The Inventions & Innovation Program: Inventors and Very Small Businesses Solving Big Energy Problems

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ABSTRACT

The U.S. Department of Energy's (DOE's) Inventions & Innovation (I&I) Program helps individual inventors and very small businesses transform their technical inventions and innovations into commercially successful technologies. Through DOE's Office of Energy Efficiency and Renewable Energy, I&I selects technologies to receive grants in a competitive process. The I&I Program also provides technical and commercial support that includes market studies, commercialization training, website descriptions of the technology, venture capital coaching, participation in conferences, and other individual assistance.

I&I's approach has resulted in an outstanding success rate. One in four grantees has sold the I&I-funded technology in the U.S. marketplace. Cumulative energy savings have totaled $4.9B through 2001.

The emphasis of this paper is three-fold:

- Provide information on how I&I uses every facet of its program to transform the new and emerging buildings technologies it funds.
- Present a case history of the technical and market transformation of the D'MAND® system, one of I&I's most successful projects.
- Briefly summarize three emerging technologies that I&I is funding and expects to be in the marketplace within three years.

Introduction

The mission of the U.S. Department of Energy's (DOE) Inventions & Innovation (I&I) grant program is to transform the energy efficiency marketplace served by DOE's Office of Energy Efficiency Renewable Energy (EERE) through the creative genius of individual inventor's and very small business's technical inventions and innovations. Every facet of I&I's Program is designed to commercialize the technologies that its grants support. I&I issues at least one solicitation a year that is restricted to individual inventors and very small business inventions that are aligned with EERE's 11 programs. In 2003 I&I's solicitation reflected a renewed emphasis on building technologies that potentially have significant energy efficiency impacts. Projects are selected for their technical merit, innovation, and commercialization potential.

I&I issues grants in three categories: conceptual, developmental, and demonstration. Conceptual grants have a benchscale prototype and an implementation plan as their outcome. Developmental grants use the existing operating data from a technology's benchscale prototype to build a full-scale industrial prototype of the technology. Demonstration grants demonstrate the technology in a commercial setting.

Integrating I&I's diverse portfolio into EERE Programs is one of I&I's strategies for commercialization success. Because technologies can range the breadth of the EERE mission,

each EERE Program has a designated liaison for the I&I Program. That liaison reviews the I&I proposals to determine if they fit within their EERE mission. The liaison is also the "inside" champion within each EERE Program, receiving technical updates on the progress of the grantees and integrating the I&I technologies into their Program's portfolios. Successful I&I projects are also included in the pertinent Program's commercialization activities.

I&I's Commercialization Assistance for New and Emerging Technologies

Commercializing technologies is the goal of the I&I Program and is reflected in its activities. I&I's corporate experience suggests that the principal investigator's commercialization experience and/or willingness to seek outside advice is key to a successful market entry. That same experience has also shown that market, not technical, considerations are more often the reason for a technology's lack of, or minimal entry into, the marketplace.

To ensure the best possibility of successful commercialization, I&I provides proactive assistance to grantees both during and after the grant period. The I&I transformation activities include selecting grantees, educating grantees in commercialization strategies, disseminating information on grants' technical and commercialization progress, and providing post-grant tracking and commercialization assistance. The commercialization process starts with the selection of projects. I&I currently weighs commercialization potential as 45% to 60% of the total selection points (technical merit and innovation comprising the remaining points).

While each technology's experience with I&I is unique, I&I offers grantees a wide range of technical and commercial support:

- Market studies
- Commercialization training
- A description of the technology on the I&I website
- Coaching from a venture capital expert to enhance a grantee's knowledge of the factors involved in obtaining venture capital and patent protection for their technology
- Third-party evaluation
- Inclusion in the portfolio of the all the pertinent EERE programs
- Analysis of energy savings' potential by laboratory experts
- Participation in tradeshows, the World's Best Technologies conference, and other technical conferences
- Additional assistance on a case-by-case basis.

Grantees' technologies are also included in I&I's technology tracking program, which is documented and published yearly. Technology tracking writeups are provided to the grantees for marketing. A compendium of the emerging and successful projects will be published in 2004 and disseminated to DOE's Regional Offices, State Energy Offices, and utilities.

