Rooftop Unit Fault Detection and Diagnostics Field Results

Prepared for Sempra Utilities

Prepared by EZENICS, Inc.

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This Fault Detection and Diagnostics report on Rooftop Air Conditioning Units (RTUs) was prepared by Kyle Lane on behalf of EZENICS, Inc. It was written for the New Building Institute and Sempra Utilities and would not have been possible without support from:

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ABSTRACT

This Fault Detection and Diagnostics (FDD) report on Rooftop Air Conditioning Units (RTUs) was written for New Buildings Institute and was funded by Sempra Utilities. Its primary objective is to summarize the following during 2011:

1. Lessons learned in the application of EZENICS' (formerly known as 'SensusMI') automated fault detection and diagnostics (AFDD) approach on packaged RTUs on a sample of big box retail stores nationally and in the Sempra Utilities service area.
2. Identified AFDD results for packaged RTUs
    a. Control Settings: Over time, the actual schedules and setpoints deviate from what the building owner desires. To ensure equipment uses the correct schedules and setpoints, EZENICS developed the *Operational Guidelines* (OG) tool which provides continuous automated commissioning.
    b. Equipment Performance: Control systems and equipment often do not perform as designed. EZENICS' AFDD tool continually checks for anomalies such as inefficient compressors, stuck dampers, cycling fans, and defective economizer operation.

The AFDD and OG analytics have been applied to 1,522 big box retails stores located throughout the United States. These 1,522 locations cover over 237 million square feet. Of these locations, 20 are located in the San Diego Gas and Electric (SDG&E) service area. The Heating Ventilation and Air Conditioning (HVAC) equipment that serves these locations includes 29,250 RTUs that range in size from 3 to 60 tons and 2,300 dehumidification units (DHU) that range in size from 10 to 30 tons.

Even though this is not the first year the solution has been deployed at the majority of these locations, in 2011 the AFDD and OG tools found 124,390 faults on RTUs and DHUs for a total of $14,210,700 in potential impact. These savings equate to an energy reduction of 142,000 megawatt hours and a reduction of 216,032,000 pounds of carbon. The owners of these buildings are saving millions of dollars, with teams of just two or three people using enterprise web based AFDD and OG tools from a centralized location.

Table 1 - AFDD Issue Summary (Source: EZENICS)

Issue Category	SDG&E # of Issues on RTUs and DHUs (Annualized Financial Impact)	Nationwide # of Issues on RTUs and DHUs (Annualized Financial Impact)
Mechanical	963 ($76,370)	73,090 ($7,397,700)
Control	182 ($55,800)	51,300 ($6,813,000)

The report's secondary objective is to discuss how OG and AFDD analytics provide a foundation to allow for the maximization of Demand Management (DM) opportunities. As the cost of electric demand (kW) increases, managing demand becomes more financially advantageous to facility owners. DM strategies are often formulated based on operational assumptions and not on the real operation of a facility. As a result, static strategies can be ineffective, leading to undesirable comfort issues and minimized energy reduction. The EZENICS approach to DM integrates centrally managed AFDD and OG technology which allows for scalable dynamic curtailment strategies that do not adversely impact comfort. In 2012, over 64 MW of demand were curtailed during Demand Response (DR) events nationwide using the EZENICS DM Optimization Module, which includes DR Optimization, Demand Limiting (DL), and Economic Load Control (ELC) programs. In 2011, over $2.5 million in revenue were generated as a result of successful DR events nationwide.

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1. INTRODUCTION

Automated Fault Detection and Diagnostics (AFDD) have been implemented on a sample of Rooftop Units (RTUs) that condition 1,522 buildings nationwide. This sample of buildings includes 20 locations in San Diego Gas and Electric (SDG&E) service area. The EZENICS tools identified 124,390 problems which produce over $14,210,700 in potential savings for these 1,522 buildings over just the past year, even though it was not the first year the results were diagnosed for the majority of the locations. The savings equate to a reduction of 142,000 megawatt hours (MWh) and 216,032,000 pounds in carbon reduction. There were 94,426 issues related to energy consumption and 29,964 issues related to comfort. The building owners utilized the EZENICS platform to realize millions of dollars in savings. These savings were achieved with no additional hardware, with the majority of the fixes performed remotely by teams of 2-3 individuals.

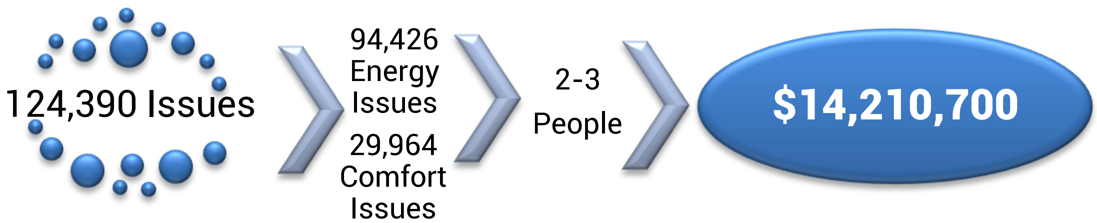


Figure 1 - Summary of Financial Impact (Source: EZENICS)

As the importance of demand increases and the costs associated with it continue to rise, managing demand becomes more financially advantageous to facility owners. Ezenics provides an AFDD driven Demand Management (DM) solution which delivers insight into the real-time operational conditions of a building, allowing for dynamic curtailment strategies that do not adversely impact comfort. These dynamic AFDD driven strategies can be easily scaled across a portfolio and managed centrally to provide significant monetary benefit to the customer through programming such as Demand Response (DR), Demand Limiting (DL) and Economic Load Control (ELC). In 2008 there were 125 locations enrolled in DR programs (Capacity, Direct Load Control, Frequency, Load Following, Peak Shaving, Rate Control, Responsive Reserves, and Synchronized Reserves); by 2012 there were 914 facilities enrolled in these programs, a 600% increase. A centralized team of four people utilized the *Demand Management Optimization Module* to successfully manage all 914 locations' events; managing multiple stores, events, aggregators, and programs at a time. Over 64 megawatts of power were curtailed in 2012. In addition, the buildings have increased their firm service level (FSL) and guaranteed load drop (GLD) bids 80%, on average from 2010 to 2011. In 2011 the successful DR events generated over $2.5 million nationwide.

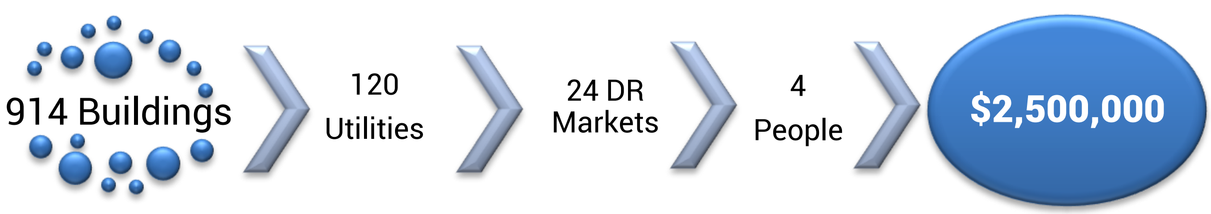


Figure 2 - Summary of Demand Response Events (Source: EZENICS)

2. THE LESSONS

There were three main lessons learned with packaged RTUs:

1. RTUs have issues that cause them to operate inefficiently with comfort, maintenance, and energy consequences
2. How to continuously detect and diagnose the issues in an automated, scalable, and economic manner
3. How to determine what equipment issues are relevant to the facilities and the process to efficiently fix the faults and realize/measure benefits across an enterprise

2.1 Lesson 1 - RTUs have Issues that Cause them to Operate Inefficiently with Comfort, Maintenance, and Energy Consequences

In a New Building Institute (NBI) 2004 report "Review of Recent Commercial Rooftop Unit Field Studies in the Pacific Northwest and California" (Figure 1, below) and as EZENICS has discovered (Table 2, page 3), the number of equipment problems is overwhelming. Problems can occur at the mechanical level and on the control level.

