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Permanent Peak Load Shift Product Deployment for Smart Grid Integration and Operation

1024634

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Technical Update, November 2012

EPRI Project Manager

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FirstEnergy Corp.

This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.

NOTE

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ACKNOWLEDGMENTS

The following organization, under contract to the Electric Power Research Institute (EPRI), prepared this report:

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This report describes research sponsored by EPRI.

This publication is a corporate document that should be cited in the literature in the following manner:

Permanent Peak Load Shift Product Deployment for Smart Grid Integration and Operation. EPRI, Palo Alto, CA: 2012. 1024634.

ABSTRACT

This project tested and evaluated an innovative energy storage technology that provides permanent peak load shifting using electro-thermal energy storage in combination with commercial unitary rooftop air conditioning systems. Four Ice Bear 30 units were deployed at a Staples facility to store an estimated 32 kWh each of energy in 10 off-peak hours and reduce an estimated 5 kW of site energy demand for an on-peak six-hour period. The Ice Bear units are monitored and controlled with a smart grid platform.

In the 2010 operation year, the units were monitored and controlled using the Ice Energy network operation center in Colorado. Subsequently, the FirstEnergy Integrated Distributed Energy Resources (IDER) monitored and controlled the units through an open architecture management platform.

Through the 2010 summer peak season, the four Ice Bear units performed as expected, providing building cooling using ice during the daily utility system peaks. With all four Ice Bear systems providing cooling, a maximum demand reduction occurred in August of 19.54 kW locally. During the same month, the energy shifted to off-peak hours was 2.96 MWh. During the entire operating year, the aggregate Ice Bear system operations provided 100% peak coverage of the scheduled peak period (12pm – 6pm). The host site customer remains pleased with the energy storage equipment and project experience itself; no complaints were noted. Flattening summer peak load and consequently improving system load factor benefits all ratepayers. Permanently reshaping load profiles of the commercial sector as demonstrated in this project can reduce economic and environmental costs by better utilizing base-load resources while enhancing reliability.

Keywords

Heating, ventilation, and air conditioning (HVAC)
Load shifting
Energy storage
Distributed energy resources
Smart grid

EXECUTIVE SUMMARY

Background

The application of distributed resources on the distribution system with an integrated control approach continues to grow. A new and innovative type of product, a unitary electro-thermal energy storage system has been tested and evaluated in this project to show how it can provide permanent peak load shifting for energy delivery systems. This project uses the regulatory model where the utility owns and controls four (4) unitary ice storage systems at a single commercial host site that were installed and operated through a central remote monitoring and control, smart grid system. These four devices model Ice Bear 30 were procured from Ice Energy, Inc. a US manufacturer located in Windsor, CO. They were integrated into four of nine existing heating, ventilating and air conditioning (HVAC) rooftop air conditioning systems at a Staples facility in FirstEnergy's operating company in New Jersey, Jersey Central Power & Light (JCP&L).

The Ice Bear units have distributed control through their local CoolData controller and communicate back to the Ice Energy network operations center (NOC) in Colorado to monitor and remotely manage their health and performance. In addition, these Ice Bear units with their central control system will be integrated into the EPRI, FirstEnergy Smart Grid Demonstration Host Site, Integrated Distributed Energy Resources (IDER) project (CF 013619-62814). Analysis of the IDER integration will be provided through that project.

This research project showed how the energy delivery utility benefited from these Ice Bear electro-thermal, ice storage units to permanently shift peak load at the facility and thereby, also on the associated electric distribution circuit.

Objectives

The main focus of this project is to investigate the applications and impacts of distributed, utility controlled, commercial customer-sited electro-thermal units integrated into existing rooftop, split-system air conditioning systems and monitored and controlled from a smart grid platform.

- To benefit the operation and management of the utility distribution system

Additional objectives of this project are:

- To test and evaluate the installation, application, operation and load shift potential of four Ice Bear units installed at one commercial national account site;
- To learn about the commercial customer behavior and overall experience associated with the installation and daily operation of the Ice Bear energy storage units;
- To understand the integration and operation of these units into a smart grid system.

Utility Benefits/Customer Benefits; Win-Win

FirstEnergy/ JCP&L experiences significant demand peaks during the summer months due to air conditioning load. When the demand peaks are extreme, load factor; the ratio of average electric load to peak load, is reduced. This increases infrastructure needs due to infrequent use of capacity assets to support higher peak needs. This problem is particularly acute in the northeast and specifically in New Jersey where the load factor is in the mid 40% range. Figure ES-1 provides the statewide load factor information from 1999 to 2004 as developed in the 2006 New

Jersey Energy Master Plan (NJEMP). Also, it should be noted that the 1991 NJEMP alluded to the fact that the average load factor for New Jersey utilities was well below the national average of over 60%. As shown in Figure ES-1, the average load factor in New Jersey has deteriorated to below 50%.

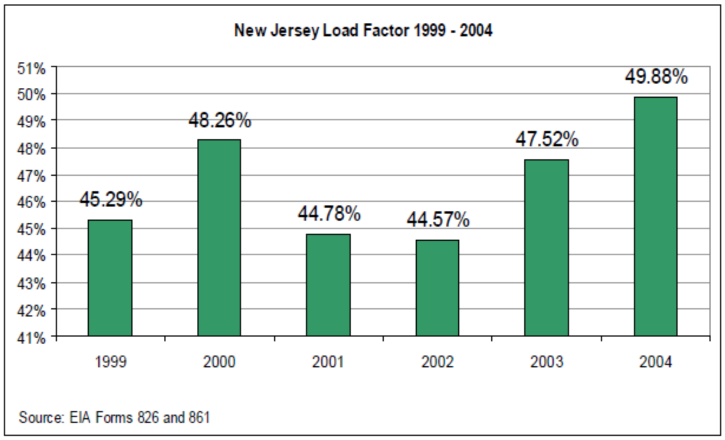

Figure ES-1
New Jersey Load Factor data

Increased penetration of air conditioning systems at residential and commercial buildings, which in part exacerbates low load factor, ends up increasing utility requirements and impacts consumers. This test using the Ice Bear has shown how storage technology can lower demand at the customer site and consequently to the circuit which demonstrates the ability to separate summer heat from summer load.

Reducing summer peak load and improving system load factor is a JCP&L/FirstEnergy and a NJ Energy Master Plan goal. Air conditioning is the primary contributor to the summer peak condition and the delivery system can operate under stress to meet the added demand of new air conditioning demand. Technology such as the Ice Bear has shown in this test and evaluation the potential to assist the electricity distribution system to shift summer heat load to off peak hours. Reducing the weather-dependant loads will alleviate peak capacity requirement.

The use of the Ice Bear by small and medium commercial customers provides them the same comfort while shifting some of their demand to off peak. It also avoids typical load management programs that might impact their customers' shopping experience, and consequently their "Brand". Decisions about temperatures within the store are rigorously controlled by store management and the Ice Bear design continues to allow this. Despite policymaker's desire to alter customer behavior with Time of Use tariffs, and providing payments to reduce consumption during system peaks, retailers will not risk customer satisfaction or comfort. Corporate environmental initiatives are also drivers here. Staples volunteered to host the Ice Bear units as they have been interested in the technology for years as they believe it supports their environmental initiatives. There is value to Staples in reducing their peak load demand as they perceive that peaking plants are adverse to the environment.

Many states have aggressive goals to reduce both energy consumption and demand, including New Jersey, where these units are being tested. Utility programs using technologies such as the Ice Bear require regulatory approval and need to pass cost-effectiveness tests, and with Ice Bear deployments, they can be cost effective, win-win providing flatter circuit load profiles with good customer comfort, cooling reliability and satisfaction. JCP&L and Ice Energy have worked with the Center for Energy, Economic & Environmental Policy (CEEEP), to model Ice Bear operations and their impacts. CEEEP is part of the Bloustein School of Planning and Public Policy at Rutgers University and they have developed cost-benefit analysis tools that have been used by the NJ Board of Public Utilities in assessing energy efficiency programs. CEEEP's focus is to explore the interrelation of energy, economics and environmental policy issues. In addition to typical cost-benefit criteria, other benefits, which are considerably harder to model, yet are tangible, include: gains in electric system efficiency, improved utilization of assets and enhanced integration of renewable resources.

Flattening summer peak load and consequently improving system load factor benefits all ratepayers – both participants and non-participants alike. Permanently reshaping load profiles of the commercial sector as demonstrated in this project can reduce economic and environmental costs by better utilizing base-load resources while enhancing reliability.

Results

Four Ice Energy Ice Bear 30 electro-thermal energy storage units were roof mounted and successfully commissioned on a national chain medium box retail store located in Howell, NJ, performed as expected and contributed to peak load shifting on the associated circuit permanently.

The installation is best described as a common HVAC electrical and mechanical scope of work, equivalent to installing a new packaged rooftop piece of equipment. Local contractors with oversight from Ice Energy and JCP&L/FirstEnergy completed the installation over the course of a few days in October, 2009. Based on this project's experience, finding local contractors to perform installation and commissioning was straightforward and can be easily expanded to a megawatt scale project.

This research project shows that singularly, each Ice Bear unit stored an estimated 32 kWh of energy in 10 off-peak hours and reduced an estimated 5 kW of site energy demand for up to and over a six-hour, on-peak period.

With all four Ice Bear systems providing cooling, a maximum demand reduction occurred in August of 19.54kW locally and 22.2 kW at the PJM bus based on the New Jersey location transmission and distribution (T&D) losses of 13.53%. During the same month, the energy shifted to off-peak hours was 2.96 MWh. During the entire operating year, the aggregate Ice Bear system operations provide 100% peak coverage of the scheduled peak period (12pm – 6pm).

Through the 2010 summer peak season, the four Ice Bear units performed as expected, providing building cooling using ice during the daily utility system peaks. The mean discharge time during the week of August 29th was 7.73 hours, and the median discharge time was 7.98 hours. When the building was being cooled via the stored energy, there was over an 18 kW reduction at the site, which equates to 20.4 kW at the PJM bus based on the NJ 13.53% T&D system losses; a higher avoided energy and capacity needs upstream of the meter due to system losses. Maximum value is seen during the hottest days and weeks of the summer, as well as during the top 100 hours when the grid, from generation to delivery, is stressed.

New Jersey summers are humid, with the potential for significant temperature variations across this 7,836 square mile state. The Township of Howell is located in Monmouth County (latitude 40.2N, longitude 74.2W, elevation 82') and is representative of the climate across the state. High latent loads require air conditioning systems to work harder to keep building space at expected comfort levels. Also, rooftop units work harder when temperatures are higher, consuming more kW/ton of cooling as temperatures increase because they are in the heat of the sun. In effect, they do "less work, less efficiently", which is a reason why the electricity grid experiences higher demand during prolonged heat events. In contrast, Ice Bear cooling performance does not degrade with increasing daytime temperatures because the energy to cool was used and stored during the prior night. An additional benefit of Ice Bear cooling is during part load conditions with improved dehumidification and therefore, comfort. Part load conditions cause air conditioning systems to short cycle, reducing dehumidification, i.e. the thermostat is satisfied before sufficient dehumidification has occurred – this is even more apparent when units are oversized and can reduce the temperature in a building space very quickly without sufficient dehumidification. In contrast to this start/stop cycle, the Ice Bear discharges its stored energy using a variable speed pump and liquid overfeed coil, which keeps the evaporator full of refrigerant without using a thermostatic expansion valve.

This research project also demonstrated benefits to the electric distribution system. JCP&L saw a permanent peak load shift on the circuit that can contribute to better system management with potential to defer infrastructure investment. Benefits of this installation are the permanent reshaping of the air conditioning driven load profile of this commercial building while maintaining building cooling customer comfort. This is important as the commercial sector imposes significant summer peak demands from air conditioning load and they are reluctant to participate in load reduction programs that could potentially impact their customer experience and service.