The I&I Program started in 1976 as the Energy Related Inventions Program and had initial funding of $1.5 million. During the next 26 years its cumulative funding was $117 million. The cumulative value of energy savings that can be attributed to I&I technologies through 2002 is $4.9 billion – or $42 of energy savings for every $1 spent by DOE. In addition, I&I technologies have increased productivity and worker safety and have resulted in spinoff technologies and secondary energy impacts.

I&I continually improves on its program design and implementation based on lessons learned from the successes and failures of its technologies. I&I's tracking of its technologies' progress provides EERE Program Managers and the I&I Program Manager with the commercialization status of each technology.

I&I has sponsored 110 currently commercial projects and has identified 77 emerging projects, i.e., that are likely to be in the market within two to three years. Of the emerging technologies, 24 are buildings related. Table 1 lists the I&I building technologies that have been commercialized, and Table 2 lists the buildings technologies that have not yet sold but that are being actively marketed and commercialized (DOE 2004).

Case History of Hot Water D'MAND Waste Prevention System

One of I&I's more successful buildings-related technologies is the Hot Water D'MAND Waste Prevention System. I&I awarded Advanced Conservation Technology, Inc. (ACT), of Costa Mesa, California, a $90,000 grant in 1991 to develop the precursor technology to the D'MAND system. That technology was acquired and substantially improved by Metlund Systems. More than 30,000 D'MAND units are in operation today.

The novel D'MAND system conserves water and energy in water heating systems (see Figure 1). In conventional water heating systems, water standing in the pipe is sent down the sewer drain until heated water arrives, wasting both water and energy. The system employs a logic that returns stranded water in the hot-water pipe to the water heater through the cold-water line until a delta-T temperature rise is reached (DOE 2001a).

In commercial and multifamily applications, the D'MAND system can be designed into buildings using flow switches and highly accurate electronic thermo-sensors that can reduce the energy loss by more than 80% over the commonly used recirculation system. Gary Klein of the California Energy Commission is currently heading studies that are testing the system in a 20-unit apartment building in Southern California. The studies are expected to provide an enhanced understanding of the piping conventions within housing units and to quantify additional energy efficiency improvement opportunities in hot water usage. In addition, Gary is also a Technical Advisor to the I&I Program and is assessing the buildings technologies within the I&I portfolio.

The D'MAND system is installed under the sink farthest from the water heater and is activated by a button at a switch plate next to the fixture, wireless remote control, delay-type motion sensors, or a D'MAND flow switch. This allows the ambient house temperature water normally discarded down the drain to return back to the water heater through the cold water line. At the same time, the D'MAND system pumps the hot water rapidly from the water heater to the fixture. When a predetermined rise of temperature (usually 5ºF [-15ºC] above room temperature) in the line near the fixture is reached, the pump stops automatically and hot water is subsequently available at the faucet.

Table 1. Buildings-Related Commercial Technologies Funded by I&I

Technology	Company	Cumulative Savings (energy and dollar)[a]	Year of Grant
AlasCan Composting Toilet and Greywater Treatment System	AlasCan, Inc.	NA[b]	1990
Aluminum Roofing System	Transmet Corporation	0.65 trillion Btu $6.43 million	1985
Direct Source-to-Object Radiant Heating Panels	Solid State Heating Corporation Inc.	1.447 trillion Btu $21.81 million	1982
Electronic Starter Device for Fluorescent Lamps	Beacon Light Products, Inc.	2.006 trillion Btu $28.26 million	1997
Guide for Window Routing Device	Bi-Glass Systems	0.52 trillion Btu $2.99 million	1992
High Speed, Permanent Magnet Motor Testing for the AC Market	SatCon Technology Corporation	NA[b]	1998
Hot Water D'MAND Waste Prevention System	Advanced Conservation Technology, Inc./Metlund Systems	0.386 trillion Btu $3.45 million	1982
Improved Poured Concrete Wall Forming System	Lite-Form International	0.786 trillion Btu $4.56 million	1991
Insulation Containment Apparatus – The Ultimate 'R'	The Ultimate R	NA[b]	1997
Method of Constructing Insulated Foam Homes	Amhome USA, Inc.	0.022 trillion Btu $0.15 million	1996
Nightsky – A New Roofing Technology	Davis Energy Group, Inc.	0.002 trillion Btu $0.03 million	1994
PowerRim High Wattage Energy Saving Compact Fluorescent Lamp (CFL) Adaptor for Recessed Downlights	PowerLux® Corporation	NA[b]	1997
Refrigerator with Pan Chiller System	KaiRaki, Inc.	NA[b]	1996
Restaurant Exhaust Ventilation Monitor	Melink Corporation	0.210 trillion Btu $2.95 million	1992
RR-1 Insulating Screw Cap	Romine Co.	0.005 trillion Btu $0.04 million	1997
Selective Zone Isolation for HVAC Systems	Enerzone Systems Corp	0.305 trillion Btu $1.74 million	1987

