GUIDEBOOK

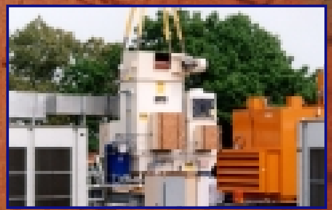
Integrated Energy Systems Test Center at the University of Maryland

Cooling

- Chillers
- Desiccants

Heating

- Space
- Water



Power

- Microturbines and industrial turbines
- Reciprocating engines
- Fuel cells

"Roughly 67 percent of the energy contained in the fuel for electrical generation is rejected as waste heat into the environment. This waste heat is available at recoverable temperatures and can be utilized for air conditioning, heating, humidity control, and other usable forms of energy. By doing so, average energy efficiency can increase from 33 percent or less, typical for a conventional system, to as high as 70 percent for an integrated energy system [IES], although the efficiency of electricity generation is reduced."

Reinhard Radermacher, Professor of Mechanical Engineering and Director of the Center for Environmental Energy Engineering, University of Maryland, College Park

"Our nation has been good at improving the energy efficiency of individual pieces of energy technology. American manufacturers are very good at developing air conditioners, boilers, and power generation as stand-alone pieces of equipment that perform very well. However, we have not considered that, in the real world, these individual contributors do not function efficiently with one another. What an IES is about is integrating technologies like on-site power generation, heat recovery, and thermally activated technologies to achieve synergistic efficiency gains not possible from individual contributors."

Ronald Fiskum, Program Manager for the U.S. Department of Energy's Office of Distributed Energy Resources

"The Integration Test Center and the University of Maryland are seeking to provide essential real world answers to IES integration issues. In the short time of the center's existence, we have learned important technical lessons that are being transferred to industry to develop new equipment and integration solutions."

Phil Fairchild, Program Manager for Cooling, Heating, and Power, Oak Ridge National Laboratory

ADMINISTRATION SUPPORTS ENERGY EFFICIENCY BREAKTHROUGH

President Bush's 2001 National Energy Policy recognizes that new technologies like integrated energy systems (IES) are an important part of tomorrow's portfolio of energy solutions. Industry has partnered with the U.S. Department of Energy (DOE) to form a national strategy for implementing IES technologies in commercial buildings, known as the *BCHP Initiative Roadmap*. In 2001 Energy Secretary Spencer Abraham also announced DOE's goal of making IES technology the preferred system for commercial buildings by 2020.

Current integrated energy systems are all erected in the field. This is fine for large systems, but far too costly and complex for systems providing less than 1,000 kW. Therefore, industry and DOE have together concluded that integrated energy systems need to be developed.

Notes Ronald Fiskum, a Program Manager for DOE's Office of Distributed Energy Resources, "In the near future, IES for buildings systems will be engineered in the factory instead of in the field. The test bed located at the University of Maryland will yield a series of packaged integrated energy systems where you deliver a system; make electrical, hot water, and chilled water connections; and push the start button."

"New technologies are proving that we can save energy without sacrificing our standard of living. And we're going to encourage it in every way possible."

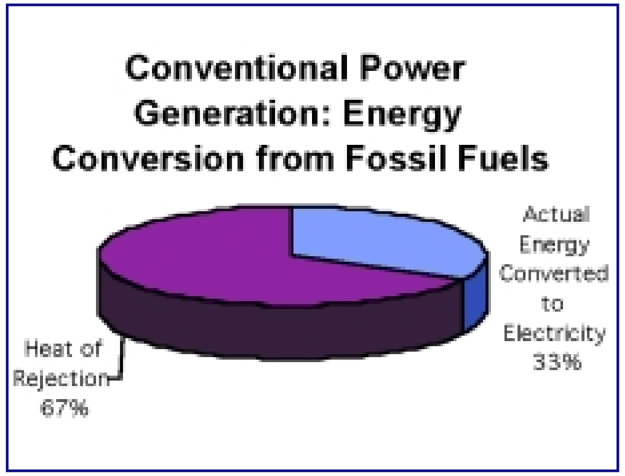
Richard B. Cheney,
Vice President of the United States
Statement made at the release of the National Energy Policy, May 17, 2001

Packaged or modular integrated energy systems and universal connection standards would greatly simplify installation and maintenance—encouraging acceptance of the technology by the architectural and engineering communities. DOE is investing in integration research and development to provide industry with essential systems and building knowledge, allowing for development of the next generation of integrated systems.