Mechanical issues are problems with the functionality of the equipment and can cause problems in two general areas: comfort and energy. For example, if an outside damper was stuck open during the cooling season, the RTU could have to use additional energy to cool the air. If the heat load was too high for the RTU, the zone temperature could increase, causing discomfort.

The mechanical problems are not isolated to one specific component of the RTU. Issues exist with fans, sensors, outdoor air dampers, economizers, and compressors. All of these problems contribute to increased energy consumption (kWh) and potentially an increase in demand (kW). All of these mechanical issues, and more, can be detected using an Automated Fault Detection and Diagnostics (AFDD) Tool created by EZENICS.

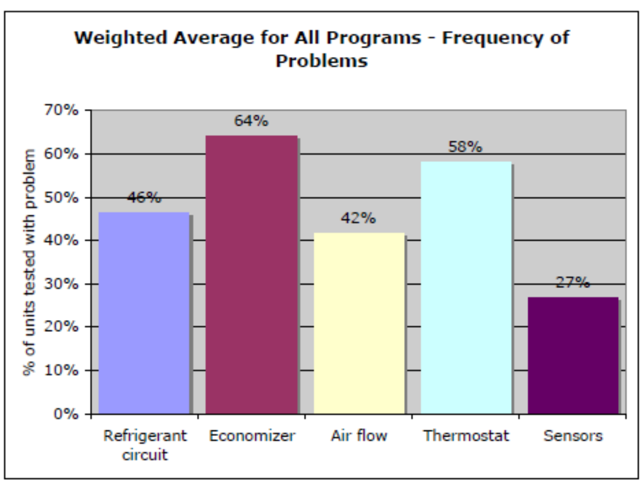


Figure 3 - Average Percent of Issues Found in Field RTUs (Source: NBI Report 2004)

Table 2 - Summary of Mechanical Issues (Source: EZENICS)

Problem Area	SDG&E Utilities # of Issues on RTUs/DHUs (Avg. # of Issues per RTU/DHU)	Nationwide # of Issues on RTUs/DHUs (Avg. # of Issues per RTU/DHU)
Economizer	851 (1.73)	57,800 (1.83)
General RTU	112 (0.22)	15,290 (0.48)
Totals	963 (1.96)	73,090 (2.31)
NOTES: 1. 20 Locations (465 RTUs/26 DHUs) in the sample are in the SDG&E service area 2. There are 1,522 Locations (29,255 RTUs/2,299 DHUs) in the sample		

In addition to the types of mechanical problems that the NBI report noted, there are also control issues related to maintaining equipment schedules and setpoints. These control issues can go undetected using traditional FDD techniques because the issues often do not cause client discomfort and they are not related to the equipment working poorly. The issue is that the equipment is operating when it does not need to. An example of an often undetected issue is a low cooling setpoint. A client may have operational guidelines that state their cooling setpoints should be 73°F for all RTUs. However, it would not be unusual to find RTUs that are set to operate at a cooling setpoint of 71°F. The reason for the lower setpoint could be because it was changed to help compensate for an adjacent zone in an open space that had an issue or because of poor thermostat or diffuser positions creating a 'too hot' complaint. The lowered setpoint is often a fast easy 'fix' hiding the root cause of an issue or needed temporarily, but then was forgot to be changed back after the main issue was resolved. Changes of schedules for temporary needs that are not changed back are often even more common and costly. These types of issues do not raise any flags as often occupants do not complain when they are 'too comfortable', but they are a continual waste of energy. Additionally, this control issue may not be considered a fault by diagnostics that are embedded on a machine level because the machine is operating based off of a user input. However, the user input is frequently not the designed control setting. Only an external system could detect the issue. A summary of the control issues found can be seen in Table 2 above.

To ensure the equipment is in sync with the client's operational guidelines, EZENICS created the *Operation Guideline (OG)* Tool. This tool continually checks the active setpoints and schedules for all equipment against what the client wants the setpoints and schedules to be. When the OG tool identifies a setpoint or schedule that does not conform to the client's specification, it displays the current setting, design intent, variance, duration, and financial impact of the issues in an online report that facility personnel can access at any time. Correcting these control issues to the client's specifications ensures the equipment is running appropriately and often the corrections result in significant energy and monetary savings. The monetary savings that are displayed in the tool are projected annual savings based off of the excess energy consumption caused by the issue, the local weather patterns, and the local utility rates. As clients fix issues the projected monetary savings are realized and the savings become actual savings. The OG automatically tracks the actual savings as the issues are corrected.

Table 3 - Summary of Control Issues (Source: EZENICS)

Problem	SDG&E			Nationwide		
	# of Issues on RTUs/DHUs	Avg. # of Issues per RTU/DHU	Projected Yearly Savings	# of Issues on RTUs/DHUs	Avg. # of Issues per RTU/DHU	Projected Yearly Savings
Incorrect Setpoints	554	1.12	$49,500	25,500	1.12	$1,488,000
Incorrect Schedules	260	0.52	$8,000	25,800	0.82	$5,325,000
Totals	814	1.65	$57,500	51,300	1.62	$6,813,000

NOTES:
1. 20 Locations (465 RTUs/26 DHUs) in the sample are in the SDG&E service area
2. There are 1,522 Locations (29,255 RTUs/2,299 DHUs) in the sample
3. Projected yearly savings are based on local weather patterns and local utility rates

It is beneficial to investigate the potential multitude of issues that bring significant comfort and financial benefits when solved. It has been found that the issues are often not a result of poor facility or operations management, but result from the barriers listed below. Automated continuous analytics providing actionable, prioritized results can help empower facility operators to overcome some of these barriers.

1. RTUs have a relatively short lifespan and they are more economical compared to other heating, ventilation, and air-conditioning (HVAC) solutions such as chillers. Additionally, the cost of repairs can be high compared to the perceived value of fixing them. Therefore, business owners are inclined to let RTUs run until they fail then replace the entire RTU rather than maintain or repair the unit. This behavior is contrasted with building owner's attitudes towards chillers for example, which represent a substantial investment that owners are willing to spend money to maintain.

   In big-box retail environments, RTUs serve open zones in the store that means one RTU can be operating poorly, but the comfort of the store is not impacted. Many building owners view customer and employee comfort as the greatest driver for maintaining or replacing equipment. If the comfort of their buildings is not impacted, they are not inclined to fix problems. Furthermore, if alarms or identified faults are not deemed relevant then they are commonly ignored. Since there are often many issues, the result is an overwhelming list of problems. The list of irrelevant issues buries the critical items for a facility operator.
2. Control strategies for setpoints and schedules can be generic in the interest of simplicity. This means that few issues might be outside of a guideline, but the opportunity to utilize a more efficient strategy is lost out of the fear of it not being implemented or maintained properly.
3. Control strategies can be complicated, unique, and highly tuned for a particular facility. Such strategies often work well only if all the design assumptions are maintained and the facility does not change or evolve. Since facility use often does evolve, that means these strategies can quickly become ineffective and are thus often overridden.
4. RTUs operate as if the zone that they serve is isolated from everything else. However, in a large store retail environment the zones are entirely open, which means factors

outside of an RTU's zone can easily influence operation. For example, if the thermostat for a specific RTU is positioned too close to the diffuser of a different RTU, the thermostat could perceive the zone is satisfied. Also, the thermostat could read the zone is too cold and call for heating.

5. Facility managers dealing with RTUs often have to manage a fleet of buildings located throughout different geographic regions. Thus the volume of RTUs makes it difficult to continuously ensure they are optimized without automated tools to help provide prioritized actionable information.

Both control and mechanical issues can cause an increase in energy consumption and demand. While it is important to recognize excess energy consumption and the potential savings that are associated with correcting the problem, it seems that few integrated solutions are focusing on managing demand.

Electric demand is becoming increasingly important to manage for commercial energy consumers. In the demand response sector, utilities incentivize or provide rebates to those curtailing load during peak times on the grid. The lesser known consequence of poor demand management is that in the last 5 years, electricity consumption charges have decreased, but demand charges have significantly risen as seen in table 4. The increase in demand charges on the monthly utility bill is not always obvious to consumers as taxes and other line item charges that were once based on kWh are now based on the monthly peak kW instead.

