem the facilities department has since addressed by servicing them and making sure they work properly. And Wesolowski found that more people use these doors if signs explain why it's a good idea and thank them for doing so. Permanent versions of those signs are now installed across campus.

But getting people to change their behavior isn't enough. The $24,000 per year saved by closing the fume hoods, for example, was less than 7 percent of what Amanti had expected; according to the data Swager collected, the hoods weren't being left open as wide as Amanti had estimated, so far less energy was being wasted. Another problem with behavioral changes is that they don't always last. A recent study of energy-efficient buildings by the National Renewable Energy Laboratory in Golden, CO, showed that bad habits can return quickly: people who at first responded to prompts to save energy in a new building were ignoring them after a year. At the least, maintaining savings from behavior requires continuing education, Lanou says--especially at a place like MIT, where new people are constantly arriving.

Where people fail, however, technology can sometimes help. And even disappointing results can be instructive if they yield enough data. Such detailed information has been missing from many efforts to improve energy efficiency because making the necessary measurements can be costly; but MIT has decided to focus on carefully quantifying changes in energy use to determine what approaches work, and how well.

Steam Traps and Data Floods

Most of MIT's projects for cutting energy use won't win any prizes for innovation. The lights in the duPont squash courts used to burn 24 hours a day. No more: occupancy sensors now shut them off when no one is playing. Likewise, installing occupancy sensors in the ice rink and swapping old high-intensity discharge lamps for fluorescent lamps has cut electricity consumption for lighting in half, while making the rink twice as bright. Still, these and similar changes to be made across campus are expected to pay for themselves in a little over two years.

The facilities department is rigorously tracking results from such projects to verify which ones pay off. To test one energy-saving measure, they replaced faulty steam traps in one of the two nearly identical East Campus dorm buildings. Properly functioning steam traps keep the steam in radiators until it condenses and gives off its heat; when they don't work, steam passes through continuously. Not only does this make the radiator too hot, it also wastes much of the energy in the steam. Replacing the traps campuswide saved about $800,000 in one year, more than covering the $765,000 bill for the repairs and the sensors installed to monitor the system. Although it cost more to install the East Campus sensors than it did to fix the two dorms' steam traps, Cooper considers the money well spent since it allowed MIT to quantify the savings.

Some of the changes rely on more advanced technologies, at least to identify the problems that need fixing. MIT's large buildings use heating, ventilation, and air-conditioning systems very different from those used in homes. Enormous air handlers regulate temperature with steam coils for heating and chilled-water coils for cooling--both fed by MIT's central cogeneration plant, which captures the waste heat from electricity generation to make steam that can be used directly or harnessed to drive compressors and refrigerators. Such air handlers are often controlled by a system that records data such as temperatures and flow rates of air and water, and pressure differentials in the ductwork.

MIT's control system, one of the largest in North America, collects and sends about 50,000 data points every 15 minutes. Typically, this kind of information isn't preserved or analyzed; it's used only to control air handling from moment to moment. But lately a few companies have started to set up systems that translate measurements originally recorded in different terms so that certain data can be archived and analyzed comprehensively with the help of computer models and algorithms devised by mechanical engineers and other experts. This type of analysis helps companies determine whether a building is operating the way it's designed to. They can then identify problems and estimate how much it will cost to fix them.

MIT has enlisted one of these companies, Boston-based Cimetrics, to monitor and analyze some of its buildings. The company has so far identified ways to save more than $500,000 a year; about half of these projects have been completed. In Building E25, for example, the readings revealed that a new system designed to capture some of the heat being pumped out of the building by the ventilation system wasn't working properly. "Our guys went crawling through the ductwork and found that it had collapsed," Cooper says. Without the analysis from Cimetrics, "this might never have been found--and certainly not soon enough to be fixed under warranty."

But while most buildings on campus are on the building control system, analyzing all of the captured data "is hard, expensive, and almost impossible to do by hand for over 100 buildings on MIT's campus," says Stephen Samouhos '04, SM '06, a mechanical-engineering doctoral student involved in several energy projects on campus. "Even for one building, control data analysis is very challenging to perform." Samouhos speaks from experience, having studied the information science and technology building (N42) to identify opportunities to conserve energy. But within days of installing sensors in N42, he found ways to reduce energy consumption by 25 percent. One source of waste: the lights stayed on all night. "If you walk around that building, you can't even find where the light switches are," he says. He also discovered that because the building was designed to hold a never-installed data center, which would have generated a lot of heat, it has a bigger air conditioner than it needs. And even though that air conditioner can cool the building in about 20 minutes, it's switched on four hours before anyone arrives for the day. The fix is simple, Samouhos says: just uncheck one box in the control software.