IES FOR BUILDINGS: SUPERIOR ENERGY EFFICIENCY, RELIABILITY, AND AIR QUALITY

Approximately 67 percent of energy contained in fossil fuels for conventional power generation is rejected as waste heat into the environment. Advanced integrated energy systems use waste heat from distributed generation to cool and heat buildings, increasing system efficiency to 70 percent or more.

On-site power generation technologies—microturbines, turbines, reciprocating engines, and fuel cells—are becoming effective ways to generate electricity. Recovered waste heat from these technologies can be used to power thermally activated technologies, control humidity with desiccant dehumidifiers, and heat buildings with steam or hot water.



Benefits of IES include:

- **Increase reliability of a building's power supply**. When coupled with uninterruptible power supply systems, IES can provide highly reliable power for mission-critical facilities—a substantial advantage in today's volatile electricity market.
- **Delay or eliminate the need for construction of new power facilities**, especially for hard-to-site transmission line and expensive distribution upgrades.
- **Reduce CO_2 emissions**. According to DOE, integrated energy systems could reduce annual greenhouse gas emissions by at least 25 million metric tons of carbon if goals to double U.S. installed capacity by 2010 were met. IES will also reduce emissions at the regional level.
- **Improve indoor air quality (IAQ)**. In combination with a desiccant dehumidifier, IES can provide better humidity control than conventional systems, and reduce the potential for mold and bacteria growth.
- **Reduce reliance on imported energy resources**

INTEGRATION TEST CENTER

The IES Test Center at the University of Maryland was designed to create a new understanding of how to integrate equipment into IES and integrate IES into buildings.

Sponsors of the Test Center include the U.S. DOE, manufacturers, and utilities. Program management is provided by Oak Ridge National Laboratory (ORNL). The Test Center is examining energy efficiency from the perspective of the Second Law of Thermodynamics — securing the highest level of energy performance from each BTU of fuel.

University of Maryland's Chesapeake Building

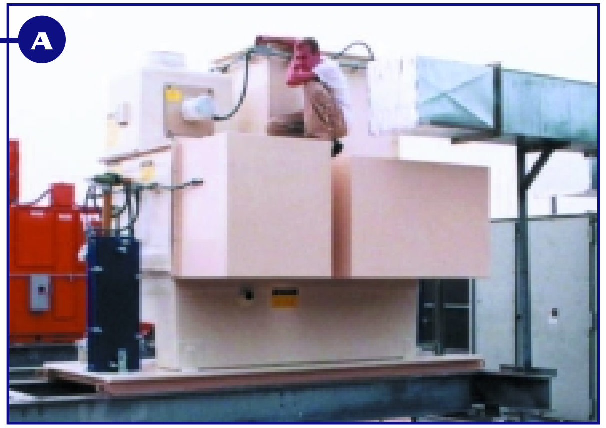
"The Integration Test Center will show that distributed generation equipment—properly integrated with heating, cooling and/or humidity control equipment—can be successfully packaged and coupled with an office building. We expect to show that future generations of integrated energy systems will provide reliable and economically viable services to the customers who use them."

Patti Garland, Technical Project Manager, Oak Ridge National Laboratory

The University of Maryland's Chesapeake Building was chosen for the Test Center partly because the 52,700-square-foot building is representative of medium-sized commercial buildings, which comprise 23 percent of all buildings in the United States

Students and research professionals working on Test Center projects will share their findings with industry, government, educators, and the engineering community. Lessons learned will provide manufacturers with the knowledge to build the next generation of packaged IES for commercial buildings.