Table 4 - Sample of Demand % of Utility Bills (Source: EZENICS)

Utility	Demand % of Utility Bill
Dominion VA & NC Power	53.5-54.8%
Memphis Light, Gas, & Water	24.1-26.7%
Southern California Edison	16.8-31.3%
Tampa Electric Company	21.8-25.1%
Consolidated Edison of New York	19.9-21.3%
Exelon Energy	12.4-31.9%
Mid American	13.8-21.4%
*Based on a sample of Demand charges from 60 commercial buildings for February - May	

Unaware of the potential impact demand can have on the monthly utility bill, energy and facility managers often put emphasis instead on managing consumption. However, due to the dual importance of reducing demand on the grid during critical times and reducing peak demand to lessen the monthly utility bill, managing demand in a facility or portfolio can represent a significant opportunity to save energy costs.

There are a myriad of issues that cause a general increase in consumption as well as the possible failure of a static demand management strategy including: if the standard cooling setpoint or schedule has been changed, the controller is offline, HOA lighting switches are set to manual, there are already comfort issues in a space, equipment has failed potentially causing increased zone temperature in the space and adjacent zones which would cause the unit in an adjacent zone to "work harder" than it normally would. These situational conditions are only a few of the issues that can potentially plague a static demand management event, preventing optimized performance. There are many methods for identifying these issues; each with their own inherent characteristics. Knowledge of the actual operational state of a facility through the use of FDD can allow the deployment of a dynamic DM strategy that maximizes the energy savings opportunity while ensuring comfort thresholds are not breached.

2.2 Lesson 2 - How to Continuously Detect and Diagnose the Issues in an Automated, Scalable, and Economic Manner

There have been a number of solutions developed to aid in the detection of equipment problems. Additionally, there are also traditional DM strategies. These traditional solutions all provide differing levels of resolution, each with limitations. The traditional solutions include:

- On Site Commissioning
- Enhanced Embedded Diagnostics
- Hardware/Data logging/Additional Sensors
- Trending/Visual Analysis
- Alarm Management Systems
- Static Demand Management Strategies

2.2.1 On Site Commissioning

The major limitation for on site commissioning is that the commissioning agent is only onsite for a limited period of time. The majority of issues may only occur under specific conditions. If the specific conditions are not met, the commissioning agent may not be able to detect the issue. Additionally, issues can appear the day after the commissioning agent leaves and they will not be detected until the store is re-commissioned. Finally, because on site commissioning requires a person to physically walk through the location and spend time there, it is expensive and not scalable. The company is not only paying for the expertise of the commissioning agent, but also for related expenses such as travel, food, and lodging.

2.2.2 Enhanced Embedded Diagnostics

Many hardware controllers are now offering some form of Fault Detection, which seems like an ideal solution. However, even with sophisticated fault severity rank structures, these enhanced diagnostics boil down to additional alarms specific to that piece of equipment or control system at the time of installation and can create an information overload.

These embedded systems often do not have external inputs such as energy rate structures, comfort and maintenance thresholds, or a refrigeration control system and thus cannot detect or accurately prioritize related issues that occur with the inputs to the equipment or control system such as the outdoor air temperature and relative humidity sensors.

An example of an alarm that might only be relevant under certain conditions is a broken compressor on an RTU. If an embedded diagnostic system detected a failed compressor, it would probably be a high priority fault. However, often HVAC equipment, including RTUs and DHUs, are oversized and the RTUs operate in a completely open space. Therefore, a building owner may not want to immediately replace a failed compressor because comfort is not impacted by one bad compressor in one RTU. This reality means all the additional diagnostics on the unit become noise lost in the sea of alarms. This issue is compounded especially when there are many machines and locations to manage that have different equipment types, brands, ages, and control systems. There becomes a need for normalization and consistency at an enterprise level in order to prioritize what issues are relevant and justify attention for resolution.

2.2.3 Hardware / Data Logging / Additional Sensors

It can be challenging to obtain the required data from existing systems and equipment; one solution is to install additional hardware that logs and analyzes data. The main problem with this approach is that it is expensive. The added hardware cost must be multiplied across an entire portfolio of RTUs. Additionally, there is the cost of the actual solution; the sensor plus the labor to install it is a necessary expense. This additional cost makes the return on investment much lower than a solution that would avoid using additional hardware. The data logging solution might use more accurate sensors for analysis, but it disregards the sensor that can control the equipment. However, the root problem can be the disregarded sensor which can make it difficult, if not impossible, to find the root cause of the issue.

2.2.4 Trending with Visualization Analysis

The trending solution involves storing data for long periods of time and involving users to graph data to analyze trends. The limitation of this solution is that manually looking at trends is often reactive, time consuming, and slow. Additionally, the user must know what issues to look for, what data points to look at, and the values of the data points, in order to determine that an issue exists.

2.2.5 Alarm Management System

Many alarm management systems take existing alarms that come from building management systems and equipment then apply specific rules to help organize and prioritize the alarms. This system can greatly assist in reducing the information overload that typically exists with managing multiple locations and lots of equipment. One limitation of the alarm management system is that alarms can be generic and mainly exist to prevent catastrophic failures or comfort issues. For example, a common alarm could state "High Pressure". The goal of an FDD system would be to provide a more intuitive result leading to a conclusion of what to do to solve the problem such as stating "Dirty Coil" instead of the less specific "High Pressure" alarm. Moreover, traditional alarm systems typically do not include severity rankings, financial impact, summary information, duration details, and the number of occurrence.

Traditional alarm management can be limiting, but when the alarm management process concepts are combined with the more specific FDD analyses, the end results can go a long way towards realizing greater savings.

2.2.6 Static Demand Management Strategies

Many control strategies established for demand management, either demand response or peak load reduction, are static and do not take into account the changing operational conditions such as setpoints, schedules, mechanical and electrical load, space conditions, equipment issues, and controls issues within a facility. As a facility ages, its operational variables will change; however, its control strategies will commonly stay consistent. These constantly changing operational variables are not considered in most demand management strategies and can cause many facility managers to not deploy any strategies despite the fact that demand charges account for a significant part of a facility's bill and participating in DR events can yield in monetary incentives and rebates. There are a myriad of issues that can contribute to the underperformance of a static demand management strategy, including:

- The standard cooling setpoint has been changed
- The schedule has been changed

- The controller is offline
- HOA lighting switches are set to manual
- There are already comfort issues in the space
- Equipment has failed, potentially causing increased zone temperature in the space and an adjacent zone; this would cause the unit in an adjacent zone to work harder than it normally should

Utilizing AFDD provides significant insight into building operations and greatly enhances the ability to quickly and reliably find problems that can be prioritized across a portfolio for issues that contribute to the electric demand. Often, identified faults do not have to be eliminated in order to achieve Demand Management results; instead, the dynamic demand management strategies take into account the analytic outputs to adjust strategies accordingly and optimize load shed and therefore monetary results.

2.3 Lesson 3 - How to Determine What Equipment Issues are Relevant to the Facilities and the Process to Efficiently Fix the Faults and Realize/Measure Benefits across an Enterprise

As EZENICS has worked with various clients and systems, the difficulty in gaining adoption has not been from a lack of results or potential savings. Rather, the issue has been highlighting the results that are the most relevant and actionable for each specific facility operator. As a result, EZENICS has changed its approach in how it conveys information.

2.3.1 Previous Method of Presenting AFDD Results

Previously, information was collected by EZENICS from the RTUs and analyzed, with results displayed in reports users could generate at any time. It was not uncommon to run a report for one location and have over 40 pages worth of faults to look through. Even though each fault included a description, severity ranking, duration, occurrence quantity, and financial impact, the assumption with the AFDD solution was that the facility managers would know the major priorities specific to their building and then use the tool to sort and filter results accordingly. If 40 pages of faults for one building are multiplied across an entire portfolio, with possibly thousands of locations, the result is too many faults to manage. Unfiltered results resulted in an overwhelming amount of data.