This evaluation has shown an approximate 20kW load drop at the study facility. Extrapolating this from 4 to 400 units gives a total of a 2MW load reduction or load flattening on the circuit. The graph below (Figure ES-2) shows a day from the 2010 summer peaking season, with two operational methodologies. The first method has each 20kW load aggregated coincidentally, and the second, staggers the *Ice Bear* operations based on different types of commercial customer business operations, which actually provides a better flattening of the circuit load profile

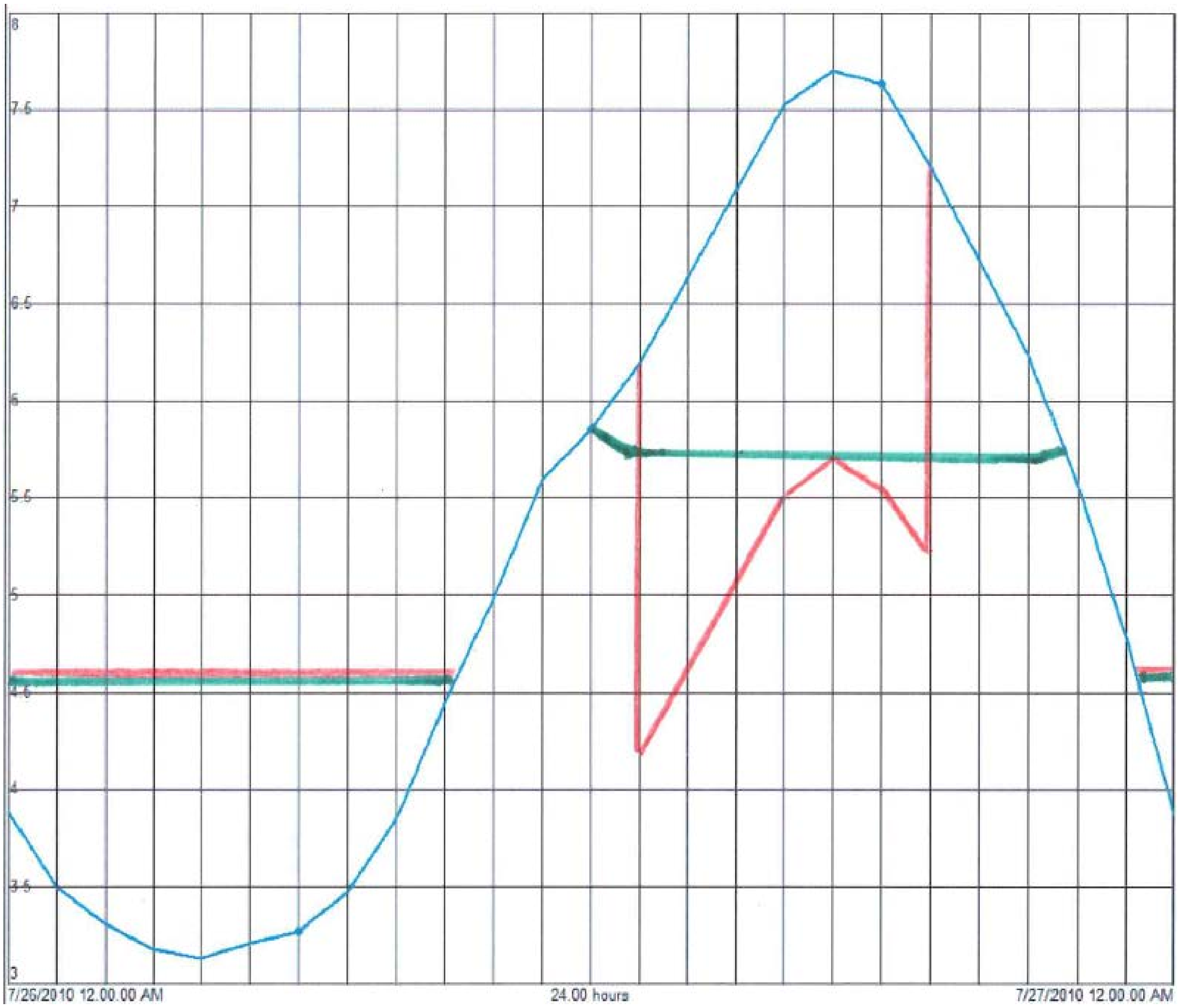

Figure ES-2
Summer Average Peak Day on Selected Circuit, July 26, 2010 showing potential load shift of coincident 2MW (100 sites of 20kW each) from 1-7pm (in red) or an equivalent load shift (in green) staggered based on business operations of the facilities and to shave the circuit's peak.

The host site customer remains pleased with the energy storage equipment and project experience itself; no complaints were noted[1].

The four units are deployed at a facility in Howell, which is within the EPRI, FirstEnergy Smart Grid Demonstration Host Site, IDER project, targeted area to facilitate the smart grid IDER platform integration and analysis. Continued evaluation and analysis of the Ice Bear units are planned as it will be integrated into the IDER smart grid platform in the spring of 2011 to

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[1] The published case study can be found on http://www.ice-energy.com/stuff/contentmgr/files/1/e0a38e3eaf9a297a0f63511e0806155a/download/ie_casestudy_staples.pdf

monitor and control them. The IDER project is integrating various technologies into a platform for central control of them. The IDER smart grid platform open architecture interoperates with third party sensors, devices and equipment via published application interfaces and control drivers and works with system algorithms and command orders to be processed and then communicated to the various distributed energy resources.

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1
PROJECT DESCRIPTION

The application of distributed resources and central integrated control of them on the distribution system continues to grow. An innovative energy storage technology described as electro-thermal energy storage for use with commercial unitary rooftop air conditioning systems, has been tested and evaluated under this project for its ability to provide permanent peak load shifting for energy delivery systems. This project explored the application of a regulatory model where the utility owns and controls commercial, customer-sited electro-thermal energy storage. The permanent peak load shift equipment was provided by Ice Energy who manufactures Ice Bear energy storage units. The Ice Bear units were connected to existing rooftop air conditioning systems at a Staples store, which is a commercial medium box retail store. They were installed to shift energy and demand for the building's cooling load. Ice Energy also provided a local control system, the CoolData controller.

Figure 1-1
Rooftop units at Staples demonstration site

This research project tested and evaluated the deployment of four Ice Bear 30 units to show that they can store an estimated 32 kWh each of energy in 10 off-peak hours and reduce an estimated 5 kW of site energy demand for an on-peak six-hour period. The HVAC units at the Staples facility provide 10 tons of cooling with 2 - 5 ton circuits. The Ice Bears were integrated with Lennox 10 ton, model # LGA120HHIG HVAC units. These Lennox HVAC units are two stage units consisting of two refrigeration circuits and with the Ice Bear, a third coil is added that is paired with the Ice Bear, which effectively replaces the primary coil/compressor and is used daily. The secondary coil/compressor operates as originally designed and comes on when temperatures require more cooling than a single stage. These Ice Bear units are monitored and controlled with a smart grid platform.

In the 2010 operation year, the units were monitored and controlled using the Ice Energy NOC. In 2011 and beyond, the IDER platform will monitor and control the units through an open architecture management platform. The IDER smart grid platform is designed to interoperate with third party sensors, devices and equipment via published application interfaces and control drivers and works with system algorithms and command orders to be processed and then communicated to system devices.

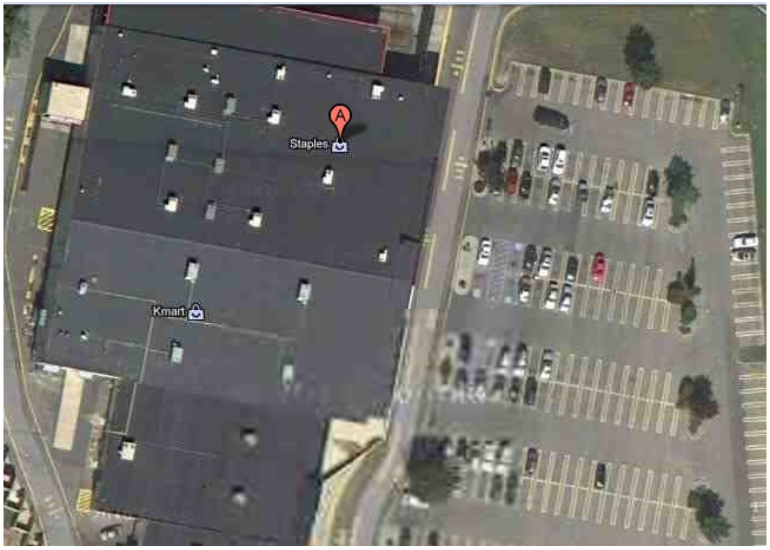

Figure 1-2
Satellite picture of Staples facility

Objectives

The main focus of this project is to investigate the applications and impacts of distributed, utility controlled, commercial customer-sited electro-thermal units integrated into existing rooftop, split-system air conditioning systems and monitored and controlled from a smart grid platform:

- To benefit the operation and management of the utility distribution system

Additional objectives of this project are:

- To test and evaluate the installation, application, operation and load shift potential of four Ice Bear units installed at one commercial national account site;
- To learn about the commercial customer behavior and overall experience associated with the installation and daily operation of the Ice Bear energy storage units;
- To understand the integration and operation of these units into a smart grid system.

In addition to accomplishing the objectives, this project is providing insight related to defining system integration requirements, project development, permanent peak load shift asset use, and business case analysis for the FirstEnergy Smart Grid Demonstration Host Site, IDER project.

2
PRODUCT DESCRIPTION

Ice Bear

The Ice Bear 30 unit is an off-the-shelf distributed energy storage system for use with direct expansion air conditioning units. The Ice Bear unit is designed to store energy at night and then shift the on-peak electrical energy of a condensing unit common to packaged rooftop, split, and mini-split systems. A typical application will shift the electrical energy consumed by a 5-ton compressor and its associated condensing unit fans operating under full load conditions for at least 6 hours continuously.

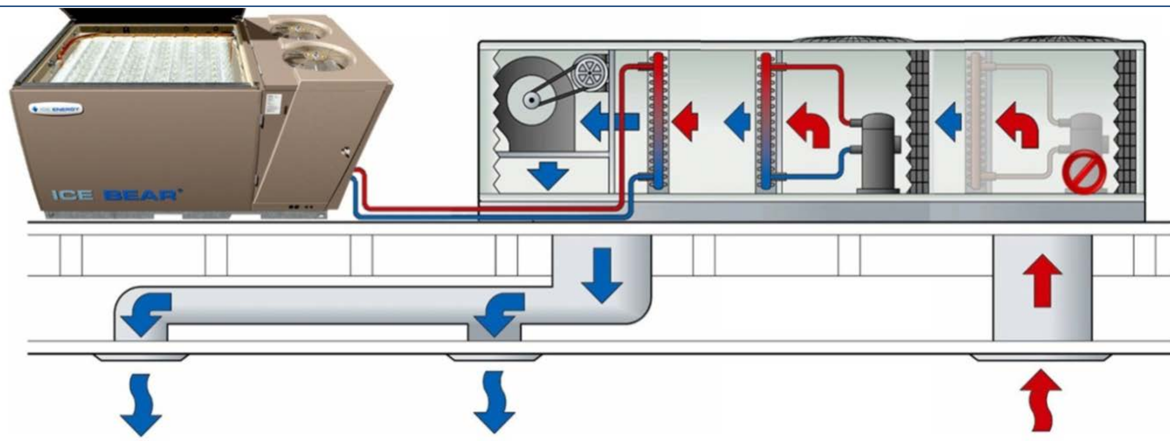

Figure 2-1
Rooftop unit showing Ice Bear integration. Two refrigeration circuits shown to right and an additional 5-ton coil to discharge the Ice Bear inserted next to the HVAC air handler, to the left.

The standard operation of an HVAC unit begins with a thermostat calling for cooling, which starts a compressor and a condenser fan to dissipate the heat rejected from the building. Many HVAC units, like the Lennox units installed at Staples, have two compressors, with the secondary compressor starting when the cooling requirement exceeds the capability of the lead compressor, or after a time delay intended to prevent tripping the breaker with excessive inrush current. When an Ice Bear is added to the system, it substitutes energy stored in the ice tank for the cooling done by the lead compressor, typically from noon until 6 PM. After the ice is depleted, the compressor that had been held out is made available until noon the following day, when the Ice Bear is fully recharged from its own, dedicated, high efficiency refrigeration compressor. The temperature set points are still dictated by the customer, but the source of the energy for cooling is from the stored ice energy.

The Ice Bear is a hybrid cooling and energy storage solution for distribution utilities to manage circuit load profiles using equipment installed at commercial and institutional customers. The most obvious is to leverage night and day temperature differentials, allowing this technology the best “Round Trip Efficiency” in the storage marketplace since the Ice Bear is charged when temperatures are at their lowest, and discharged when daily temperatures are at their highest. An air conditioning unit's compressor power consumption will vary significantly with outdoor air temperature, and since the Ice Bear keeps its accompanying HVAC unit's poor power factor motor off line every afternoon, the benefits to the grid are significant. These benefits challenge the entrenched approach for meeting peak cooling load that rely on building additional distribution, transmission and generation infrastructure upstream of where the power is needed. This is done without compromising cooling comfort for the utility's commercial customer.

The Ice Bear[2] is not a stand-alone device. Rather, it is a device in a distributed energy storage network. Ice Bear units can be controlled individually or in clusters by building, by feeder, by substation, and/or control area. Individual units are pre-configured to shift load for six hours each day; typically from noon – 6 pm and to store energy each night for 10 hours from 9 PM to 7 AM each day. As an energy storage resource, it is designed to both deliver and store energy on command. The ability to switch between storing and delivering energy in a highly distributed fashion is an important feature for the electric grid of the future that must be able to handle variable bursts and declines in energy generated from renewable energy resources such as solar and wind.

CoolData Controller

Figure 2-2
CoolData controller

The energy storage units incorporate an advanced CoolData controller referred to in industry as a remote terminal unit. The CoolData controller collects, analyzes, transmits and accepts data and instruction sets. The controller is connected directly to serial devices, typically pressure, temperature, current, and discrete sensors via an extensible sensor bus using a digital communications protocol. In addition to its main function, to control and manage an Ice Bear unit, the I/O portion of the controller is also designed to act as a data "shuttle" for maintenance providers, utility sensors, and direct load control devices. The additional major elements of the

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[2] Product specifications can be found on http://www.ice-energy.com/stuff/contentmgr/files/1/b5fef8f4e945bef09e48aca6714b5c51/download/ice_bear_product_sheet.pdf.

CoolData controller include a data logger, microprocessor to run scripted or compiled control commands, a real time clock and battery backup.