Technology	Company	Cumulative Savings (energy and dollar)[a]	Year of Grant
SolaRoll Solar Collector System	Bio-Energy Systems Inc.	25.735 trillion Btu $188.02 million	1980
SOLARWALL Air Preheating System	Conserval Systems, Inc.	0.076 trillion Btu $0.55 million	1992
System for Reducing Heat Losses from Indoor Swimming Pools By Use of Automatic Covers	Lof Energy Systems, Inc.	NA[b]	1993
The Energy Saver Gas-Broiler Control	Custom Electronics, Inc.	NA[b]	1995
The Solar SKYLITE Water Heater	American Solar Network, Ltd.	0.076 trillion Btu $1.07 million	1993
Ultraflo Automated Plumbing System	Ultraflo Corporation	NA[b][c]	1993
Wallace Energy Systems Solar Assisted Heat Pump Water Heater	Wallace Energy Systems	0.118 trillion Btu $1.64 million[c]	1992
Waste Fluid Heat Recovery System	WaterFilm Energy, Inc.	0.039 trillion Btu $0.35 million	1989

(a) Commercialized technologies funded by I&I are tracked for 10 years, so the savings reflect only that tracking period.
(b) This is the first year that the technology is in the tracking system, so savings are not yet available.
(c) The technology is no longer being sold.

(Source: DOE 2004)

The I&I tracking program shows that D'MAND systems saved more than 1 billion gallons of water and 1 trillion Btu of energy from 1991 to 2003. The systems have also reduced NO_x pollution by 160 tons and carbon emissions by 100,000 tons. In addition, the systems have reduced standby losses in tank-type water heaters and have extended water heater life. Because the systems reduce water consumption, they have also reduced the demands on, and the costs of, operating both water and wastewater treatment systems and have effectively contributed to increasing the capacity of these systems.

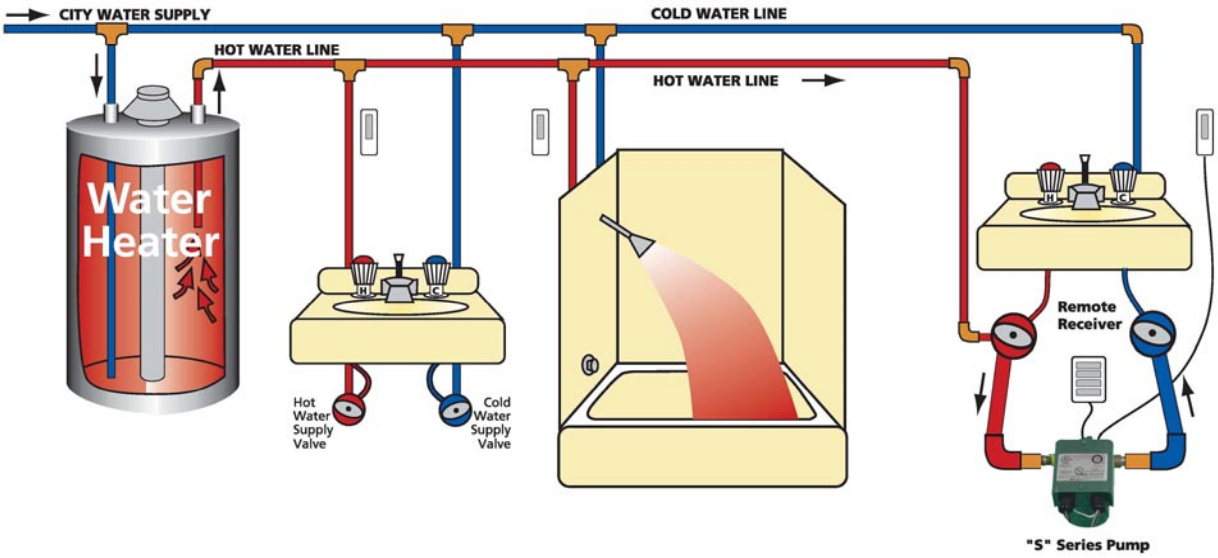
In 2004, ACT licensed D'MAND systems to be marketed by two large U.S. companies. Taco Inc., the largest manufacturer of circulators in North America, has introduced three models of D'MAND systems to be sold in the United States and Canada. Wirsbo Uponor, one of the largest manufacturers of cross linked polyethylene (PEX) plastic pipes in North America, introduced two models of D'MAND systems in April 2004. In 2004, ACT also plans to private label the systems in Australia, parts of Asia, and South Africa (Acker personal communication April 2004).