To turn data into action items, a business filtering approach was implemented. The so-called worst faults may not always be worth fixing from a business standpoint. A primary example is a compressor failure. When detected, this fault has a high ranking problem. The reason it does not make sense for a business owner to fix this fault is because big-box retail stores are large open spaces internally. That shared space means an adjacent RTU could potentially pick up the load of the failed compressor and no customer discomfort results. However, if there are enough failed compressors or if there is a larger unit that serves multiple zones, there may be reason to write a work order. These situations are standard business rules.

Over time it was found that often the people using the tool had the responsibility of fixing issues, but had no control over the budget or the authority to decide what to fix. By incorporating the management level business rules, the general user has already received approval from the authority in place to fix the filtered faults.

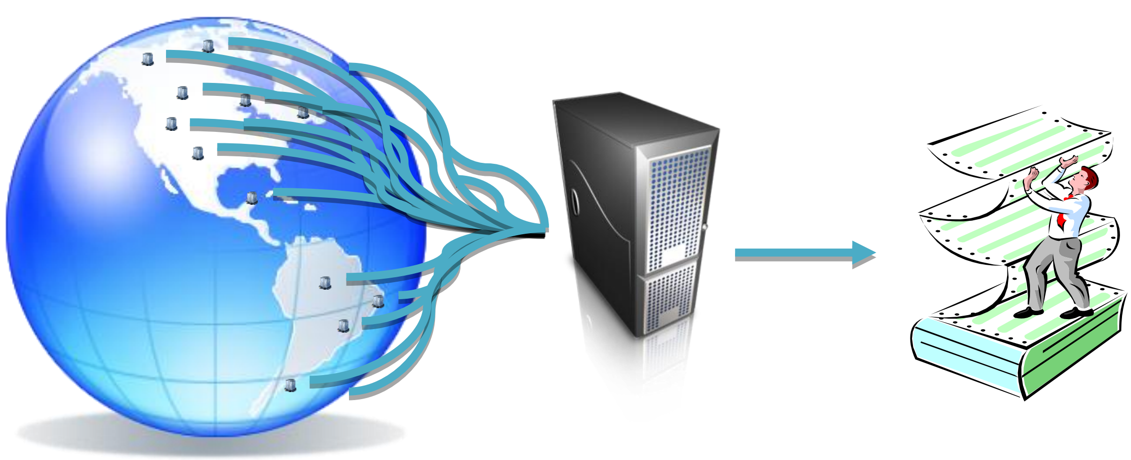


Figure 4 - Previous Method for Relaying Information to Clients (Source: EZENICS**)**

2.3.2 New Method of Presenting AFDD Results

The ability to create business rules that can be customized on a management layer to filter results based on what facility managers deem important creates specific prioritized results for traditional users that are responsible for solving the issues. The filtered results can then be acted upon immediately without having to decide if the issue is worth fixing or not. These business rules allow clients to find the issues that are causing the greatest impact in the areas they have identified as critical and that they want to fix. All of the facility managers already have these rules in their head. They know what conditions need to be present before they roll a truck. For example, a facility manager will know when a location is too uncomfortable. By filtering the results based on their business rules, work orders can be instantly created without the need for approval from upper management, which means problems are corrected faster. Results can even flow directly into a pre-existing work order system, avoiding the need to train users how to use a new system or tools. This method also allows for no loss of information since all of the pages of unfiltered, detected faults are still in the system.

Here are a few examples of potential business rules that users could input into the system:

1. Do not display the cause of any comfort related failures until the zone temperature is 2°F above the setpoint.
2. Only display certain issues after they have happened for 3 days consecutively.
3. Only display certain issues if there were more than 4 occurrences of that issue at a specific location.

Figure 5 - New Method of Relaying Information to Clients (Source: EZENICS)

2.3.3 Demand Management

In order to effectively manage a facility's electric demand, many variables must be considered. For all Demand Management events, a balance must be achieved between building comfort, monetary gain, load shed, and equipment function. The EZENICS Demand Management Optimization Module, as seen in figure 6 on page 12, provides a solution which integrates AFDD and OG diagnostics, real-time power meter data, and zone temperatures and thresholds in order to achieve maximized demand management event performance. Each strategy is tested, then through measurement and verification, tuned and performance maximized. With the ability through supervisory control over the BMS to adjust control strategies based on real-time analytics and business rules, dynamic curtailment strategies can be formed and executed instantaneously. The Demand Management Optimization Module provides the ability to maximize performance for Demand Response, Demand Limiting, and Economic Load Control events.

2.3.3.1 Demand Response

The opportunity to get involved in Demand Response programming is well known in the industry with the allure of monetary incentives from utilities and the ease of solutions provided by vendors. Even though DR programs are being adopted all over the US and internationally, there are still many commercial buildings that are not participating or are not maximizing the opportunities associated with DR programming. In the Demand Response setting, Fault detection and diagnostics in an enterprise platform provides the ability to manage many events, vendors, and locations concurrently. The current state of equipment and the environment within a building is known, so load shed strategies can be adjusted accordingly providing dynamic load curtailment strategies that maximize event performance while ensuring that there are no adverse comfort issues. Thus, confidence is enabled so that a more aggressive solution that maximizes results can be achieved.

Figure 6 - Demand Response Optimizer (Source: EZENICS)

The DR Optimizer has been used to manage events across numerous utility companies, including:

California

San Diego Gas and Electric (SDG&E)
Southern California Edison (SCE)
Pacific Gas and Electric Company (PG&E)
Sacramento Metropolitan Utilities District (SMUD)

Nationwide

American Electric Power Co., Inc. (AEP)
Allegeny Power
APS
Aquila
Atlantic City Elec
Austin Utilities
Baltimore Gas & Electric
Bangor Hydro Elec
Beaches Energy Services
Borough of Chambersburg, PA
Bristol Virginia Utilities Board (BVUB)
CenterPoint Energy
Central Georgia EMC (elec)/ Georgia Power
Exelon Energy
First Choice Power
Georgia Power
Harrisonburg Electric Commission
Huntsville Utilities
Idaho Power
Jersey Central Light & Power
Kansas City Power & Light Co. - KCPL
Knoxville Utilities Board
Lenoir City Utilities Board (LCUB)
LIPA
Louisville Gas & Electric
Memphis Light, Gas & Water

Central Hudson Gas & Electric
Central Maine Power
Choptank Electric Coop
City Of Danville, VA
City of Denton, TX
City of Naperville, IL
City of Opelika, AL
City of San Marcos, TX
City of Seattle, WA
Cleveland Utilities
Com Ed
Con Edison
Constellation
Coserv
CPS Energy
CT Light & Power
Cumberland Electric
Dayton Power & Light
Delmarva Power
Dominion Virginia Power
Duke Energy
Duquesne Light Company
Rappahannock Electric COOP
Reliant Energy
Rochester G&E
Sempra Utilities
Sierra Pacific
SMECO
SRP
Strategic
Tampa Electric Company
Merced Irrigation
Met-Ed
Mid American
Middle Tennessee Electric Membership
Modesto Irrigation District
Nashville Electric Service
National Grid
Nevada Power
North Central Elec Pwr Assoc.
Northern Virginia Electrical CO-OP
NSTAR
NYSEG
Ohio Edison
Orange Rockland Utilities
PECO Energy
Penelec
Penn Power
PEPCO
PNM
PPL Utilities
PSE&G
Public Service of NH
The Illuminating Co
Town of Danvers
Tucson Electric
TVA
TXU
United Illuminating Co
Western MA Electric
Xcel Energy

ISO/RTOs

CAISO
ERCOT
ISO-NE
NYISO
PJM

2.3.3.2 Demand Limiting

The increase in charges based on the peak kW during the month, combined with the ability to deploy a dynamic strategy driven by fault detection and diagnostics analytics has created a significant opportunity for savings on a commercial building's monthly electric utility bill.