The CoolData Controller communications are enabled with a Web server that communicates over the Internet using Ethernet protocol carried by typical by a private 3G wireless network. By network enabling each device, the CoolData controllers support stand-alone or remotely controlled operation and serve as distributed units to supervisory control, in this case the IDER platform. The user can continually monitor the performance of each Ice Bear unit against whatever key performance indicators have been defined for a single unit, group of units, or population of units as a whole. The units can receive and implement continual upgrades of the software and firmware of the controllers, and leverage the network to serve those updates to each individual unit. For local customer and service access, the interface is through a browser-based Web portal that can even run on certain mobile phone such as the iPhone.

Ice Energy Network Operations Center and Visualization via a Dashboard

The Ice Energy NOC is located in Windsor, CO and serves the warehousing location of the data servers and the central control system. Visualization is enabled with a dashboard that is the interface used by utility personnel for monitoring and controlling the Ice Bear units. The visualization has been designed to report key metrics for evaluating permanent load shift performance including demand reduction, energy shift, and peak coverage. Navigation is intuitive and customization tools allow utilities to change the way resources are aggregated and controlled. FirstEnergy's visualization page(s) have been created and are shown below on Figure 2-3 and Figure 2-4:

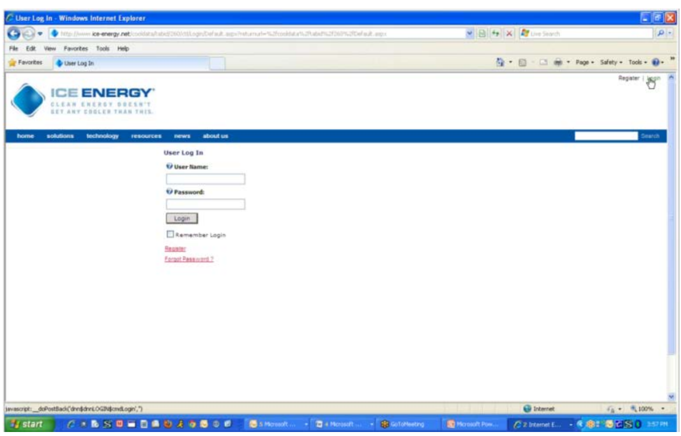

Figure 2-3
Sign in screen

Figure 2-4
Aggregate load and energy shift of four Ice Bear units for a week in April 2011

The visualization includes three performance metrics that are essential to evaluating the permanent load shift resource and are shown in section 5 below. Demand reduction, energy shift, and peak coverage are aggregated for the deployment and reported on a daily, weekly, or monthly basis. Peak coverage is defined as the actual percentage of energy shifted vs. expected energy shift for the identified 6 hour time period. These metrics are calculated for each storage cycle which is defined as a 24-hour period starting at the beginning of a peak period and ending 24 hours later.

Site data is combined with system models to generate storage cycle performance for each Ice Bear. Using the air conditioner (HVAC) equipment model data tables, the appropriate kW value is applied based on the capacity and age of the specific integrated HVAC (IHVAC) system being displaced by the Ice Bear. The dashboard presents the impact of the IHVAC on the utility distribution system by applying the source equivalent multiplier (SEM) for the region. The SEM used in the FirstEnergy dashboard is 1.1353 which represents on-peak distribution losses only of the transmission and distribution system and represents the load reduction at the PJM-JCP&L connection point.

Demand reduction is calculated using the appropriate Ice Bear and HVAC unit model data along with the outdoor ambient temperature measured at the Ice Bear. The maximum ambient temperature recorded during peak cooling is used to calculate the maximum peak IHVAC demand. Ice Bear cooling demand is subtracted from this value to determine the maximum peak demand reduction for the storage cycle.

Demand Reduction = (IHVAC Demand – Ice Bear Demand) * SEM

The dashboard aggregates demand reduction by adding the maximum demand reduction values for each Ice Bear unit selected in the dashboard navigation tree and within the selected time frame. Depending on the demand reduction values reported, the engineering units will change. Values less than 1000 kW will be reported in units of kW and values of 1000 kW and greater will automatically be converted and reported in units of MW.

Energy shift is also calculated using the appropriate Ice Bear and HVAC models along with the outdoor ambient temperature measured at the Ice Bear. The average ambient temperature recorded during peak cooling is used to calculate the average IHVAC demand per unit of cooling. Likewise, the average ambient temperature recorded during the charge operation is used to calculate the Ice Bear charge rate and stored cooling capacity for the cycle. After insulation losses are removed, the stored cooling capacity (equivalent to the stored cooling delivered on-peak) is multiplied by the average IHVAC demand per unit of cooling to determine the energy shift for the storage cycle.

Energy Shift = (Average IHVAC Demand per Unit of Cooling) * (Stored Capacity – Insulation Losses) * SEM

The dashboard aggregates energy shift by adding the daily energy shift values for all Ice Bear units selected in the navigation tree and over the selected time frame. Similar to demand reduction, energy shift engineering units will change depending on the values being reported. Values less than 1000 kWh will be reported in units of kWh and values of 1000 kWh and greater will automatically be converted and reported in units of MWh. The engineering units being used to report performance are displayed in the energy shift axis label.

Peak coverage is calculated using site data. Utility program Ice Bear installations include an IHVAC compressor current switch as part of the standard sensor package. This digital signal is used to monitor the IHVAC compressor operation during the scheduled peak cooling period. Peak coverage is reduced proportionally by the amount of time the IHVAC compressor ran during the scheduled peak cooling period to calculate the daily percent peak coverage value for each Ice Bear.

Peak Coverage = (1 – IHVAC On-Peak Run Time / Peak Period) * 100

The dashboard aggregates peak coverage by averaging the daily values for all *Ice Bear* units selected in the dashboard navigation tree and over the selected time frame. Peak coverage is reported as a percentage for all active selections versus the kWh goal for that time period.

Communications and Control Integration

Communications are carried through a two-way Ethernet via cellular modem, which facilitates monitoring and control. The schematic below shows the specific steps in the communication/control integration path.

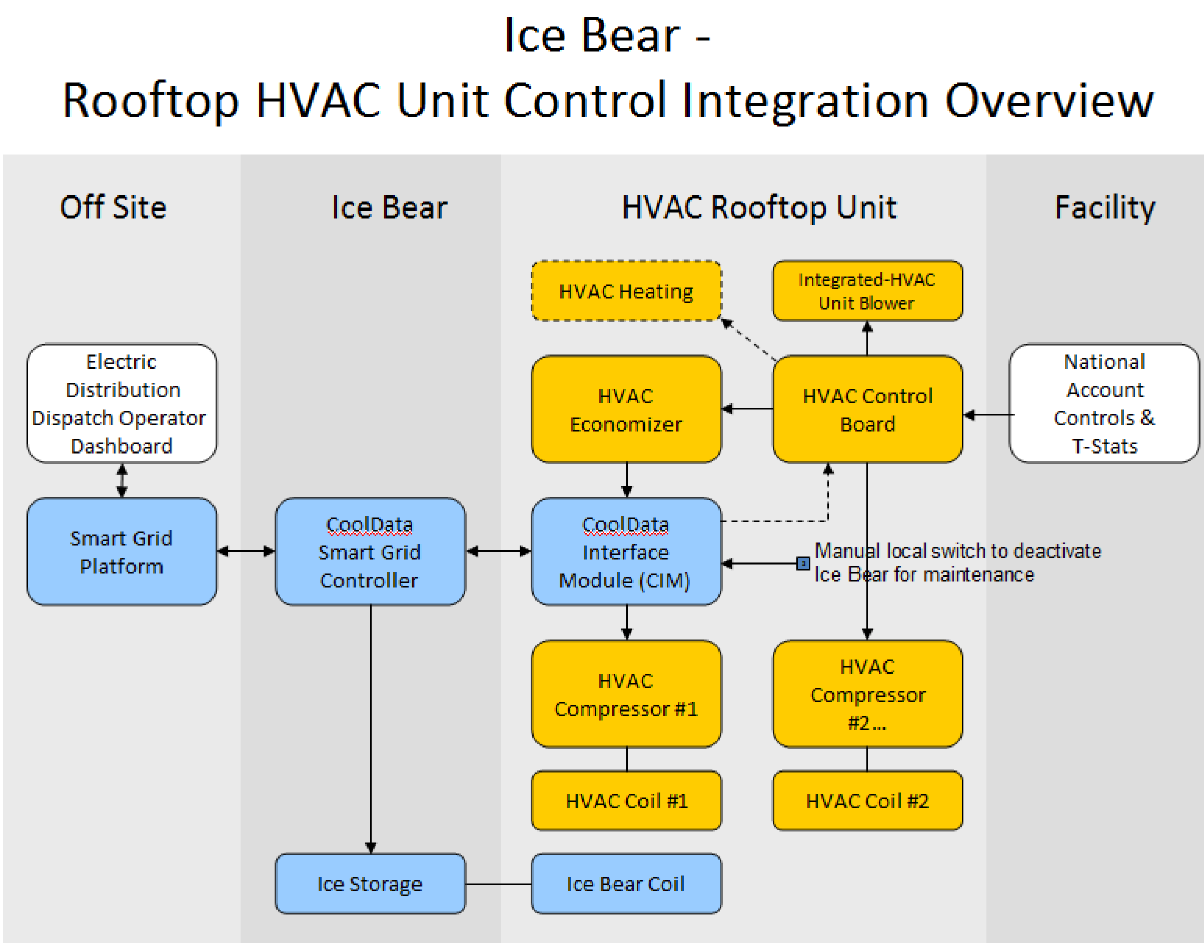

Figure 2-5
Monitoring Package

Following is the list of monitoring points on the FirstEnergy-Staples test and evaluation site that are beyond the usual *Ice Bear* sensor package.

Four direct expansion systems integrated with *Ice Bear* units

- Indoor fan motor (current transducer)
- Total system (current transducer)
- Return air temperature (digital temperature sensor)
- Supply air temperature (digital temperature sensor)
- Outdoor ambient temperature (digital temperature sensor)

Four other roof-top units

- Total system A5 (current transducer)
- Total system A7 (current transducer)
- Total system A8 (current transducer)
- Total system A9 (current transducer)

Whole building, power meter monitoring demand:

- Building (power meter)

Maintenance

Maintenance of each Ice Bear sub-system is suggested as follows:

- Ice Bear Coil - follow industry standards for service and maintenance of evaporator coils.
- Condensate Drain - Check and clean each year at the start of cooling season. In winter, keep drain dry or protect against freeze-up.
- Condenser Coil - Keep condenser coil fins clean and inside of condenser free of debris, following standard practices.
- Maintaining Adequate Water Level - Inspect water level annually. If necessary, fill Ice bear unit storage tank with tap water to the bottom of the top pipe
- Periodic Maintenance - A technician provides an annual on-site check up visit every spring to confirm system readiness and was on site March 25, 2010 and May10-11, 2011.
- The check list in Table 2-1 is used when performing service calls on Ice Bear equipment.

Table 2-1
Check list used when performing service calls on Ice Bear equipment

Interval	Maintenance Required
During each service/maintenance call, or at a minimum, annually	Verify CoolData® Controller program, including time/date (daylight savings, if applicable). Cycle all applicable modes of operation (ice charging, ice cooling). Verify operating pressures (during ice charging).
Annually	Check electrical connections Check and record Amp draws of Ice Bear 30 unit and corresponding direct expansion unit. Visually inspect fan blades. Visually inspect overall system (look for leaks, inspect fan blades, inspect insulation & piping, etc.). Check operation of refrigerant pump and water pump. Check water level in tank; top off water level if necessary to the bottom of top pipe, shown in Figure 34. Add water treatment. Suggested biocides: ▪ MB-10® (Quip Laboratories Inc.) – two (2) 6 gram tablets ▪ #90 Algaecide (Nu-Calgon)– two (2) tablets for clean water; five (5) tablets for fouled water
As needed	Oil condenser fan motor bearings, if applicable. Clean condenser coil.

Integrated Distributed Energy Resources Platform Integration with Ice Bear

Integrated Distributed Energy Resources (IDER) Platform is in the process of integrating the monitoring and control of the Ice Bear units. Discussion between Ice Energy and the IDER platform provider were held and all communication interfaces have been created and validated by Ice Energy. The IDER platform provider is qualifying the system for monitoring and control of the Ice Bear units through the IDER platform and it will go live in the spring of 2011. Below (Figure 2-6, Figure 2-7, Figure 2-8) are dashboard screens from the IDER platform. They show how to program and monitor the Ice Bear units.