And in building 6C, Samouhos discovered that occupancy sensors--designed to shut off the lights when no one was around--had been mistaken for light switches and turned off. "It's the last mile of finishing a project that prevents us from capitalizing on projected savings," Samouhos says. Labeling sensor switches "is not very hard to do," he points out. "You just have to have somebody to do it."

Taking care of such details will be important in new campus construction, which is being guided in part by a process called integrated design, says Leon Glicksman '59, PhD '64, a professor of building technology and mechanical engineering, who cochairs the Campus Energy Task Force. In integrated design, efficiency measures--such as more thoroughly insulated windows with better coatings to keep heat out in the summer and in during the winter--are considered at the same time as basic systems such as heating and air-conditioning. That way, for example, a smaller-than-usual air conditioner can be chosen in anticipation of lower cooling requirements. The new Sloan Building, which Glicksman says will probably be the most energy efficient building on campus, will use windows that will enhance energy savings in the winter by capturing more solar energy and yet reduce the amount of heat lost through the windows at night. But integrated design pays off only if building managers make sure that the energy-saving designs work as planned. So the new buildings will be monitored to confirm energy savings.

Doing More

All these projects are just a sampling of the energy efficiency work going on at MIT. Professors such as Harvey Michaels, an energy efficiency scientist in the Department of Urban Studies and Planning, are researching effective approaches to government policy. Samouhos is working with Neal Gershenfeld, the director of MIT's Center for

Bits and Atoms, to develop networks that can collect data less expensively than the control systems in large buildings--and in even finer detail. For example, every lightbulb in a building could be monitored separately. They're also developing algorithms to use this information to do such things as alert building managers if heating systems are, as Samouhos puts it, "digressing in their behavior." The next step is to develop software that helps people decide what to do with the information. "I can't just say, Your chiller's not working," Samouhos says. "I have to say, Your chiller is wasting $100 a day, and the return on investment for you to get a service manager is x."

For all the activity on campus, however, many people think there should be more. "I don't think we've seen anywhere close to what we should see in terms of investment," says Jason Jay, a Sloan doctoral student and a member of the Campus Energy Task Force. He points out that the facilities department identified $1 billion worth of capital renewal projects that have been postponed, many of which could have an impact on energy efficiency. And so far only $2 million has been allocated toward the $14 million worth of energy-saving projects that the Sloan group helped identify. Money is scarce, especially in the current economic climate. A quarter of that $2 million came from discretionary funds--and no discretionary funds are available this year, according to Theresa Stone.

The current approach to raising money for efficiency projects is to ask alumni and other donors. But Jay would like to see MIT seek out alternative funding as well. Even in this economy, he says, many banks, for example, are willing to provide loans for energy efficiency projects, because their results are so reliable.

Such financing could allow MIT "to get the boring stuff done, like repairing steam traps and putting in fluorescent lighting," Jay says. "Then we can turn our attention to the interesting and exciting stuff." He'd like to see MIT start taking technologies out of the lab and applying them on campus, both as a learning tool for students and as a source of inspiration to green architects. "It would allow MIT to be a demonstration site and a sort of beacon for the rest of the world for what energy efficiency leadership looks like," he says.

He may soon be getting his wish, at least in part, when building space on the north side of campus is transformed into the headquarters of the MIT-Fraunhofer Center for Sustainable Energy Systems. "They're going to renovate that building and make it a showcase for energy efficiency," says Glicksman. The idea is to make it a proving ground for new technologies, and to demonstrate what works.

In the end, beyond saving money, that's what all the energy efficiency projects at MIT are supposed to do.

Upcoming Events

Lab to Market Workshop (http://www.technologyreview.com/emtech/09/workshop.aspx)
Cambridge, MA
Tuesday, September 22, 2009
http://www.technologyreview.com/emtech/09/workshop.aspx (http://www.technologyreview.com/emtech/09/workshop.aspx)

EmTech 09 (http://www.technologyreview.com/emtech)
Cambridge, MA
Tuesday, September 22, 2009 - Thursday, September 24, 2009
http://www.technologyreview.com/emtech (http://www.technologyreview.com/emtech)

Nanotech Europe 2009 (http://www.nanotech.net/)
Berlin, Germany
Monday, September 28, 2009 - Wednesday, September 30, 2009
http://www.nanotech.net (http://www.nanotech.net/)

2009 Medical Innovation Summit (http://www.clevelandclinic.org/innovations/summit)
Cleveland, OH
Monday, October 05, 2009 - Wednesday, October 07, 2009
http://www.ClevelandClinic.org/innovations/summit (http://www.clevelandclinic.org/innovations/summit)