Commercial buildings that are successful in demand response programming often do not implement any DL strategies due to the varying conditions in environment, potential adverse implications on comfort in the space, and the difficulty of predicting times of peak demand. Successful DR deployment provides proof that the strategies utilized are acceptable by shedding a determined amount of load while not affecting comfort in the facility. These existing strategies can also provide the same benefits in limiting demand. The challenge with doing this is to know when to deploy the strategy and for how long. These are variables that are already determined with DR, but are less pronounced in DL activities.

Often commercial buildings that are successful in demand response programming do not implement any demand limiting strategies due to the varying conditions in enrivonment, potential adverse implecations on comfort in the space, and difficulties predicting times of peak demand. Successful demand response deployment provides proof that the strategies utilized are acceptable by sheding a determined amount of load while not affecting comfort in the facility. These existing strategies can also provide the same benefits in limiting demand. The challenge with doing this is to know when to deploy the strategy and for how long. These are variables that are already determined with demand response, but are less pronounced in demand limiting activities.

DR often occurs during the hottest days of the year where demand on the grid is the highest, while many times the greatest opportunities for limiting demand are during months where environmental conditions create a few unanticipated sharp peaks.

Many facilities have energy signatures that would require running a DL curtailment strategy only a small percentage of the time throughout the month in order to achieve significant savings through the reduction of the peak demand. There are months where the opportunity for limiting demand is low because the energy signature displays a smoothed curve. The smoothed load necessitates elongated DL curtailment events in order to shed the amount of load necessary to affect the monthly peak. Elongated event periods where HVAC and refrigeration loads are curtailed, can also cause significant comfort issues, nullifying monetary gain. Therefore, during months where peak curves are smooth, demand limiting DL is not opportunistic. The peak curve can be seen in figure 7, on page 15.

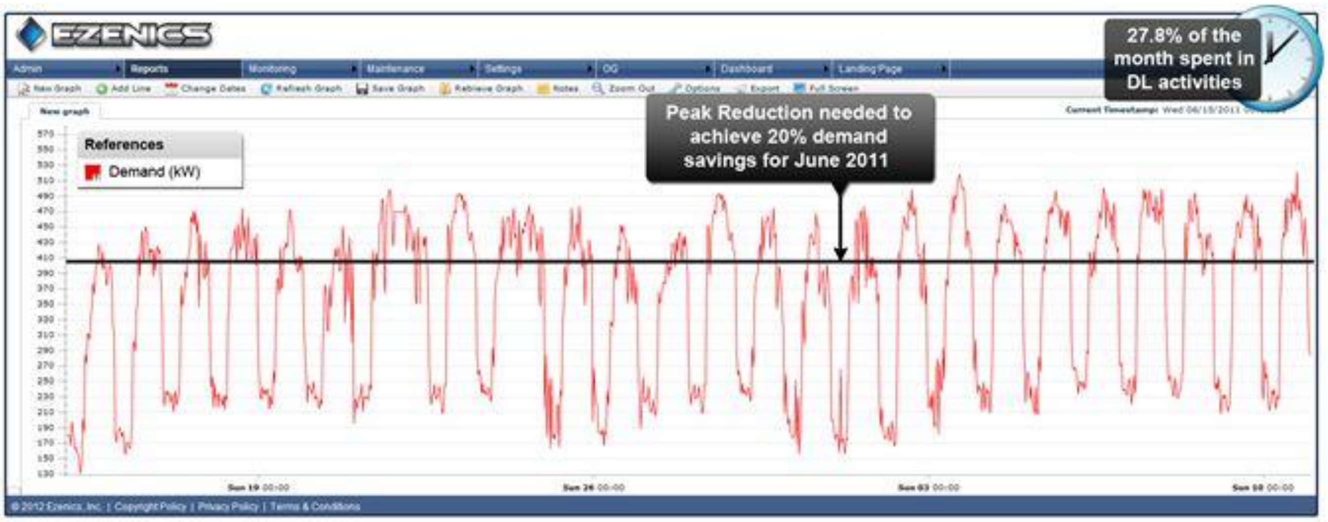


Figure 7 - Non-opportunistic Peak Curves (Source: EZENICS)

Conversely, there are often more months throughout the year where the energy signature provides sharp peaks for only a few days throughout the monthly billing cycle. These sharp peaks provide the greatest opportunity to curtail load because they require short periods of load shed that will not adversely affect comfort. This load profile can be seen in figure 8, below.

Figure 8 - Opportunistic Peak Curves (Source: EZENICS)

Past interval energy data from a facility can aid identification of the percentage of the time that the kW is above certain levels for a month. For example, in Figure 9 on page 16, the client only had to execute the Demand Limiting strategy during 5% of the monthly billing period to achieve a 13% or 700 kW reduction in the peak demand for the month. This totaled savings equal to 8.1% of the total energy cost savings as shown in figure 9, on page 16.

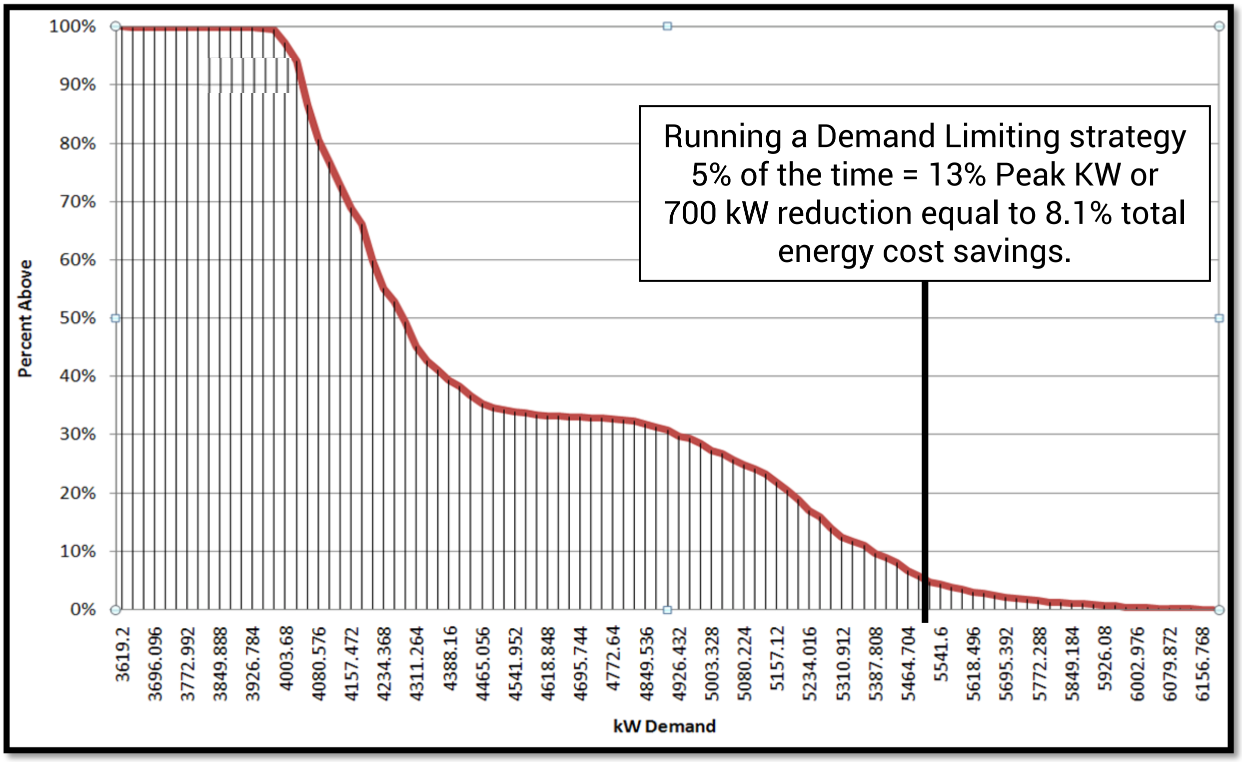


Figure 9 - Percent of Time Table & kW Reduction Impact (Source: EZENICS)

Equipment and systems data that is collected every minute by the EZENICS data collectors drive real time analytics that are utilized to provide equipment and operational conditions to prediction models that determine when to run a demand limiting strategy. If the strategy is enabled prematurely then comfort thresholds may be breached before the peak occurs; thereby resulting in a failure to avoid the peak demand and save money. However, if the peak is avoided, the space may be uncomfortable and potential de-merchandizing can occur. Conversely, if the strategy is enabled belatedly, the peak for the month may be missed. In order to avoid the potential implications of poorly timed strategy deployment, prediction models may be employed that take AFDD results as inputs so that the demand reduction strategy can be dynamic and perform according to the real-time operations of the facility. Thus, the strategy is constantly tuned according to the operational conditions so that peaks are avoided without having to fix identified faults.