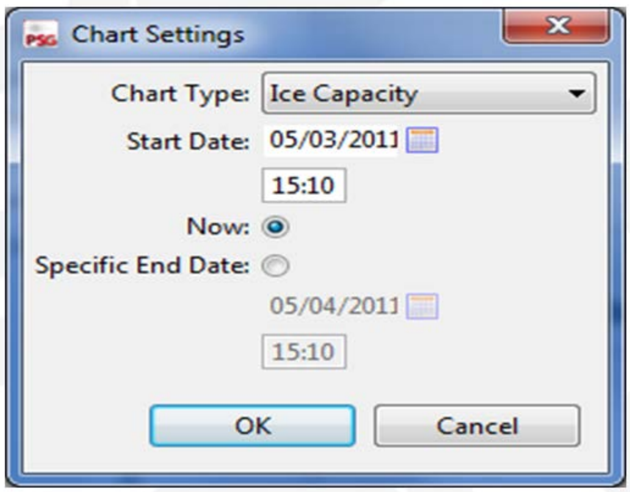

Figure 2-6
IDER control screen to set ice melt start time

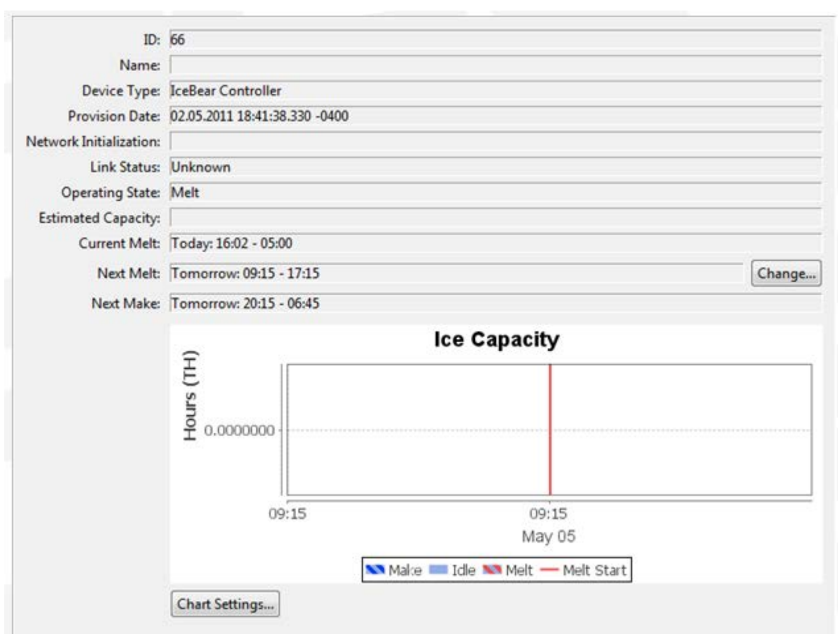

Figure 2-7
IDER control screen showing Ice Bear operation parameters

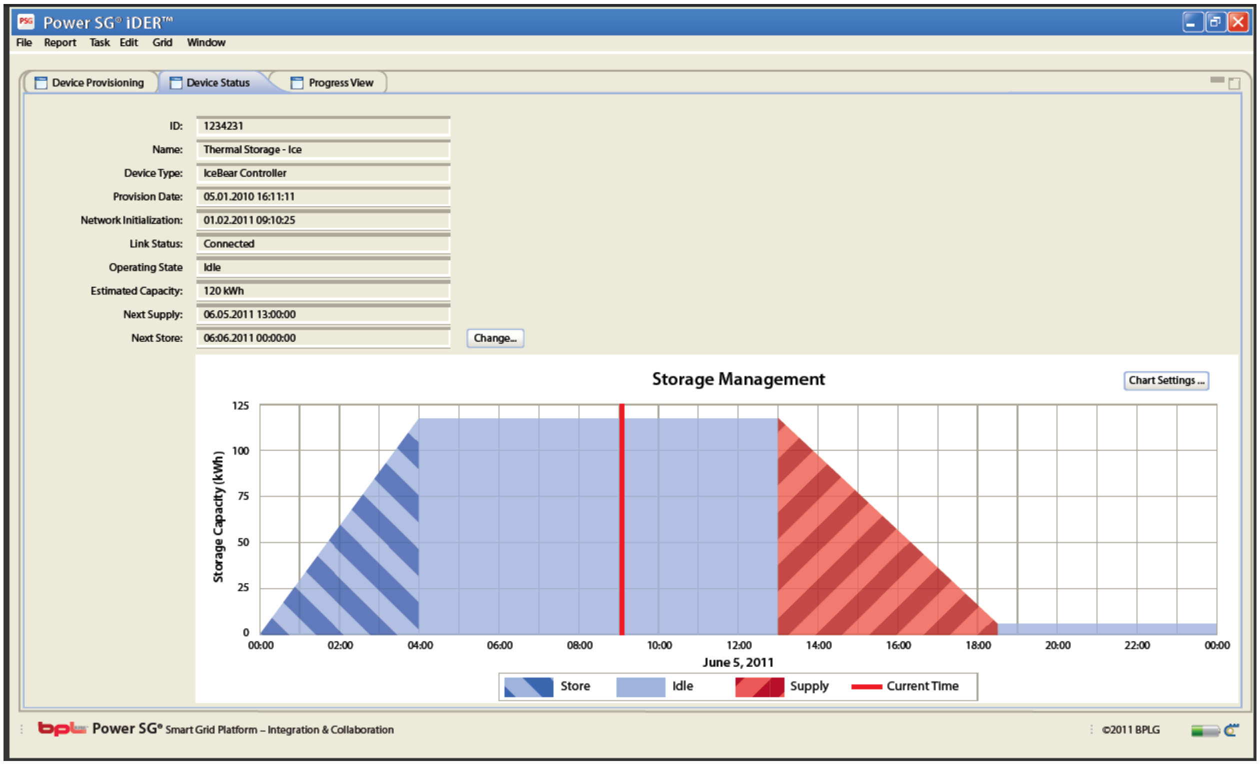

Figure 2-8
IDER Dashboard

During 2011 and going forward, the Ice Bear operations will be performed through the IDER platform. Evaluation of this integration will be documented with the FirstEnergy EPRI Smart Grid Host Site project as discussed previously.

3
TASKS ACTIVITIES

Procure and install the Ice Bear, electro-thermal, ice storage systems

FirstEnergy procured the Ice Bear units, contracted with the operating company's national account customer, installed the units on the roof (see Figure 3-1) without need for structural modification, and mechanically/electrically interconnected the energy storage units into four existing packaged rooftop air conditioning units. The mechanical scope included generating "stamped" structural detail drawings to place roof curbs used as a platform to mount the Ice Bear units. The electrical scope included running three phase power from a distribution panel to each of the Ice Bear units. A distributed energy resource project using electro-thermal energy storage is greatly simplified as it does not require the use of an inverter, synchronizing and isolating relays, nor an emissions permit. The installation is best considered as simple HVAC electrical and mechanical design-build work, equivalent to setting a new piece of packaged HVAC equipment. Local contractors were able to install this equipment with a minimal amount of direction. The host site customer remains pleased with the energy storage equipment and project experience itself; no unusual or outstanding punch list items nor complaints were noted.

Figure 3-1
Installation of the units

Connect Ice Bear

The staples facility has two stage HVAC units, consisting of two refrigeration stages, which provide 10 tons of cooling with 2 - 5 ton circuits as shown on Figure 3-2.

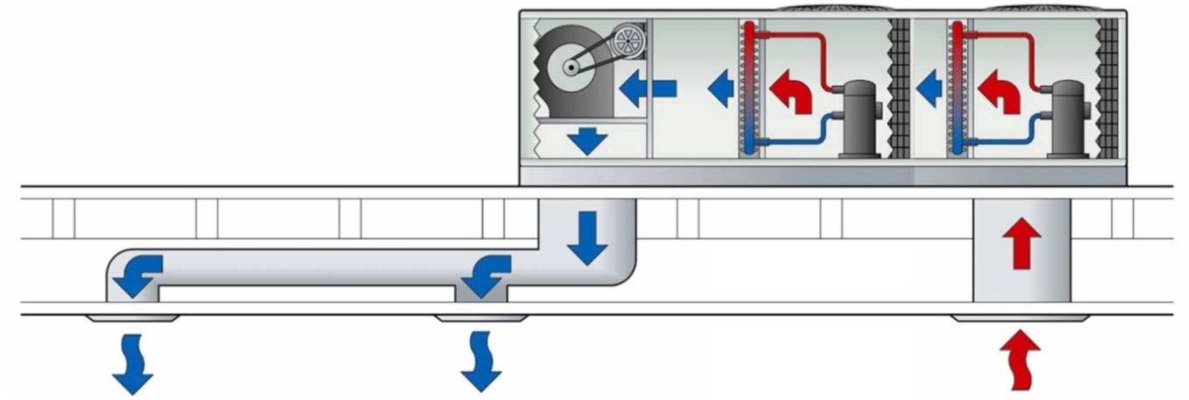

Figure 3-2
Staples facility HVAC system

The four HVAC units chosen to be integrated with Ice Bear units were retrofitted by adding a cooling circuit served by the Ice Bear. The Ice Bear is designed to perform the work of one cooling stage for at least six hours every day. The temperature set points for all cooling are controlled by the customer, but the source of the energy for cooling is from the stored, ice energy, as illustrated on Figure 3-3.

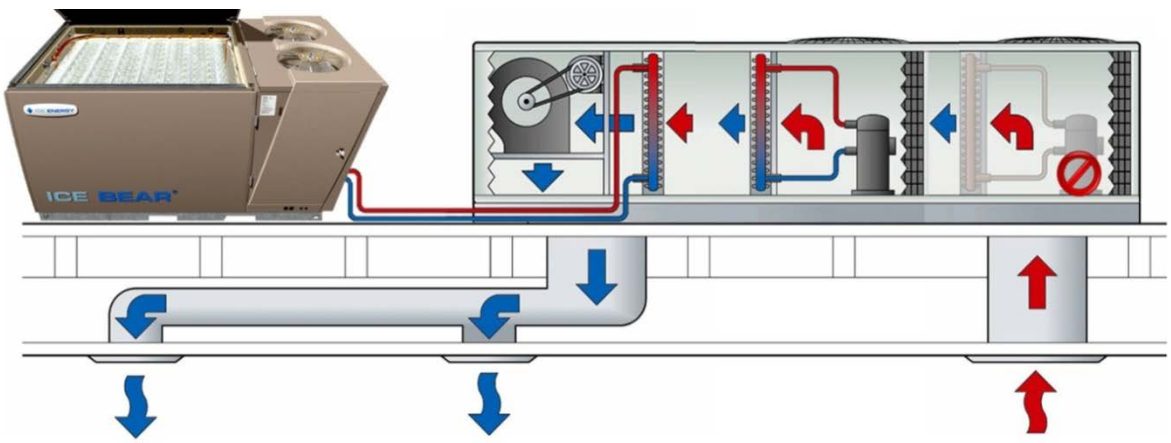

Figure 3-3
Use of the energy stored in ice to provide cooling

JCP&L Site Visit

A visit was made by JCP&L representatives during the turn-key installation of the Ice Bear system. The contractor gave an overview of the work being preformed and an update on the progress of the installation; it appeared that the start to finish took about two weeks.

At the time of the visit, the installing contractor had already set the four Ice Bear units by crane and was in the process of piping to interconnect to the existing roof top units. The construction site on the roof was clean and orderly. An inspection of the existing roof top units found the installation of the new cooling coil was neat and clean. The Ice Bear units were set on equipment support curbs protecting the customer's roof. The installers were worked on the piping between the Ice Bear and the rooftop units. The piping was insulated and then placed in a sheet metal enclosure for protection. The contractor provided electrical connection of the four new Ice Bear units and Cool Data control system.

JCP&L installed a new remote-read, interval meter on site to supply daily data for evaluation which will be used to corroborate the vendor data.

The store manager seemed pleased with the installation as it did not impact his store operations or the comfort of their customers.

Operate Ice Bear units and collect data

The Ice Bear systems were commissioned in October 2009 and operated until Nov 1, 2009 before the weather turned cold. The units began providing cooling again on March 17, 2010 and operated through November 1, 2010. A tech typically provides an annual on-site check up visit every spring to confirm system readiness and was on site March 25, 2010 and again on May 10 and 11, 2011 when the Ice Energy technician performed routine maintenance as well as upgraded some cellular modem components. The Ice Bear units operate automatically when the building calls for air conditioning.

For the first year operation, the Ice Bear systems were operated on different fixed schedules for summer and winter. During the cooling season (May – October), the Ice Bears provided cooling noon – 8pm and then began charging 8pm and completed their ice make by 10am the following morning. During the off-season (November – April), the Ice Bears would provide cooling, if requested, between 11am and 8pm and made ice from 8pm to 10am the following morning. Winter hours of operation were longer in order to melt all or as much of the ice make as possible. Also, for the upcoming cooling season, the ice make time will start at 9pm which is when the store closes and the tail peak as shown on page 4-9 will be eliminated. This should flatten both the customer's and the circuit's load profile.

No specific tests or operations were commanded from the central control system during 2010, although the capability was demonstrated, and is ready for integration to the IDER platform.

The Ice Bear system includes an expanded monitoring package used for reporting purposes as well as onboard and remote diagnostics. The package includes current sensors to monitor Ice Bear and target direct expansion system power and temperature sensors that monitor ambient, supply, and return air temperatures as well as all air handling units, both those integrated with nor without Ice Bears. Sensor values are read every second and averaged over a one minute period. The one minute averages are recorded and archived in Ice Energy's historian. These data are used to calculate daily performance values which in turn are displayed in the Ice Energy utility dashboard.