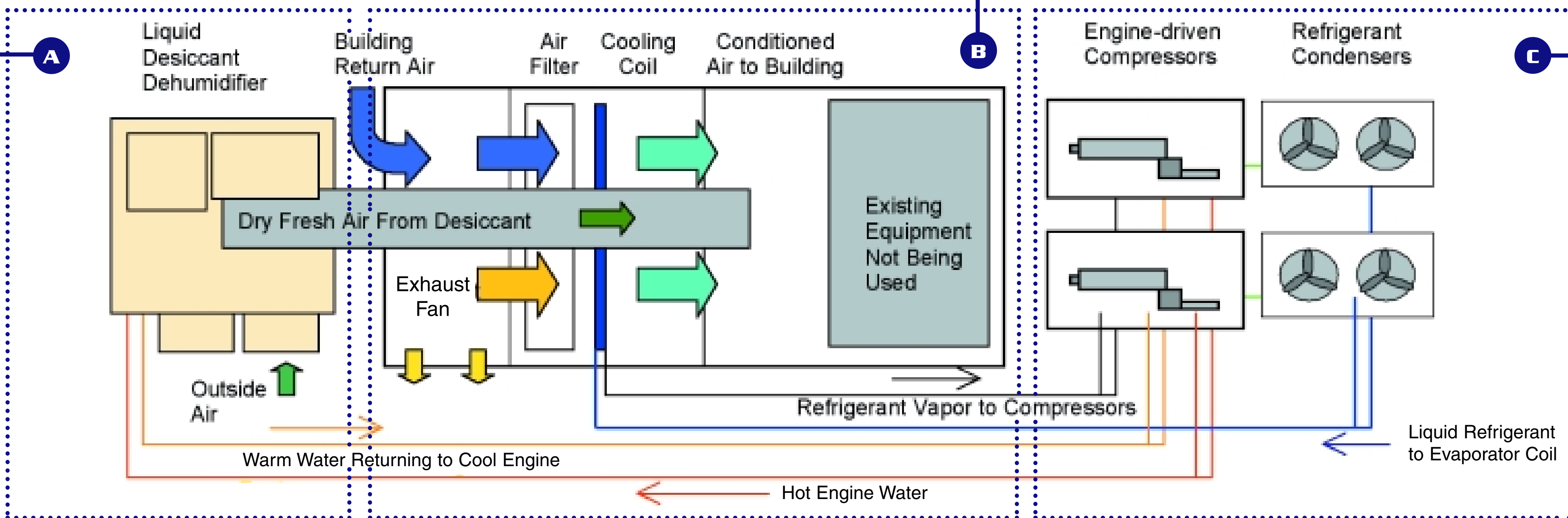
TESTING: COOLING ZONE ONE



Liquid desiccant dehumidifier

Rooftop air conditioning unit (RTU)

Engine-driven compressors and refrigerant condensers



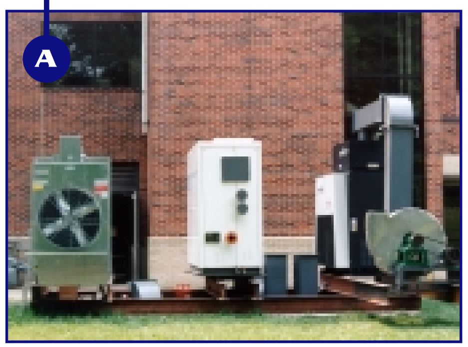
Two natural gas-powered, engine-driven air conditioners (EDAC), along with engine jacket water and exhaust, power a liquid desiccant dehumidifier to cool and dry the air in Cooling Zone One. Using natural gas to power the EDAC cuts the need for grid-based electrical power.

The dehumidifier supplements the cooling load on the EDAC and RTU by drying supply air, a function typically accomplished by mechanical cooling of the EDAC and RTU alone. Together, these interactive components cool Zone One, reducing both pollution and energy use.