A significant benefit to applying AFDD analytics to equipment and controls data is that they can bring to light issues that are contributing to the demand peak for the month. Solving these issues can often be one time fixes or can be done through automated supervisory control. Poor equipment staging is a common issue that can be avoided through alterations to a control strategy that will not cause any adverse implications on comfort. This is very common as equipment is often controlled with separate thermostats or even control systems without efficient logic in place to avoid equipment running at once. A common example of such an occurrence is non-optimal start sequences. Staggering run times on units will often result in one unit being able to meet the demand before others even need to start. Strategies can additionally be put in place for refrigeration by optimizing defrosts cycles with no effect on meeting the needed setpoints.

The knowledge of the actual operational conditions of a facility combined with energy data can additionally enable time of use and real-time energy pricing optimization strategies to further maximize the savings opportunities which dynamic strategies can provide.

2.4 The Ideal Solution

After examining the benefits and limitations of the traditional solutions, the criteria for an ideal solution were clear. An ideal solution should include:

1. Continuous Automated Remote Monitoring and Analysis with real time result availability
2. No additional hardware to get data or extra sensors
3. No software to install or maintain
4. Utilize analytics for Automated Demand Management that does not breach comfort thresholds and adds significant value
5. Scalable to quickly and reliably manage thousands of machines and locations without a large investment or management disruptions
6. Affordable to ensure net realized value it high to drive adoption
7. Intelligent Robust Analytics that provide accurate intuitive prioritized actionable results
8. Enterprise Level Business Rules with client specific customizable filters that allow users to focus on critical issues

3. SAMPLE INFORMATIONON

During 2011 the AFDD and OG tools identified 119,290 issues that produced over $14,210,700 in potential savings which, if corrected, equates to a reduction of 216,032,000 pounds of carbon and a reduction of 142,000 megawatt-hours. Groups of 2-3 people have worked to realize millions of dollars in saving in just over 5 months.

The following summary information is for the sample of locations that were selected. The majority of the sample locations have general merchandise and grocery sections.

3.1 Personnel

There are several groups within the sample that utilize the EZENICS platform for various reasons. A fully staffed engineering department of HVAC and refrigeration engineers uses the tools to find current setpoints and develop new control strategies that can enhance comfort and reduce cost. Additionally, the engineers use the impact calculations to make decisions about which setpoints will best serve them financially with the ability to make 'what if' scenarios in the OG tool. A call center that operates 24 hours a day, 7 days a week, 365 days a year utilizes the tools to track short term changes made to the BMS so the changes can be put back at a later date. Finally, a commissioning team utilizes the EZENICS platform for their daily tasks including the changing of setpoints and schedules for HVAC and refrigeration equipment in the BMS to match their guidelines and the writing of work orders based off of the information from the AFFD reports generated by EZENICS. In addition to the ongoing focus, the AFDD and OG tools are used for Monitoring Based Commissioning that takes place after a location is built or a retrofit is performed. The EZENICS solutions can be quickly deployed, so the results can be utilized to resolve issues while contractors are still on site.

3.2 Locations

SDG&E Area – 20

Nationwide – 1,522

Total Square Feet – approx. 237,000,000

3.3 Equipment

Table 5 - Equipment Brand Included in the Sample Locations (Source: EZENICS)

HVAC	Refrigeration
Carrier	Hussmann
AAON	Tyler
Trane	Hill Phoenix
Lennox	Barker
Munters	Floraline
Seasons 4	Zero Zone

Table 6 - Equipment Types Included in the Sample Locations (Source: EZENICS)

HVAC	Refrigeration
RTU	Walk-in
Variable Air Volume (VAV) RTU	Medium Temperature
DHU	Freezers
Forced Air Fan	Dual Temperature
VAV Terminal Unit	Compressors
Chillers	Condensers
Boilers	Anti-sweat Heaters
Unit Heaters	
Fan Coil Unit	

Table 7 - RTUs and DHUs in the SDG&E Area (Source: EZENICS)

Type	Count	Tonnage Range
RTU	279	3 to 50
DHU	26	12.5 to 20

Table 8 - RTUs and DHUs Nationwide (Source: EZENICS)

Type	Count	Tonnage Range
RTU	29,255	3 to 60
DHU	2,299	10 to 30

4. DATA COLLECTION

Data collection is the first thing that has to happen before any analytics can be applied. It is the foundation for everything. Analytics are only as good as the data that are fed into them. The task of establishing data storage is challenging because there are so few standards within the heating, ventilation, air-conditioning, and refrigeration (HVACR) industry. For example, for the same sensor, one client could label it a supply air temperature (SAT) sensor and another could label it a discharge air temperature (DAT) sensor. These discrepancies necessitate standardization when establishing data collection.

4.1 Data Collection Platform

Ezenics has developed a centralized facility data collection and distribution platform for billions of continuously arriving facility related data points that can be provided from an unlimited number of equipment, building systems, weather stations, work order systems, and utilities. The service oriented architecture (SOA) has been optimized to manage multiple processes, threads, and connections to many databases in an automatically scaling cloud based infrastructure based on data collection, analysis, and distribution need. All data are normalized with standard label, engineering unit, and conversion criteria and then never deleted. An underlying OLAP multi-dimensional database allows quick queries and data organization. All data from any machine or location combination are available for analysis in graphing tools, web-based viewing, CSV downloads, integration through provided web services, RSS, or automatic FTP pushes.

4.2 Data Extraction

In order to analyze data from controllers and sensors throughout a facility, the data must be extracted from them. To maintain low costs to clients and to achieve scalability, no new hardware is required for data collection. EZENICS has worked with clients utilizing over 20 different data collection methods and protocols that encompass various strategies of obtaining data in a feasible and reliable manner. Location level data is collected for HVAC, Lighting, and Refrigeration systems as well as power meters (with data sources ranging from the direct utility or from a third party vendor PM). In addition, EZENICS provides a solution that extracts external weather station data from weather stations which are less than 5 miles from the site. Equipment and control systems related to RTUs are from companies including Emerson, Automated Logic, Gridpoint/ADMMicro, and Novar. All open protocols such as BACnet, LONWorks, Modbus, and Webservices (XML/SOAP/JSON) are available along with more simple methods using Text data.

Data can be extracted multiple ways from a client's network depending on the level of security that is required, and on which method provides the fastest, most reliable stream of data. The methods developed by EZENICS are currently managing 2.6 million data points per minute for the buildings in this sample. This volume of data points equates to 112 Trillion data points per month. EZENICS has proved successful in setting up and collecting data at one-minute intervals, normalizing, and then storing that data with no effect on the regular building management system operation. Only data collected at one-minute intervals can be used to accurately detect many problems in a remote automated system. The equipment issues that require data collected at one minute intervals include general equipment inefficiencies, hunting, short run times, and cycling. All are common issues, especially when humidity, ventilation needs, refrigeration, and equipment are considered. Once data is in the EZENICS cloud storage system, it remains there forever. No data is ever purged from the system after any length of time unless requested by the client. Storing data in a cloud system means that data is available at any time to any client with an internet connection.