Data collected on the Ice Bear units include:

- Refrigerant System pressure
- Refrigerant System suction temperature
- Water Tank temperature
- System amps (current transducer)
- Cabinet temperature

- Compressor suction pressure
- Compressor suction temperature
- Condenser liquid temperature

The information collected by the CoolData Controller (temperatures, pressures, amperage, etc) is replicated to the NOC to remotely monitor the operation of the equipment and to validate the system is achieving the peak load coverage intended by the utility. Typical, the Ice Bear unit will "call home" every twenty minutes or so, report information to the NOC and accept instructions about any changes in strategy, including reducing the communications intervals. Exception reporting will alarm any deviations, and categorize them into discreet types for resolution. In the event of the loss of communication, the CoolData Controller will store at least two weeks of data, depending on the internal sampling frequency.

4
PERFORMANCE AND ANALYSIS

Performance Metrics

Site data along with HVAC system model information were used to calculate daily performance of the four Ice Bear systems in aggregate as discussed in section 3, Product Description. The results are available to FirstEnergy via a password protected, secure web interface the Ice Energy utility dashboard that uses data from the Ice Energy NOC.

The four units have been named to identify each unit as shown in the roof layout diagram on Figure 4-1.

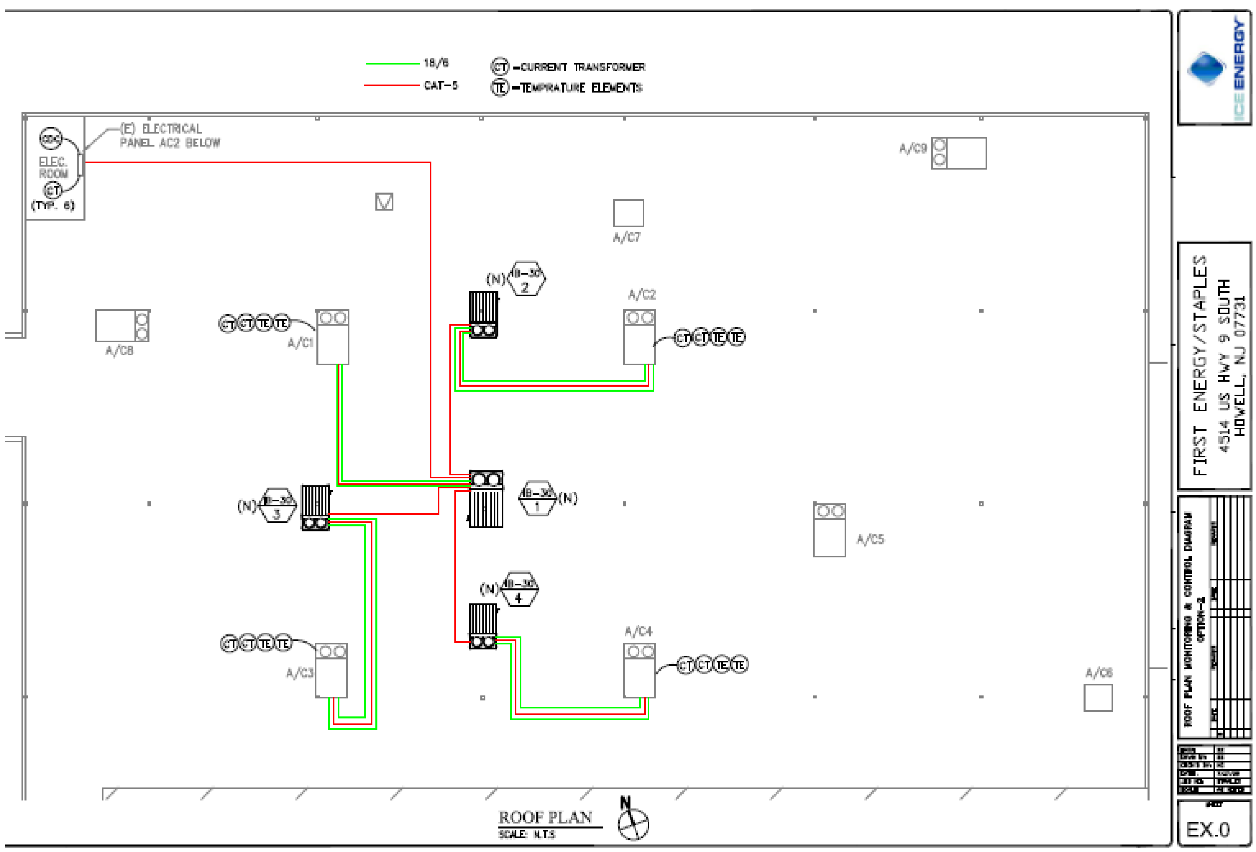

Figure 4-1
Roof top layout

The following image, taken from the FirstEnergy utility dashboard view, shows the monthly aggregation of Ice Bear performance metrics for 2010. The sharp increase in performance apparent in August 2010 is because one of the integrated HVAC unit #3 came on line on 8/11/2010 after being under repair since May 2010. The HVAC unit #3 needed a new indoor fan motor. The Ice Energy's remote diagnostics identified the failed HVAC unit, the associated Ice Bear was taken off line via the central control system and the local facilities manager was notified to repair the unit. It is unknown why it took more than 3 months to repair the HVAC unit. These types of issues will be handled with the appropriate contract language in the future.

Once HVAC unit #3 was on line, and with all four Ice Bear systems providing cooling, a maximum demand reduction occurred in August of 19.54kW locally and 22.2 kW at the PJM bus based on the industry standard transmission and distribution (T&D) losses of 13.53%. During the same month, the energy shifted to off-peak hours was 2.96 MWh. During the entire operating year, the aggregate Ice Bear system operations provide 100% peak coverage of the scheduled peak period (12pm – 6pm).

Figure 4-2
Aggregate monthly load and energy shift at PJM bus of four Ice Bear units, June 2010-May 2011.

The following Figure 4-3 shows the weekly aggregation of Ice Bear performance metrics for the month of August 2010 as seen at the PJM bus.

Figure 4-3
Aggregate load and energy shift at PJM bus of four Ice Bear units, Aug 2010.

The step in load shift performance can be seen during the week of August 8th when the HVAC unit that was under repair for Ice Bear unit #3 was brought back online. This information shows the peak demand reduction of 22.2 kW occurring during the week of the 29th and energy shift of 2.96 MWh for the whole month of August. Below is information for the specific week of August 29, 2010. The four Ice Bear units provided a peak demand reduction of 22.2 kW, also as shown above, and an energy shift high of 129 kWh on August 31, 2010 while providing 100% peak coverage.

Figure 4-4
Aggregate load and energy shift at PJM bus of 4 Ice Bear units for week of Aug-Sept 2010.

The following Table 4-1 shows unit specific local performance data for all four *Ice Bear* systems during the week of August 29, 2010.

Table 4-1
Table showing local performance data of 4 Ice Bear systems, week of August 29, 2010

System	Daily On Site Performance Metrics			
	Date	Demand, kW	Energy, kWh	Total Runtime, h
NJA1	08/29/2010	4.27	20.38	6.52
	08/30/2010	4.20	26.97	8.00
	08/31/2010	4.48	28.86	8.00
	09/01/2010	4.55	29.14	8.02
	09/02/2010	4.51	28.64	8.00
	09/03/2010	3.86	24.89	7.98
	09/04/2010	3.82	17.80	7.37
NJA2	08/29/2010	5.18	24.72	6.45
	08/30/2010	5.13	30.27	7.97
	08/31/2010	5.34	31.48	7.95
	09/01/2010	5.11	30.25	7.97
	09/02/2010	4.77	29.32	8.00
	09/03/2010	4.18	25.96	7.92
	09/04/2010	4.23	19.26	7.98
NJA3	08/29/2010	5.20	18.67	6.48
	08/30/2010	5.10	25.43	7.98
	08/31/2010	5.26	24.56	8.00
	09/01/2010	5.08	23.77	8.00
	09/02/2010	4.81	24.01	7.98
	09/03/2010	4.15	21.95	7.97
	09/04/2010	4.23	13.10	7.20
NJA4	08/29/2010	4.30	22.56	6.52
	08/30/2010	4.18	27.57	7.98
	08/31/2010	4.46	28.83	8.00
	09/01/2010	4.50	29.03	8.00
	09/02/2010	4.50	28.61	8.02
	09/03/2010	3.91	25.44	8.03
	09/04/2010	3.70	20.38	8.02

Table 4-1 (continued)
Table showing local performance data of 4 Ice Bear systems, week of August 29, 2010

System	Daily On Site Performance Metrics			
	Date	Demand, kW	Energy, kWh	Total Runtime, h
Aggregate	08/29/2010	18.95	86.34	25.97
	08/30/2010	18.61	110.24	31.93
	08/31/2010	19.54	113.73	31.95
	09/01/2010	19.23	112.20	31.98
	09/02/2010	18.59	110.58	32.00
	09/03/2010	16.09	98.25	31.90
	09/04/2010	15.97	70.54	30.57

The staples store has limited hours on Sundays, and consequently, the Ice Bear resource was used less on 8/29/10

Cooling Performance

These characteristics are apparent in the temperature data collected at the FirstEnergy – Staples demonstration site as shown below.

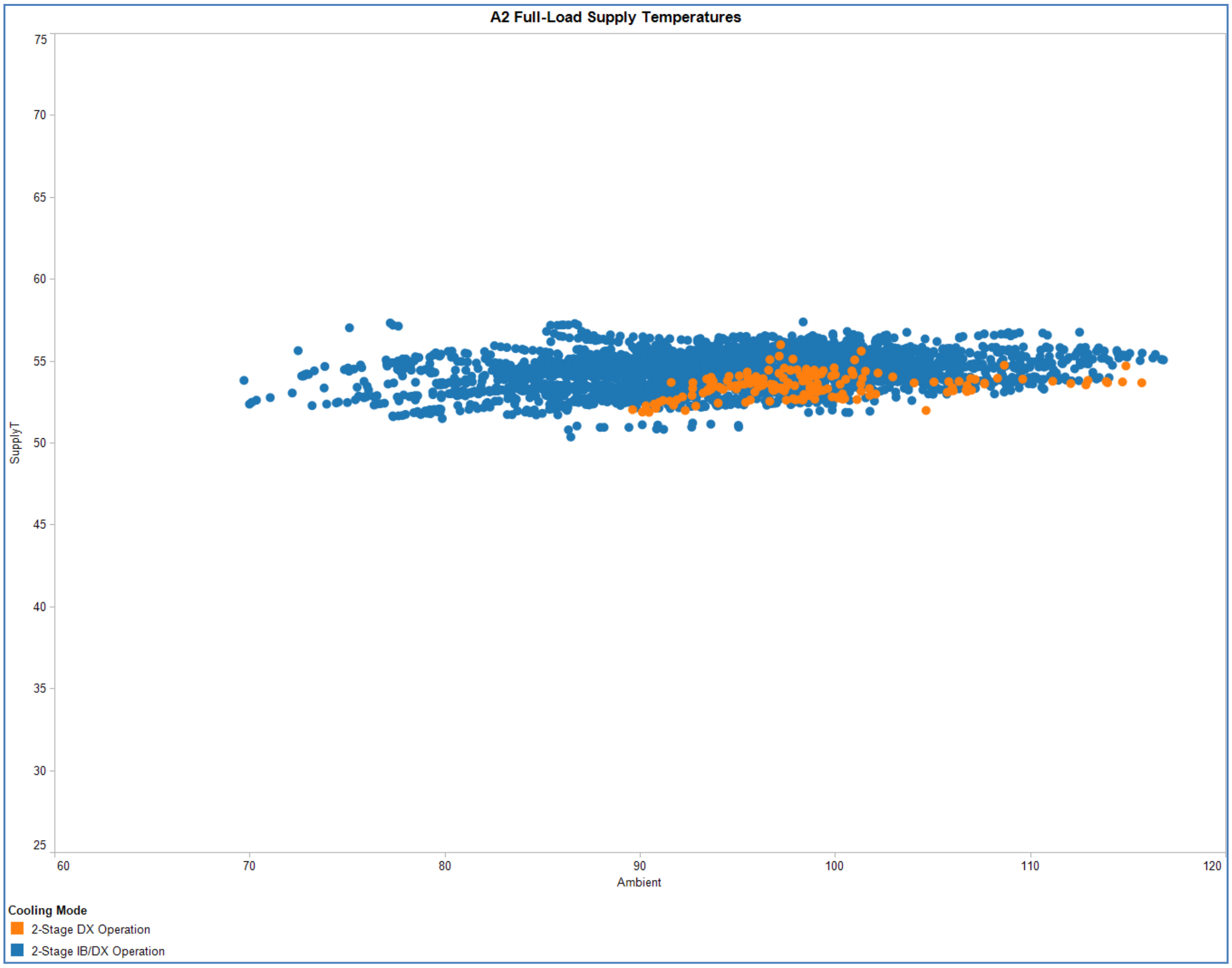

Figure 4-5
Chart showing unit 2 supply air temperatures during 2-stage operation plotted versus outdoor ambient temperatures.

Using temperature data during 2-stage operation allows a comparison of Ice Bear and direct expansion cooling performance under similar conditions. As a result, unit 2 data is presented since this system experience the most 2-stage operation. Even so, there is limited direct expansion data during 2-stage operation since the Ice Bear systems typically provided cooling for 8 hours a day during 2010 operation. This also indicates that the direct expansion systems at the site may be oversized for the application, a characteristic that is common in commercial buildings. Regardless, the data shows equivalent supply temperatures across a wide range of conditions, confirming the Ice Bear cooling performance.