Table 2. Emerging, Open, and Continuing Technologies

Technology	Company	Year of Grant
Carbon Dioxide Nanoelectronic Sensors	Nanomix, Inc.	2003
Cromer Cycle Air Conditioner	Solar Engineering Co.	1999
Electrochromatic Window Film	Chameleon Optics, Inc.	2000
Electrochromic Windows: Advanced Processing Technology	SAGE Electrochromics, Inc.	2003
Electronic High Pressure Sodium Ballast	LCB Corporation	1993
Energy-Efficient Production and Utilization of Lightweight Structural Panels	Genesis Laboratories, Inc.	2000
GibBAR-Wall System	Industrial Foam Products, Inc.	1994
High Efficiency Liquid-Desiccant Regenerator	AIL Research	2003
High-Efficiency Variable Dehumidification for Air Conditioners	Advantek Consulting, Inc.	2003
High Energy Efficiency Air Conditioning	Nimitz, Inc.	2002
Inner Roof Solar System	Inner Solar Roof Systems, Inc.	1997
Innovative, Energy-Efficient Dryer	Research Triangle Institute	1998
Liquid Leak Detection System	Check-A-Leak	1997
Multi-Element Selective Emitter	Sonsight, Inc.	2002
Multi-Element Selective Emitter: A New High Efficiency Incandescent Light Source	Sonsight Projects, Inc.	1998
Multi-pliance	Charles F. Mullen	1997
Phosphors for Use in High-Efficiency Lighting and Displays	Brilliant Technologies	1999
Simple Control for Single-Phase AC Induction Motors in HVAC&R Systems	Opto Generic Devices, Inc.	2000
Thermal Energy Storage for the Small Packaged Terminal Air Conditioning Unit	Ice Energy, LLC	1997
Variable Speed, High Efficiency, Integrated Electronic Motor for Residential HVAC Systems	DynaMotors Inc	2002

(Source: DOE 2004)

Figure 1. Flow Diagram of Metlund Hot Water D'MAND System



Source: Advanced Conservation Technology, Inc.
(Acker personal communication April 2004)

Three Emerging Buildings-Related Technologies Funded by I&I

Three emerging technologies that I&I currently is funding and expects to be in the U.S. marketplace within three years are the Cromer cycle air conditioner, Opto Generic Devices' simple control for single-phase AC induction motors in heating, ventilation, and air conditioning (HVAC) systems, and Ice Energy's distributed energy storage for mainstream refrigerant-based, unitary air conditioners. Each technology is briefly described below, along with information on how I&I provided support in developing the technologies.

Cromer Cycle Air Conditioner

Invented and patented by Charles Cromer, PH.D., P.E. (Solar Engineering Company), the Cromer cycle air conditioner reduces air conditioning energy use from 12% to 40% compared with other dehumidification control strategies such as air conditioning with reheat. The cycle improves dehumidification efficiencies of air conditioners by dehumidifying at high evaporator coil temperatures. The technology has a potentially wide market in more humid climates and may be sold internationally (Cromer personal communication April 2004).