4.3 Data Quality Checks

Before any high level analyses are performed, the quality of the data must be checked. One straightforward way to validate the outdoor air temperature and outdoor air relative humidity sensor readings is to compare them to the readings from a local weather station. This comparison is done for every location and is checked continuously. For other sensors that cannot be compared to an outside source, thresholds are set to check for outlandish values which would indicate a faulty sensor. Sometimes there are multiple sensors within a building that measure the same thing, such as relative humidity sensors that supply data to each RTU. Often there are scenarios when equipment components, such as fans, are on or off which creates scenarios where different sensors, such as supply air temperature and return air temperature sensors, should have similar readings. The redundant sensors and conditionally redundant sensors should record similar values. Therefore, they can be compared to each other to find anomalies. The last check for data integrity is making sure the value recorded by the sensor is fluctuating. A sensor that records the exact same value for an extended period of time is faulty.

4.4 Data and Demand Management

For the Demand Management Solution there are multiple types of additional data that can be utilized in order to achieve a balanced solution. Demand Response event signals can be pushed or pulled via OpenADR interface or through use of a client side interface. In addition, for economic load control events, day-ahead and hour-ahead real time pricing feeds (DA-RTP and HA-RTP) can be utilized in order to provide real-time pricing information with which to shed load during pre-defined critical peak pricing times. Together with the baseline information that can be provided from the end use customer, utility, aggregator, or calculated by using existing power meter and weather data (dynamic baseline calculations) these data sets drive the Demand Management Optimization Module. Lastly, EZENICS has developed an “engine” of TOU rate structures for many utilities around the United States and continues to add more in order to establish impact of demand management related events.

5. THE RESULTS

The issues detected by EZENICS fall into two main categories: setpoint/schedule validation and mechanical performance. It is important to check for issues in both of these categories because many "performance" issues can be caused by a machine operating with an incorrect setpoint or schedule. Additionally, an RTU operating at a cooling setpoint only 2 degrees below the desired setpoint may never cause a problem with the RTU other than shortening its life due to excessive runtime. It will certainly cause a significant amount of energy and money to be wasted over the lifetime of the RTU. If a client utilizes an unoccupied setback schedule for a portion of their RTUs to save energy, any RTU that is supposed to follow the setbacks, but has a schedule change, could run all night at occupied settings, resulting in excess energy consumption. The algorithms created by EZENICS for the AFDD tool run continually to check for anomalies that can cause comfort issues or excess energy consumption. The *Operational Guidelines (OG)* tool performs continuous setpoint/schedule verification. The Demand Management tools integrate the outputs of the AFDD and OG tools to optimize load shedding strategies for demand response events to maximize peak load reduction without breaching comfort thresholds.

The objective of AFDD is to find significant issues that are occurring consistently or repeatedly. Minimum requirements are built into the system to ensure there is no false reporting of issues. These minimum requirements are necessary because of abnormalities such as maintenance activities. It is critical for adoption that the results are valid so there is significant value realized when the issue is solved. For the control issues detected through the OG, the issue had to occur for at least 24 hours on one machine to qualify as an issue. Within the AFDD tool, users can select their own criteria for fault reports. Fault results in this report had to meet one of two criteria, depending on the type of fault, in order to count towards the total:

1. If the conditions for a fault were continuous, such as a temperature sensor, the fault had to occur for 200 hours in a two month window to count as a fault.
2. If the fault was the result of a status change, such as a compressor failure or fan cycling, the fault had to exist for 20 hours in a two month window for the fault to count on the machine.

Table 9 - Report Criteria (Source: EZENICS)

Tool	Criteria
OG	> 24 hours
Fault (continuous conditions)	> 200 hours within two months
Fault (dependent on varying conditions)	> 20 hours within two months

Below is the summary information of what the OG and AFFD tools have detected for the sample locations over the last year. The results of the Demand Response Optimizer, which incorporates both OG and AFDD results, are shown last. Detailed graphs are included in this report to help explain the issues. Ideally these faults will go directly to a facilities work order system or users will view a list of actionable results in the AFDD and OG tools and resolve them. Graph visualization analysis is not required to identify issues, but graphs can be easily generated by users with one click. Every fault result has a graph link to show the relevant data points and time period for that issue without additional work required by the user.

Energy savings are emphasized in this report, but it is key to highlight that most of EZENICS' clients do not consider energy savings their top priority. This is especially true with retail clients that have many RTUs. Comfort issues are also detected and diagnosed with FDD, but the specific value of such issues, even if more important than energy, is often intangible, unique to each scenario, and hard to quantify. Therefore, comfort issues are not discussed in this report.

5.1 Operational Guidelines (OG) Tool

Table 10 - Operational Guidelines (OG) Tool Results (Source: EZENICS)

Problem	San Diego Gas & Electric		Nationwide	
	# of Issues on RTUs/DHUs	Avg. # of Issues per RTU/DHU	# of RTUs /DHUs with Issues	Avg. # of Issues per RTU/DHU
Cooling Setpoint (Occupied)	148	0.30	10,200	0.32
Cooling Setpoint (Unoccupied)	110	0.22	8,400	0.26
Heating Setpoint (Occupied)	151	0.30	8,100	0.25
Heating Setpoint (Unoccupied)	112	0.22	6,600	0.20
HVAC Schedule (Occupied)	139	0.28	11,000	0.34
HVAC Schedule (Unoccupied)	121	0.24	14,800	0.46
Anti-sweat Heater[4]	33	0.26	2,100	0.26
Totals	814	1.5	51,300	1.29

NOTES:
1. 20 Locations (465 RTUs/26 DHUs) in the sample are in the SDG&E service area
2. There are 1,522 Locations (29,255 RTUs/2,299 DHUs) in the sample
3. Anti-sweat heaters affect all glass door cases at a location. 123 glass door machines at SDG&E locations.

The financial impact for the majority of mechanical and control issues is generated based on the excess energy that is consumed as a result of the issue. However, there are some issues that can also cause an increase in demand. For the relevant faults, the annualized projected demand savings are shown in Table 11, below.

Table 11 - Operational Guidelines (OG) Tool Financial Results (Source: EZENICS)

<table>
<tr><th rowspan="2">Problem</th><th colspan="2">San Diego Gas & Electric</th><th colspan="2">Nationwide</th></tr>
<tr><th>Projected Yearly Savings (kW)</th><th>Projected Yearly Savings (kWh)</th><th>Projected Yearly Savings (kW)</th><th>Projected Yearly Savings (kWh)</th></tr>
<tr><td>Cooling Setpoint (Occupied)</td><td rowspan="2">$5,000</td><td>$38,500</td><td rowspan="2">$366,000</td><td>$774,000</td></tr>
<tr><td>Cooling Setpoint (Unoccupied)</td><td>$4,200</td><td>$158,000</td></tr>
<tr><td>Heating Setpoint (Occupied)</td><td>-</td><td>-</td><td>-</td><td>$57,000</td></tr>
<tr><td>Heating Setpoint (Unoccupied)</td><td>-</td><td>-</td><td>-</td><td>$86,000</td></tr>
<tr><td>HVAC Schedule (Occupied)</td><td>-</td><td>$1,100</td><td>-</td><td>$584,000</td></tr>
<tr><td>HVAC Schedule (Unoccupied)</td><td>-</td><td>$6,900</td><td>-</td><td>$4,741,000</td></tr>
<tr><td>Anti-sweat Heater</td><td>-</td><td>$1,800</td><td>-</td><td>$47,000</td></tr>
<tr><td>Subtotals</td><td>$5,000</td><td>$52,500</td><td>$366,000</td><td>$6,447,000</td></tr>
<tr><td>Totals</td><td colspan="2">$57,500</td><td colspan="2">$6,813,000</td></tr>
<tr><td colspan="5">NOTES:
1. Projected yearly savings are based on local weather patterns that drive actual machine run times, actual machine size, and local utility rates</td></tr>
</table>