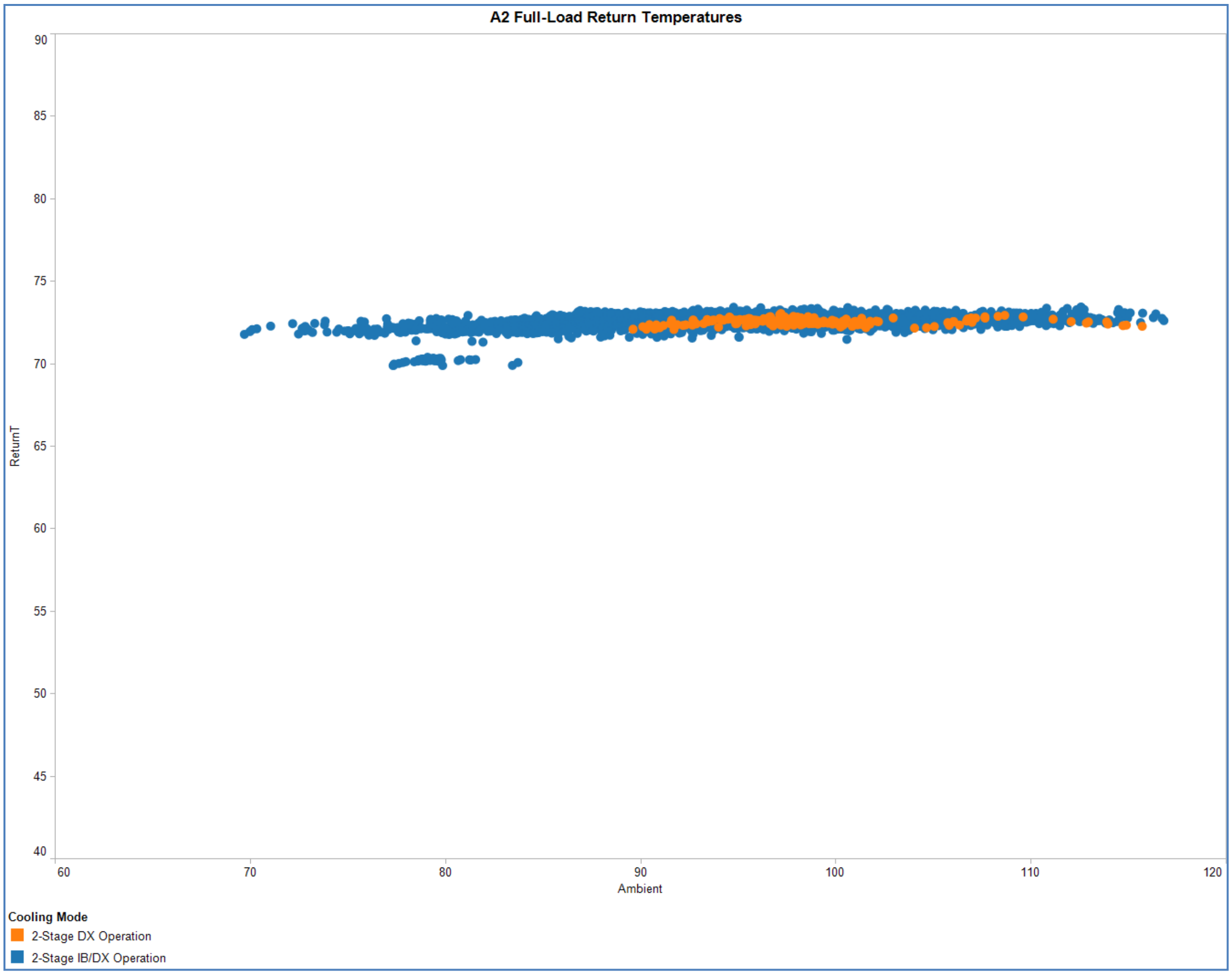

Figure 4-6
Return air temperatures for unit 2 are plotted versus ambient during 2-stage operation.

Again, the Ice Bear matches direct expansion performance under similar conditions and is shown to provide a very consistent return air temperature across a wide range of conditions.

Charge Duration

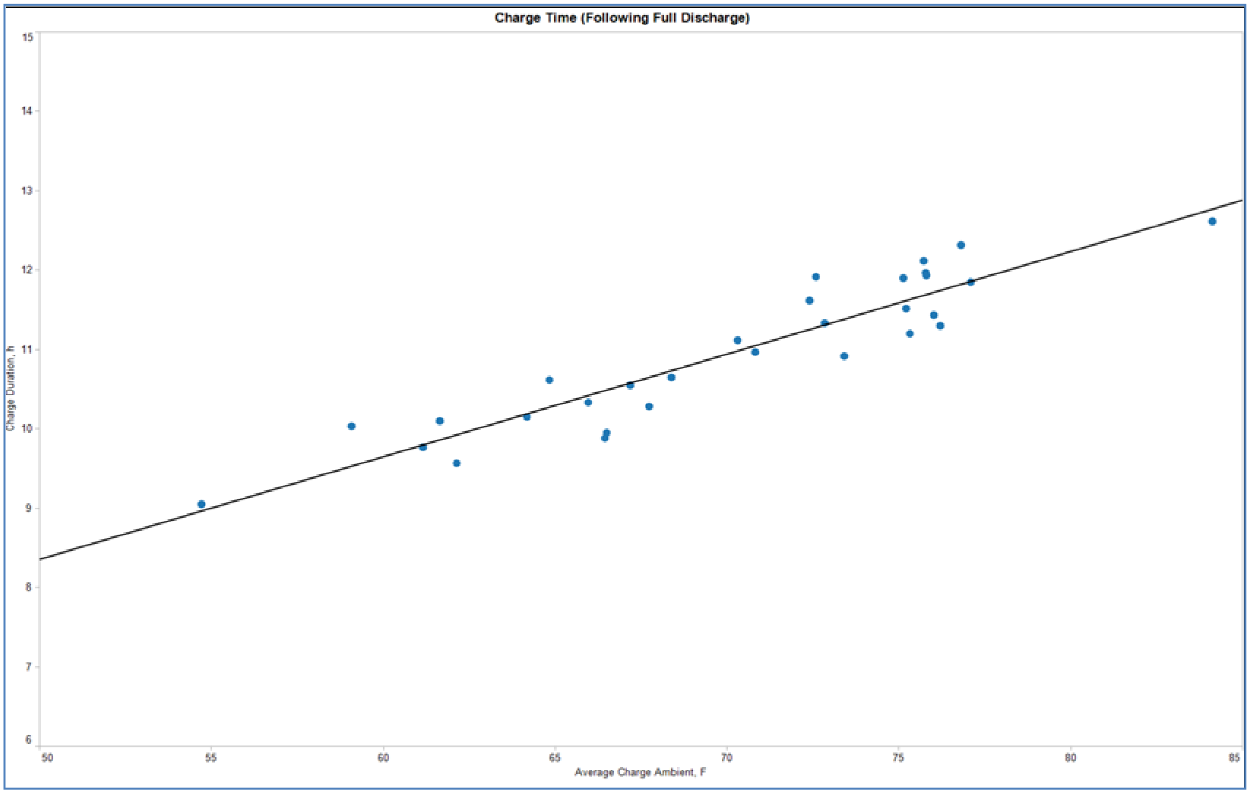

Figure 4-7
Charge (ice make) time in relation to outside temperature

The charge, or ice make time takes from 9 hours with a low night time temperature of 55ºF to just over 12 hours with a high night time temperature of 85ºF. This information provides the basis to shift the 2011 ice make start time to 9pm and have the ice completely made prior to the store opening at 9am, except for a limited number of hot summer nights.

Building Impact

In addition to the standard monitoring package, a current sensor was installed to monitor the building power. Collected data shows the impact of the four Ice Bear systems working in concert to reduce demand. The following chart shows the average building demand from August 11 to 31, 2010 to capture the four Ice Bear systems impact versus time of day.

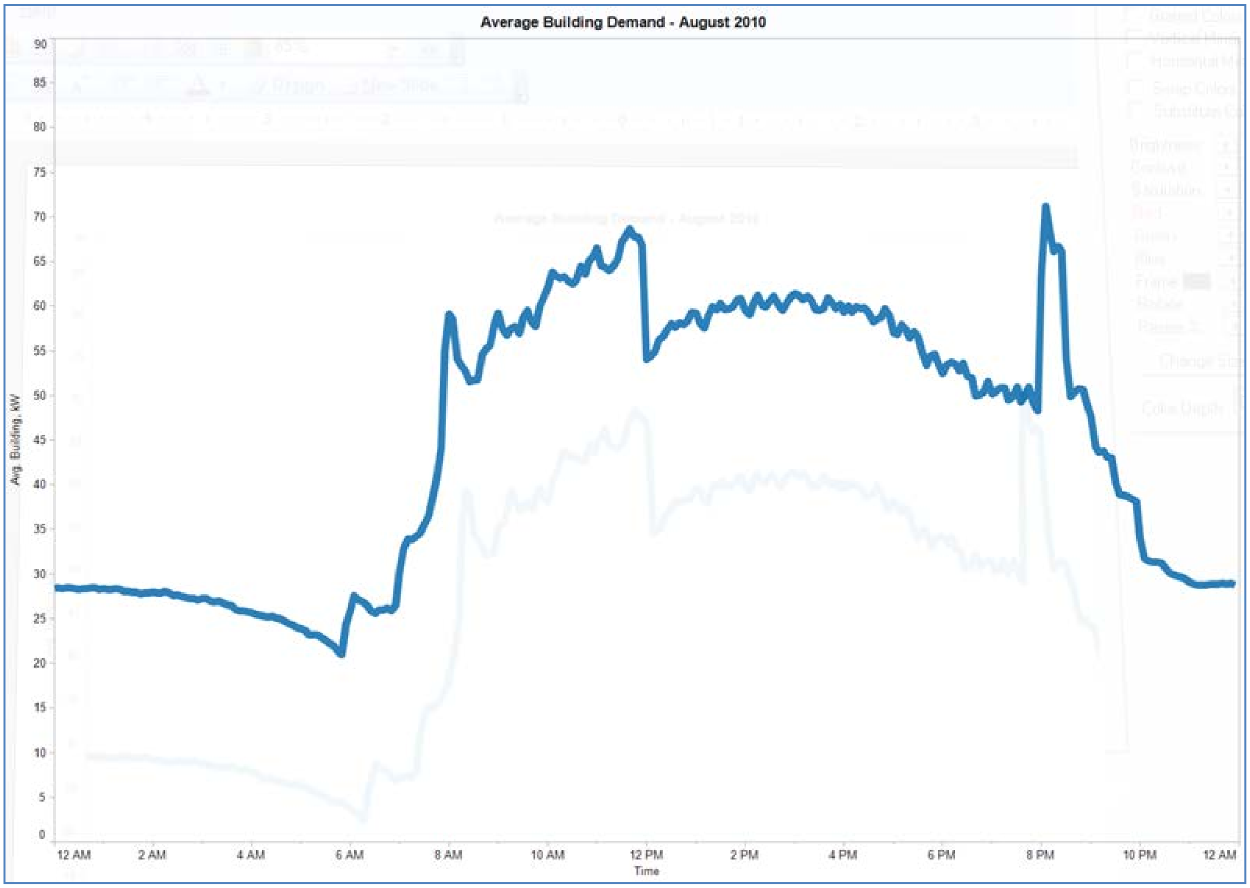

Figure 4-8
Average Building Demand load curve using project meter data, August 2010

The demand load reduction of operating four Ice Bear systems on a single building is clear and dramatic as shown above in the building load cure where a ±15 kW drop can be seen between noon and 8pm.

As mentioned in the previous section, the ice make time for 2011 will start at 9pm, which is when the store closes and the tail peak as shown above will be mitigated. This should flatten both the customer's and the circuit's load profile.