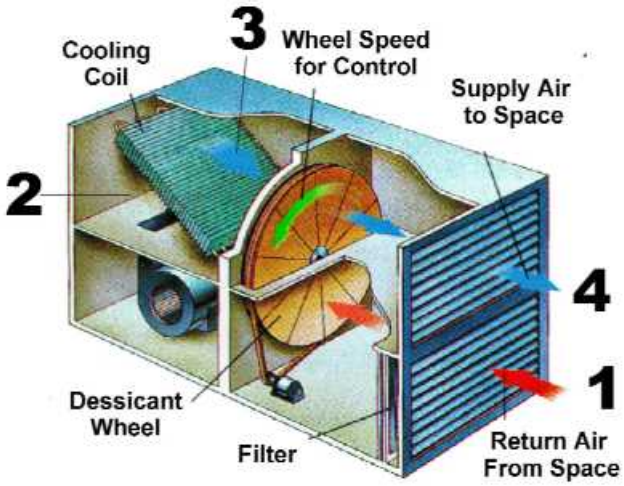
The Cromer cycle air conditioner uses a rotating desiccant wheel to transfer moisture between the supply and return air streams of the air handler. Desiccant passing in front of the humid air that is leaving the coil absorbs moisture, so the duct system and conditioned space receive drier air. As the wheel turns, the desiccant transfers moisture to the dry air returning from the conditioned space. By cycling or bypassing the desiccant wheel, the space moisture and temperature can be accurately controlled without additional energy use for reheat or independent dehumidification. The desiccant wheel used in the cycle requires no more maintenance than the coil in the air conditioning system (Cromer personal communication 2004). Figure 2 shows a diagram of the Cromer cycle air conditioner components.

The residential system is still under development, but the developer believes it may be ready for sale within the next three years. The cycle is licensed to Trane, who is proceeding with commercial product development.

In addition to funding the proposal, I&I provided all grant recipients in 1999 with a 1-1/2 day commercialization training course. The course was also designed to familiarize grantees with the myriad of assistance that I&I can provide. I&I produced a technology Fact Sheet that is on the DOE website and was printed and sent to all grantees for marketing their technology. Market assessments were also done for all grantees requesting them. I&I also worked with each grantee to produce their Graded Performance Results Act (GPRA) results. The GPRA process generally reduces the grantee's estimate of total energy savings, primarily because it uses a smaller market share.

More information about this technology is available from Charles Cromer, Solar Engineering Company, 460 Indian Creek Drive, Cocoa Beach, FL 32931; (321)-504-3421; or Charlie@fsec.ucf.edu.

Figure 2. Components of the Cromer Cycle Air Conditioner



Source: Solar Engineering Company
(Cromer personal communication 2004)

Simple Control for Single-Phase AC Induction Motors in HVAC Systems

Electric motors account for as much as 50% of total U.S. energy use (Opto Generic Devices, Inc. 2002). Because of the inefficient design and operation of the common fixed-speed motor, much of this energy is wasted. In the United States alone, millions of these single-speed

AC motors are in use. If they were equipped with controls to vary their speed and torque to match their workload, major energy savings would be achieved.

Opto Generic has a new approach to electric motor control that eliminates the need for complex, high-frequency, high-voltage digital controllers that are motor and application specific. Opto Generic's technology uses an optical programmable encoder that offers continually variable-speed, optimized commutation, dynamic vector control, real-time feedback, application tuning, and signal enhancement for operating AC and DC motors ranging from fractional horsepower to industrial motors. The application currently being developed is a drop-in unit for

the residential HVAC retrofit market and provides continuous variable adaptability to air temperature, resulting in improved comfort, reduced noise, a cleaner environment, and energy savings.

The two main applications for the technology are the residential HVAC market for variable-speed fan control and any single-speed AC motor application. The Opto Generic controller adjusts air flow to ambient temperature continuously, is a drop-in replacement for existing fan units, and has reliable closed-loop programming without electronic processors.