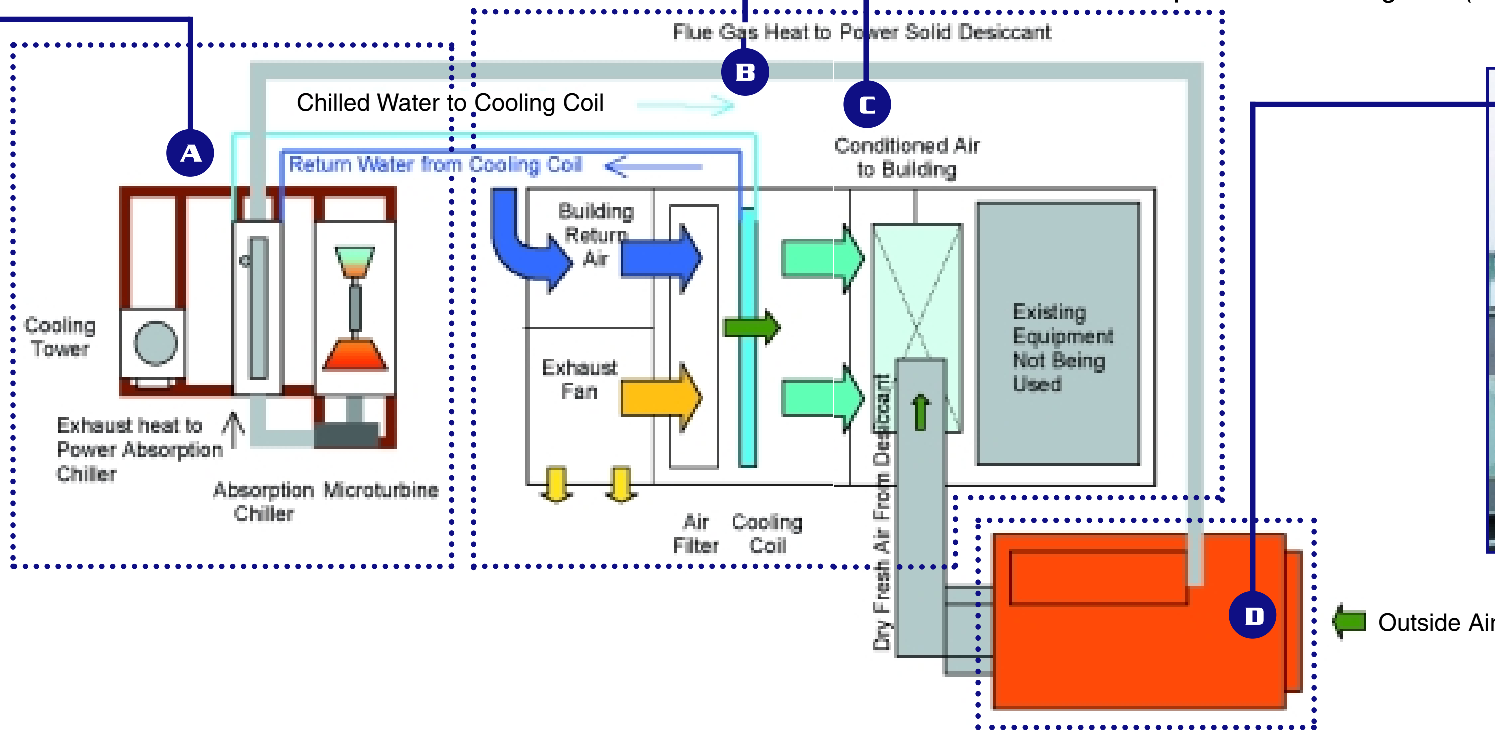
TESTING: COOLING ZONE TWO

Pictured: Chilled water piping (white) to and from the absorber to Zone Two RTU, and exhaust duct (silver) from the absorber flue to regenerate the solid desiccant unit

Rooftop air conditioning unit (RTU)



Microturbine and IES



Desiccant dehumidifier

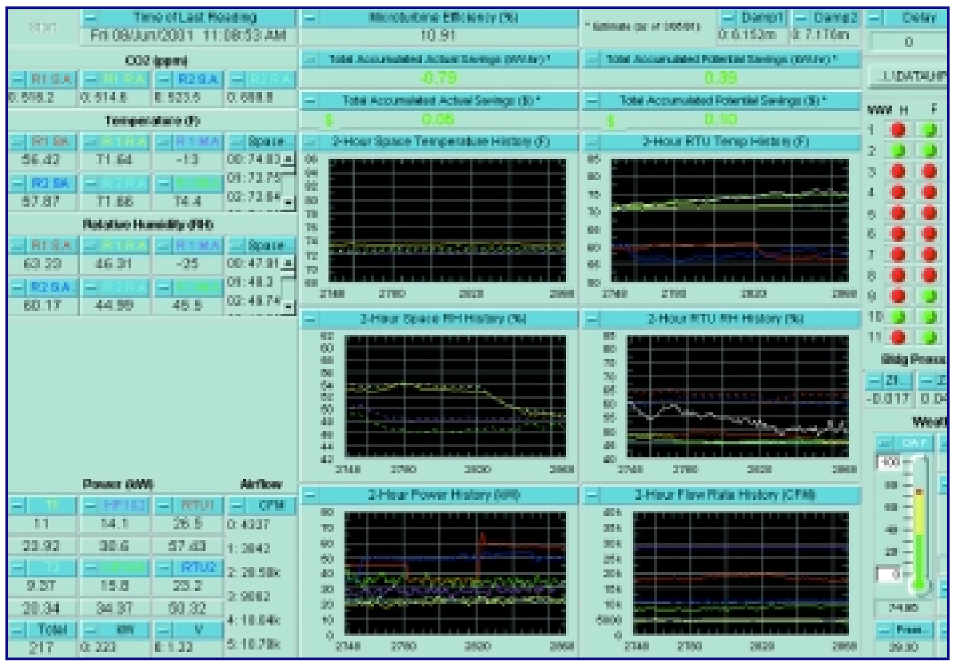
A 75-kW microturbine, 22-refrigerator ton (RT) absorption chiller, and a solid desiccant dehumidifier provide electric power for the building and cool and dry air in Cooling Zone Two. Waste heat from the microturbine exhaust powers the absorption chiller, while flue gas from the chiller powers the desiccant dehumidifier. The absorption chiller assists the RTU in providing air conditioning for Cooling Zone Two. The dehumidifier dries the supply air for the building, a function normally accomplished by the RTU and absorption chiller, reducing the need for grid-based electrical power. Together, these interactive components efficiently supply air conditioning for Cooling Zone Two and supplement the power requirement for the entire building.