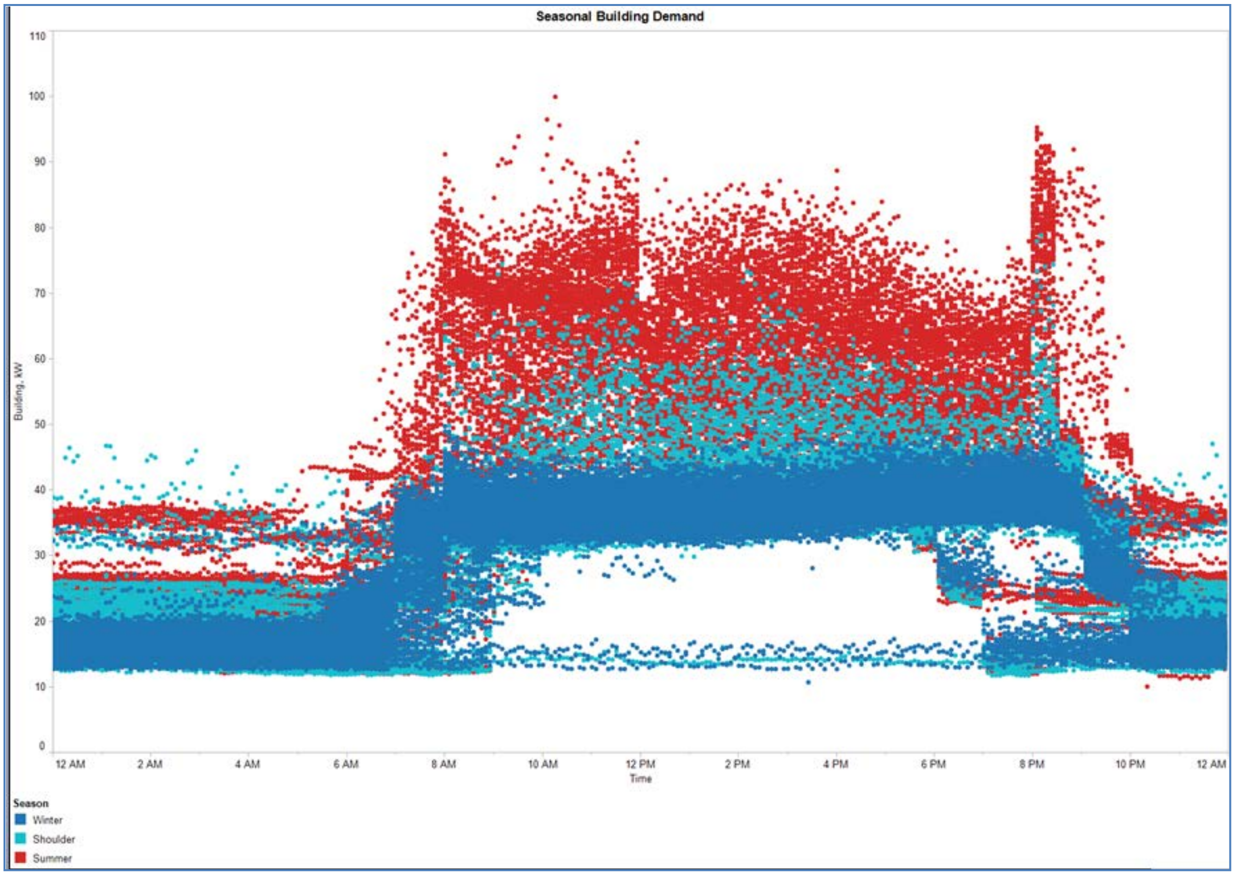

Figure 4-9
Scatter plot of building data annual demand versus time of day.

The data is categorized by season to show annual trends and the impact Ice Bear systems have on demand when displacing direct expansion HVAC systems.

Data Corroboration; Facility utility interval metering

An interval meter was installed by JCP&L/FE on the commercial facility and corroborates the curve developed from the Ice Energy monitoring system. Below is a similar graph of average building demand from Aug 11 through 30, 2010 developed from the utility interval meter.

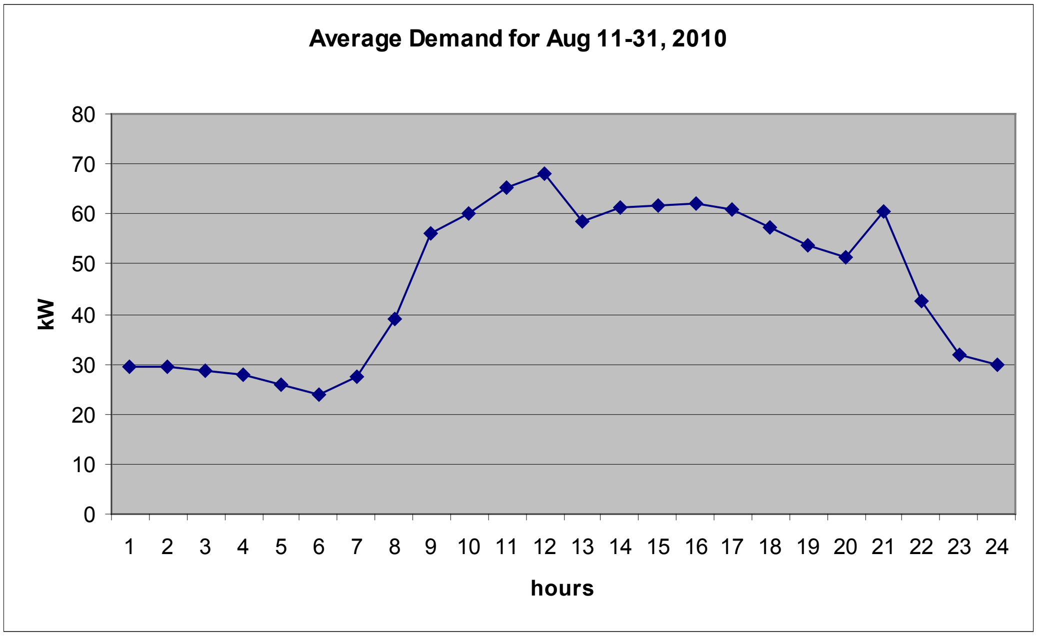

Figure 4-10
Average building demand plot using JCP&L interval meter data, Aug 2010.

5
ELECTRIC DISTRIBUTION IMPACT

An important aspect to this study is to take the actual demand load shift impact of operating four *Ice Bear* units and extrapolate the operation of multiple *Ice Bear* units at many facilities on a single circuit in order to understand how it could aid in managing peak loading situations. An analysis using the specific circuit in this study and a hypothetical deployment installing *Ice Bear* units on a portion of the commercial customers and evaluating how it may impact the peak load and the load profile of the circuit is discussed below.

This particular circuit has 1,665 Residential and 121 Commercial customers of varying size all with air conditioning requirements. A deployment of 400 units on the circuit of 4 *Ice Bear* units each at 100 commercial customers or some complement totaling 400 units, i.e. 50 commercial customers with 4 each plus 25 commercial customers with 8 each based on the number of rooftop or split systems the customers have is a reasonable hypothetical situation considering the number, the size and density of commercial customers.

This evaluation has shown an approximate 20kW load drop at the study facility. Extrapolating this from 4 to 400 units gives a total of a 2MW load reduction or load flattening on the circuit. The graphs below (Figure 5-1 and Figure 5-2) show two different days from the 2010 summer peaking season, with two operational methodologies. The first has each 20kW load aggregated coincidentally, and the second, staggers the *Ice Bear* operations based on different types of commercial customer business operations, which actually provides a better flattening of the circuit load profile.

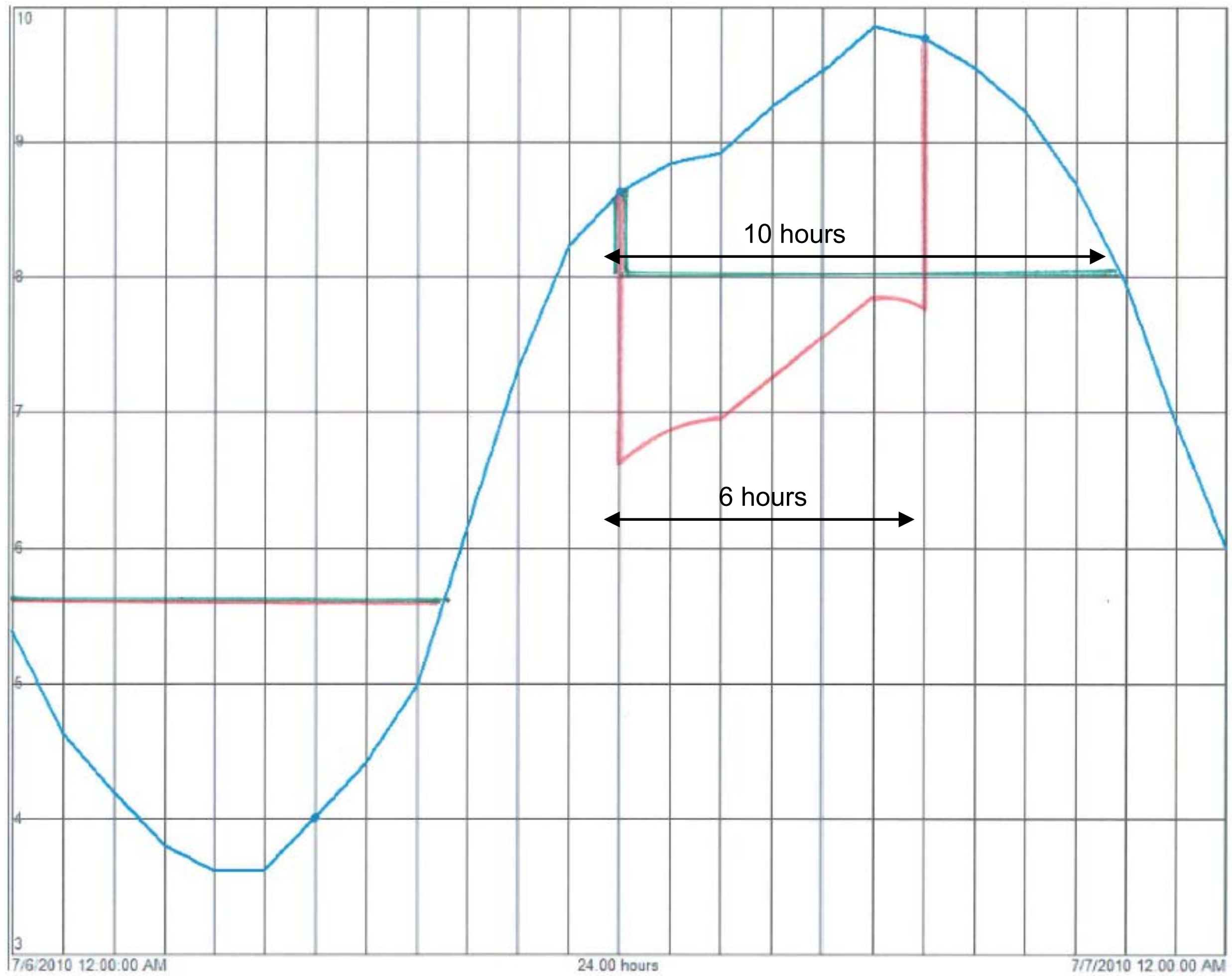

Figure 5-1
Summer Peak Loading Day on Selected Circuit, July 7, 2010 showing potential load shift of coincident 2MW (100 sites of 20kW each) from noon-6pm (in red) or an equivalent load shift (in green) staggered based on business operations of the facilities and to shave the circuit's peak.

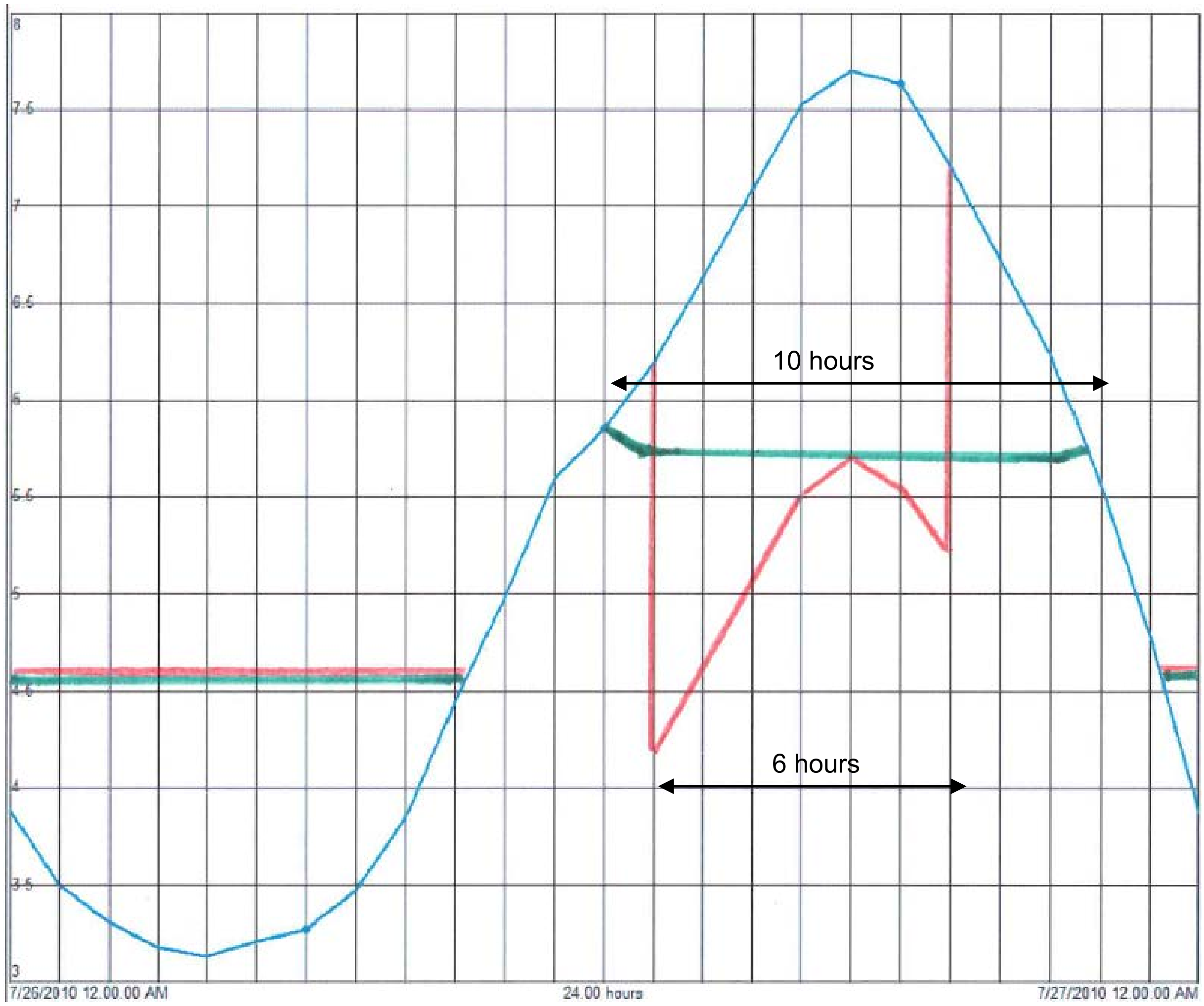

Figure 5-2
Summer Average Peak Day on Selected Circuit, July 26, 2010 showing potential load shift of coincident 2MW (100 sites of 20kW each) from 1-7pm (in red) or an equivalent load shift (in green) staggered based on business operations of the facilities and to shave the circuit's peak.