Most efforts to use variable-speed rather than single-speed motors in HVAC systems have coupled new motors with digital controls, using complex, unit-specific system designs to make the motor and controls compatible. These custom digital solutions are not translatable for use with other motors and systems and are often far more costly than the units they displace.

Using optically programmable control, the Opto Generic approach offers a universal, simple, and low-cost solution for HVAC systems, including those with single-speed AC motors. The unit will be a complete functioning fan subsystem. This fan unit will offer adaptive airflow that will track/follow air temperature. These drop-in units will replace standard, fixed-speed AC motor fans. Early variable-speed control tests using these systems have shown reductions of 20% to 60% in AC fan motor electricity consumption (DOE 2001b).

Opto Generic is currently entering into negotiations for manufacturing their device. They believe that not only will their motor and control system save energy but will reduce noise levels and improve comfort, which should have wide applicability in schools, museums, and conference rooms.

I&I provided Opto Generic with a market assessment that they felt was very useful to them. They also reported that they appreciate all the technical and market assistance as well as personalized attention they have received. Assistant Secretary Garman visited their facility as a result of I&I's recommendation.

More information is available on this technology from Frank Fischer, Opto Generic Devices, Inc., 174 Pumpkin Hook Road, P. O. Box OG, Van Hornesville, NY 1347; (315) 858-1002 (phone); or ogd3@ogd3.com.

Distributed Energy Storage for Mainstream Refrigerant-Based, Unitary Air Conditioners

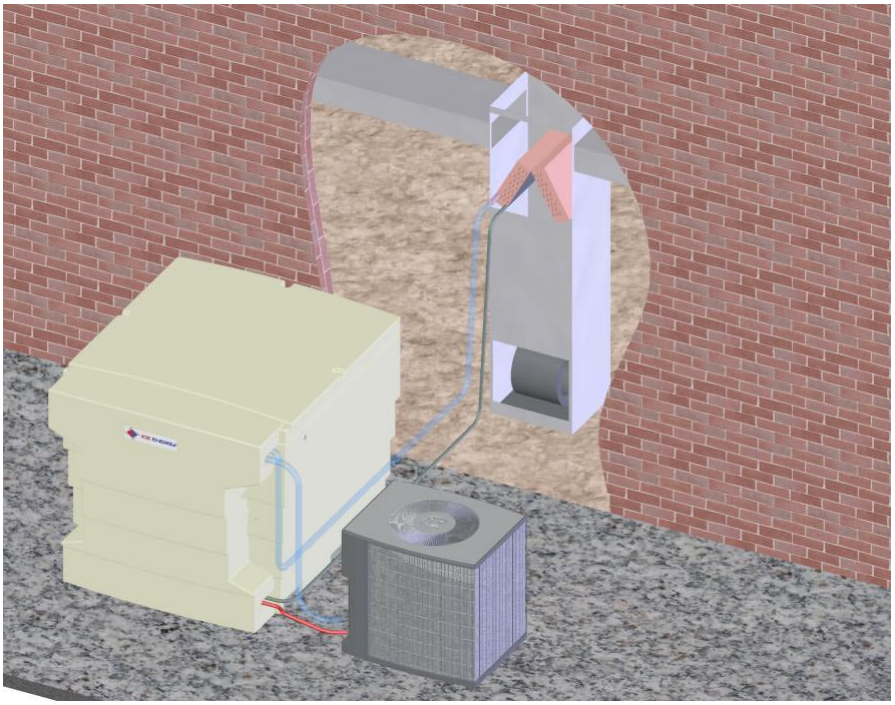
Recent blackouts have heightened awareness that our transmission system is struggling to meet the demand for peak electrical power. The root cause of the on-peak electrical problem is the increasing demand for air conditioned comfort. On a typical summer day, fully one third of all energy transmitted on the grid is consumed by residential or commercial air conditioners. Small-to-medium-sized commercial buildings and residences primarily use refrigerant-based air conditioners. Of the U.S.'s 36 billion square feet of air conditioned building space, 17 billion square feet, or 48% of the total market, is served by refrigerant-based air conditioners (Kay personal communication March 2004). These conventional air conditioners operate during the hottest time of the day when energy consumption peaks, air conditioner efficiency drops, and electricity prices soar.