CONTROLS AND COMMUNICATIONS

Controls and communications hardware and software programs enable IES equipment to work in concert, facilitating integration of the individual components. The equipment room in the University of Maryland's Chesapeake Building was converted into the IES Controls and Communications Center. Monitoring and controls tools such as the Pacific Northwest National Laboratory's *Whole Building Diagnostician* and several manufacturers' advanced building control software programs are housed at this center, including software developed by the University of Maryland.

The *Whole Building Diagnostician* is a software program that tracks a building's energy use, monitors the performance of air-handling units, and detects problems with outside air control. The program can identify and immediately diagnose common problems in the HVAC system and equipment.

A Web-based monitoring and control system has been employed to provide building-level data to system integration researchers and the public.



Screen display of a building information system developed by the University of Maryland

EARLY RESULTS

The University of Maryland's Center for Environmental Energy Engineering (CEEE) has worked closely with DOE's Oak Ridge National Laboratory (ORNL) to ensure the success of the Integration Test Center. CEEE received a Small Business Award from ORNL for being an "outstanding educational institution." Patti Garland, ORNL Technical Project Manager, notes, "We consider the University of Maryland's technical expertise, professionalism, and dedication to quality to be cornerstones of the project's success."

Early results of the project's success can be seen in the table below. Although only in their first year of operation, the Test Center's two integrated energy systems are showing significant energy savings and emissions reduction potential. The table outlines preliminary savings estimates based on measured data for the Test Center's cooling functions in the summer and compares it to baseline numbers from the local Washington, DC metro area.

	Annual Energy Consumption & Savings for Cooling in Summer 2001		Annual CO_2 Emissions & Reductions for Cooling in Summer 2001		Annual NO_x Emissions & Reductions for Cooling in Summer 2001	
Integrated Energy System #1	Baseline: Existing RTU	IES #1 (EDAC + Desiccant) kWh Reduction & Savings	Baseline: Existing RTU	IES #1 (EDAC + Desiccant) Ton Reduction & Savings	Baseline: Existing RTU	IES #1 (EDAC + Desiccant) Ton Reduction & Savings
	241,043 kWh	- 125,402 kWh **52% savings**	73.4 tons	- 50.7 tons **69% savings**	0.2 tons	+ 0.07 tons** **35% increase**
Integrated Energy System #2	Baseline: Grid + Existing RTU	IES #2 (MT + Chiller) kWh Reduction & Savings	Baseline: Grid + Existing RTU	IES #2 (MT + Chiller) Ton Reduction & Savings	Baseline: Grid + Existing RTU	IES #2 (MT + Chiller) Ton Reduction & Savings
	453,046 kWh	- 119,389 kWh **26% savings**	248.3 tons	- 104.1 tons **41% savings**	0.75 tons	- 0.49 tons **65% savings**

**This negative NO_x "reduction" reflects the fact that reciprocating engines, without additional emission reduction systems, such as selective catalytic reduction systems three-way catalysts, have relatively high NO_x emission rates. In contrast, the microturbine-based IES #2 achieves more than 50% reduction in NO_x emissions.

SO_2 emissions were not addressed in this table since integrated energy systems were assumed to generate no SO_2. The emission reductions are proportional to energy savings and turbine chiller combined systems reductions exceed 1 ton annually.

From left to right: Patti Garland, Technical Project Manager, ORNL; Predrag Popovic, Project Manager; Aris Marantan, student; Matthew Cowie, student; Werner Wongsosoputro, student; Eric Griff, student; and Ronald Fiskum, a Program Manager for DOE's Office of Distributed Energy Resources.

ACKNOWLEDGEMENTS

The Integrated Energy Systems Test Center is cosponsored by DOE's Office of Power Technologies, Office of Distributed Energy Resources, and the IES for Buildings Program, as well as the University of Maryland's Center for Environmental Energy Engineering. The Brookhaven National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory are technical support partners. We would also like to thank industry representatives participating in the Test Center.