6 RESULTS

Four Ice Energy Ice Bear 30 electro-thermal energy storage units were roof mounted and successfully commissioned on a national chain medium box retail store located in Howell, NJ, performed as expected and contributed to peak load shifting on the associated circuit permanently.

The installation is best described as a common HVAC electrical and mechanical scope of work, equivalent to installing a new packaged rooftop piece of equipment. Local contractors with oversight from Ice Energy and JCP&L/FirstEnergy completed the installation over the course of a few days in October, 2009. Based on this project's experience, finding local contractors to perform installation and commissioning is not perceived as a barrier to a megawatt scale project size.

This research project shows that singularly, each *Ice Bear* unit stored an estimated 32 kWh of energy in 10 off-peak hours and reduced an estimated 5 kW of site energy demand for up to and over a six-hour, on-peak period. The *Ice Bear* units have distributed control through their local CoolData controller and communicate back to the Ice Energy NOC in Colorado to monitor and remotely manage their health and performance.

New Jersey summers are humid, with the potential for significant temperature variations across this 7,836 square mile state. The Township of Howell is located in Monmouth County (latitude 40.2N, longitude 74.2W, elevation 82') and is representative of the climate across the state. High latent loads require air conditioning systems to work harder to keep building space at expected comfort levels. Also, rooftop units work harder when temperatures are higher, consuming more kW/ton of cooling as temperatures increase because they are in the heat of the sun. In effect, they do "less work, less efficiently", which is a reason why the electricity grid experiences higher demand during prolonged heat events. In contrast, *Ice Bear* cooling performance does not degrade with increasing daytime temperatures because the energy to cool was used and stored during the prior night. An additional benefit of *Ice Bear* cooling is during part load conditions with improved dehumidification and therefore, comfort. Part load conditions cause air conditioning systems to short cycle, reducing dehumidification, i.e. the thermostat is satisfied before sufficient dehumidification has occurred – this is even more apparent when units are oversized and can reduce the temperature in a building space very quickly without sufficient dehumidification.

Through the 2010 summer peak season, the four *Ice Bear* units performed as expected, providing building cooling using ice during the daily utility system peaks. The mean discharge time during the week of August 29th was 7.73 hours, and the median discharge time was 7.98 hours. When the building was being cooled via the stored energy, there was over an 18 kW reduction at the site, which equates to 20.4 kW at the PJM bus based on 13.53% T&D system losses; a higher avoided energy and capacity needs upstream of the meter due to system losses. Maximum value is seen during the hottest days and weeks of the summer, as well as during the top 100 hours when the grid, from generation to delivery, is stressed.

This research project also showed that the electric distribution system could see operational benefits with the use of the Ice bear technology. JCP&L saw a permanent peak load shift on the circuit that can contribute to better system management with potential to defer infrastructure investment. Benefits of this installation are the permanent reshaping of the air conditioning driven load profile of this commercial building while maintaining building cooling customer comfort. This is important as the commercial sector imposes significant summer peak demands from air conditioning load and they are reluctant to participate in load reduction programs that could potentially impact their customer experience and service.

This evaluation has shown an approximate 20kW load drop at the study facility. Extrapolating this from 4 to 400 units gives a total of a 2MW load reduction or load flattening on the circuit. The graph below (Figure 6-1) shows a day from the 2010 summer peaking season, with two operational methodologies. The first method has each 20kW load aggregated coincidentally, and the second, staggers the *Ice Bear* operations based on different types of commercial customer business operations, which actually provides a better flattening of the circuit load profile

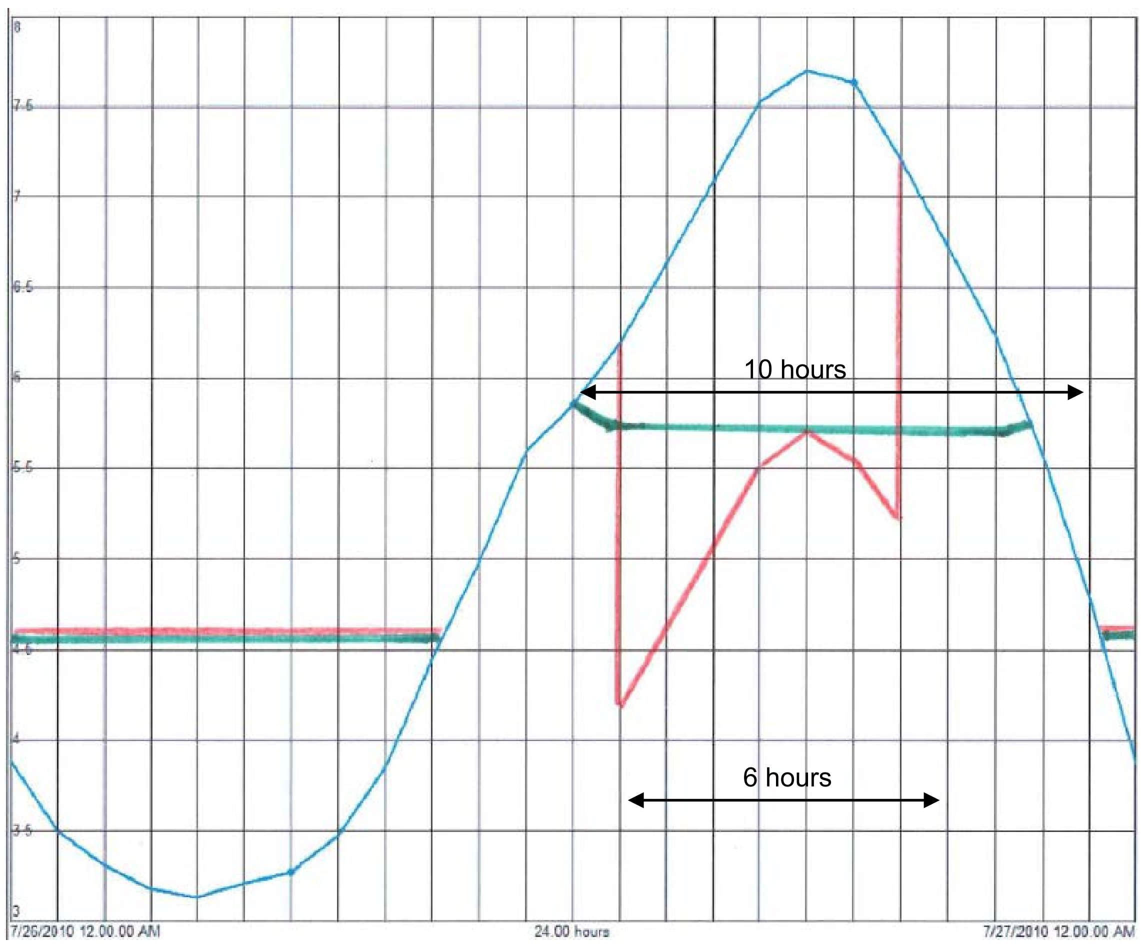

Figure 6-1
Summer Average Peak Day on Selected Circuit, July 26, 2010 showing potential load shift of coincident 2MW (100 sites of 20kW each) from 1-7pm (in red) or an equivalent load shift (in green) staggered based on business operations of the facilities and to shave the circuit's peak.

The host site customer remains pleased with the energy storage equipment and project experience itself; no complaints were noted. See appendix B for a published Case Study.

The four units are deployed at a facility in Howell, which is within the EPRI, FirstEnergy Smart Grid Demonstration Host Site, IDER project, targeted area to facilitate the smart grid IDER platform integration and analysis. Continued evaluation and analysis of the Ice Bear units are planned as it will be integrated into the IDER smart grid platform in the spring of 2011 to monitor and control them. The IDER project is integrating various technologies into a platform for central control of them. The IDER smart grid platform open architecture interoperates with third party sensors, devices and equipment via published application interfaces and control drivers and works with system algorithms and command orders to be processed and then communicated to the various distributed energy resources.

Utility Benefits/Customer Benefits; Win-Win

FirstEnergy/ JCP&L experiences significant demand peaks during the summer months due to air conditioning load. When the demand peaks are extreme, load factor; the ratio of average electric load to peak load, is reduced. This increases infrastructure needs due to infrequent use of capacity assets to support higher peak needs. This problem is particularly acute in the northeast and specifically in New Jersey where the load factor is in the mid 40% range. Figure 6-2 provides the statewide load factor information from 1999 to 2004 as developed in the 2006 New Jersey Energy Master Plan (NJEMP). Also, it should be noted that the 1991 NJEMP alluded to the fact that the average load factor for New Jersey utilities was well below the national average of over 60%. As shown in the Figure 6-2, the average load factor in New Jersey has deteriorated to below 50%.

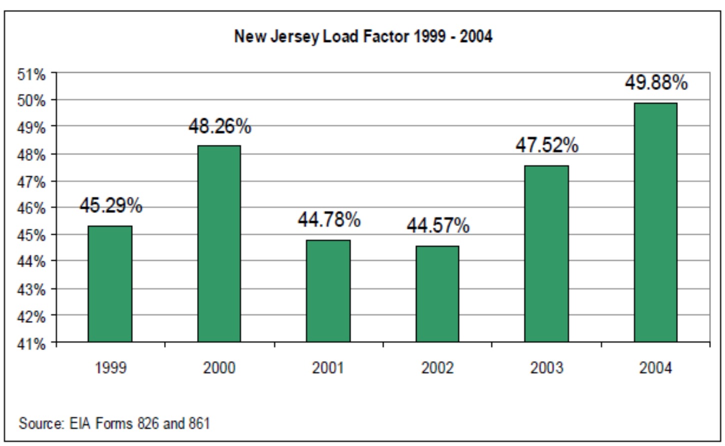

Figure 6-2
New Jersey Load Factor data

Increased penetration of air conditioning systems at residential and commercial buildings, which in part exacerbates low load factor, ends up increasing utility requirements and impacts consumers. This test using the Ice Bear has shown how storage technology can lower demand at the customer site and consequently to the circuit which demonstrates the ability to separate summer heat from summer load.

Reducing summer peak load and improving system load factor is a JCP&L/FirstEnergy and a NJ Energy Master Plan goal. Air conditioning is the primary contributor to the summer peak condition and the delivery system can operate under stress to meet the added demand of new air conditioning demand. Technology such as the Ice Bear has shown in this test and evaluation the potential to assist the electricity distribution system to shift summer heat load to off peak hours. Reducing the weather-dependant loads will alleviate peak capacity requirement.

The use of the Ice Bear by small and medium commercial customers provides them the same comfort and even improved dehumidification management while shifting some of their demand to off peak. It also avoids typical load management programs that might impact their customers' shopping experience, and consequently their "Brand". Decisions about temperatures within the store are rigorously controlled by store management and the Ice Bear design continues to allow this. Despite policymaker's desire to alter customer behavior with Time of Use tariffs, and providing payments to reduce consumption during system peaks, retailers will not risk customer satisfaction or comfort. Corporate environmental initiatives are also drivers here. Staples volunteered to host the Ice Bear units as they have been interested in the technology for years as they believe it supports their environmental initiatives. There is value to Staples in reducing their peak load demand as they perceive that peaking plants are adverse to the environment.

Many states have aggressive goals to reduce both energy consumption and demand, including New Jersey, where these units are being tested. Utility programs using technologies such as the Ice Bear require regulatory approval and need to pass cost-effectiveness tests, and with Ice Bear deployments, they can be cost effective, win-win providing flatter circuit load profiles with good customer comfort, cooling reliability and satisfaction. JCP&L and Ice Energy have worked with the Center for Energy, Economic & Environmental Policy (CEEEP), to model Ice Bear operations and their impacts. CEEEP is part of the Bloustein School of Planning and Public Policy at Rutgers University and they have developed cost-benefit analysis tools that have been used by the NJ Board of Public Utilities in assessing energy efficiency programs. CEEEP's focus is to explore the interrelation of energy, economics and environmental policy issues. In addition to typical cost-benefit criteria, other benefits, which are considerably harder to model, yet are tangible, include: gains in electric system efficiency, improved utilization of assets and enhanced integration of renewable resources.

Flattening summer peak load and consequently improving system load factor benefits all ratepayers – both participants and non-participants alike. Permanently reshaping load profiles of the commercial sector as demonstrated in this project can reduce economic and environmental costs by better utilizing base-load resources while enhancing reliability.

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