The IceBear, an innovative product by Ice Energy, LLC, is the first distributed energy storage product for the millions of customers who use refrigerant-based cooling. I&I funded the conceptual and developmental stages of IceBear. The grant included funds to build and test three pre-production prototypes. The field tests were successful, and Ice Energy plans to release the product for sale during the summer of 2004.

Operation is simple and installation is completed by licensed local HVAC technicians in just a few hours. Figure 3 shows a typical IceBear Installation. The IceBear uses a standard 5-ton air-cooled condensing unit during off-peak hours to make ice in an insulated tank. During peak daytime cooling, the IceBear functions as the condenser, circulating ice-condensed refrigerant with a 200-watt refrigerant pump. The IceBear shifts energy demand from peak energy periods to off-peak periods and provides cost effective cooling, even during the hottest days of the year.

In a peak shifting mode, the technology can reduce air conditioning electrical demand (on-peak kilowatt [kW]) by up to 90% with neutral or less energy consumption in a 24 hour period. In the energy conservation mode, the technology can reduce energy consumption (kW-hr) by up to 30%. As few as 100 IceBears can eliminate 1 megawatt of on-peak demand. Based on the building load profile and local electrical rate structure, one IceBear can slash the 12-kW peak demand of a 10-ton air conditioner (12 kW @ 10 SEER [seasonal energy efficiency ratio]) and can shift 48 kW-hr per day of electricity consumption from peak to off-peak periods. The IceBear works with air conditioning systems ranging from 3 to 50 tons. IceBear's many applications are served by low-cost, off-the-shelf refrigerant-based air conditioning systems and are well suited to adopt the IceBear and achieve significant energy savings (DOE 1999).

Figure 3. Typical Installation of an IceBear



Source: Ice Energy, LLC (Kay personal communication March 2004)

Ice Energy credits I&I's involvement with increasing the credibility of its product and test results with potential customers and investors. They also cite the importance of the field tests that were part of their I&I grant in providing a foundation for further discussions with customers and investors. Ice Energy further cites the assistance that I&I provided in having the National Institute of Standards and Technology complete a technical and commercial feasibility and energy impact assessment on IceBear.

Ice Energy also credits the I&I grant with accelerating the technology's time to market by at least 50%. Early in the grant process, Ice Energy attended the I&I Commercialization Planning Workshop held by Mohawk Research Corporation, and Ice Energy used I&I's "From Invention to Innovation" booklet as a guide.

Through I&I's encouragement for companies to promote its technologies, Ice Energy has received several awards for Ice Bear, including the 1996 "Excellence in Engineering" award from the Illinois Chapter of ASHRAE, the 1997 Ohio Governor's Award for Excellence in Energy Efficiency for the Commercial Division, a 2004 AHR Expo Innovation Award, and a Gold Award from the 2004 World's Best Technologies conference. IceBear was also added to the GREENTIE Directory as a greenhouse gas mitigating technology. Ice Energy's participation at the 2004 World's Best Technologies conference increased potential investors' awareness of the IceBear and provided additional publicity for Ice Energy's potential customers. In addition, Ice Energy received a market assessment and one-sheet handout on the IceBear from New Horizon Technologies, Inc., a contractor to I&I.

Ice Energy also reported that their alliance with DOE's national laboratories has been strengthened through I&I's involvement. Ice Energy also believes that the phone calls of encouragement, the moral support, the help required for a grant time extension, their web exposure on the I&I website, and numerous leads regarding potential applications for the IceBear technology were critical ingredients to their product's current success.

More information about this technology is available from Ice Energy, LLC, 2020 Lowe Street, Suite 201, Fort Collins, CO 80525; (970) 223-6138 (phone); or info@ice-energy.com.

Conclusions

Acting much like a seed/venture capital company for inventors and businesses, I&I has had tremendous success in selecting and nurturing technologies that have commercial potential. In mid-summer 2004, I&I will be issuing another grant solicitation, and individual inventors and very small businesses with innovative buildings technologies are encouraged to apply.

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