5.1.1 Incorrect Schedule Settings (El Cajon, CA)

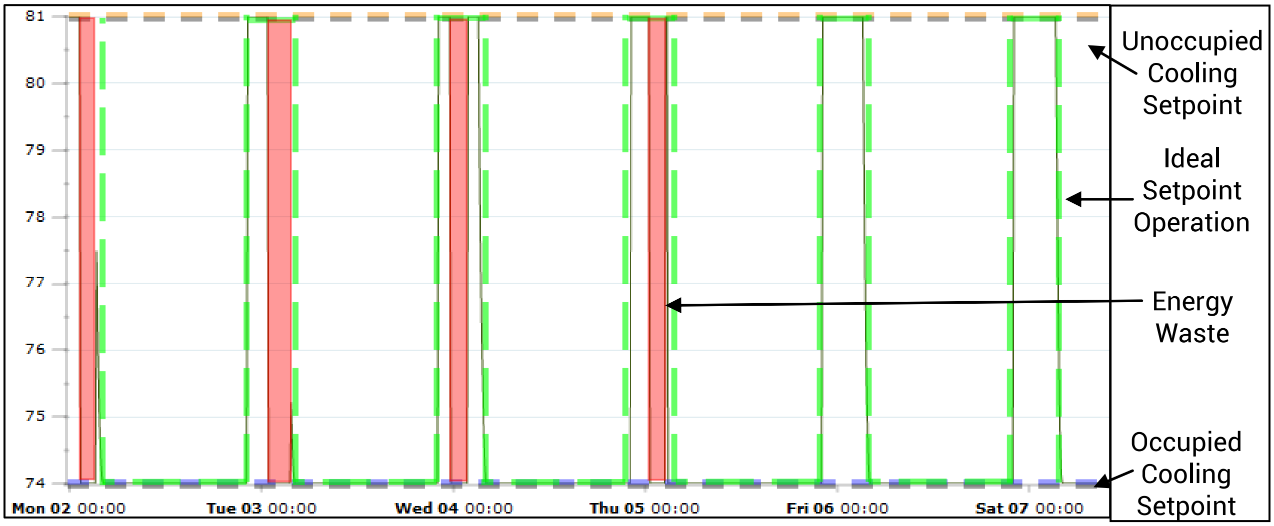


Figure 10 - Incorrect Schedule Settings (Source: EZENICS)

Description – The RTU was going into an occupied mode every night. The scheduling issue was resolved on "Fri 06", as seen in figure 10 above, and the RTU began using its unoccupied cooling setpoint every night.

Impact – The RTU running in its occupied setting every night equates to a projected yearly cost of ~ $100 based on weather patterns and local utility rates. While this example is for one RTU, the schedules for the majority of the RTUs at this location were wrong. The projected yearly cost for all of the schedule issues at this location is ~ $1,000.

Fix – Update the schedules on the BMS. This update takes less than 10 minutes and can be done remotely.

5.1.2 Anti-sweat Heaters (Chula Vista, CA)

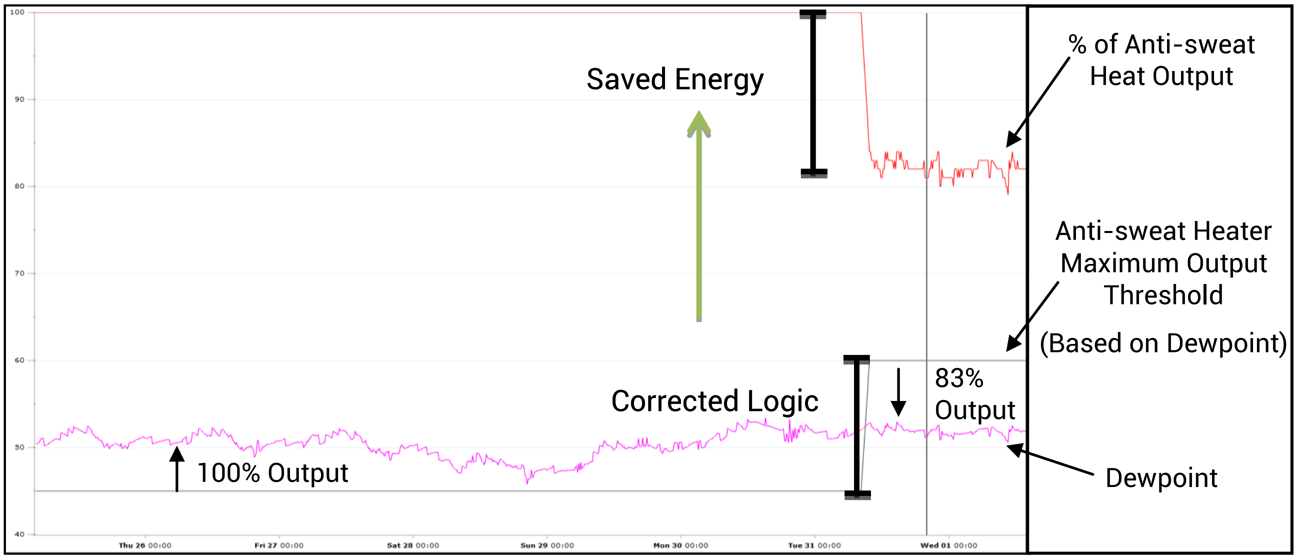


Figure 11 - Incorrect Anti-sweat Settings (Source: EZENICS)

Description – An anti-sweat heater is an electric resistance heater that warms up the glass on freezer case doors. The purpose of the device is to prevent condensation from building up on the glass. When the HVAC equipment is not adequately controlling the humidity, excessive condensation will build up on the glass. In an effort to reduce this condensation, technicians may modify the output to get extra heat from the device, thus reducing the moisture accumulation. Increasing the output is certainly a valid temporary fix to prevent moisture in the aisles, which is a customer safety issue, but eventually the external issue that drove the change will vanish and the temporary change is often forgotten, resulting in unnecessary use of energy. In figure 11, above, there was an extra 17% of the total anti-sweat heater energy output that was being consumed unnecessarily.

Impact – The year round excess heat output means there is year round excess energy consumption. The projected yearly cost is ~ $1,000 for a building with this issue depending on the severity of the modification.

Fix – Update the logic in the BMS. This update takes less than 10 minutes and can be done remotely. Additionally, the client should run an AFDD report so they can see the root cause of the inadequate dehumidification on the HVAC equipment.

5.2 AFDD Tool – Economizer

Table 12 - AFDD Tool Economizer Results (Source: EZENICS)

Problem	SDG&E		Nationwide	
	# of Issues on RTUs/DHUs	Avg. # of Issues per RTU/DHU	# of Issues on RTUs/DHUs	Avg. # of Issues per RTU/DHU
Non-optimized Economizer Settings	482	0.98	30,700	0.97
Outdoor Air Temperature Sensor	368	0.43	26,900	0.69
ERV Wheel Inefficiency[3]	1	0.03	200	0.08
Total	851	1.73	57,800	1.83
NOTES: 1. 20 Locations (465 RTUs/26 DHUs) in the sample are in the SDG&E service area 2. There are 1,522 Locations (29,255 RTUs/2,299 DHUs) in the sample 3. Only for DHUs with sensible wheels				

Table 13 - AFDD Tool Economizer Financial Results (Source: EZENICS)

Problem	SDG&E		Nationwide		Description
	Projected Yearly Savings (kW)	Projected Yearly Savings (kWh)	Projected Yearly Savings (kW)	Projected Yearly Savings (kWh)	
Non-optimized Economizer Settings	-	$29,000	-	$1,900,000	There building owners can expand their economizer thresholds across all RTUs and some DHUs to take advantage of more economizing hours which will reduce consumption.
Outdoor Air Temperature Sensor	-	$23,900	-	$3,532,000	The outdoor air temperature sensor is placed incorrectly and economizer hours are lost as a result.
ERV Wheel Inefficiency (Only DHUs)	$970	$1,500	$80,000	$325,000	The sensible wheel on DHUs is no longer transferring heat effectively. That means more cooling is required which will drive up demand and consumption.
Subtotals	$970	$54,400	$80,000	$5,757,000	
Total	$55,370		$5,837,000		
NOTES: 1. Projected yearly savings are based on local weather patterns that drive actual machine run times, actual machine size, and local utility rates					

5.2.1 Suboptimal Economizer Settings

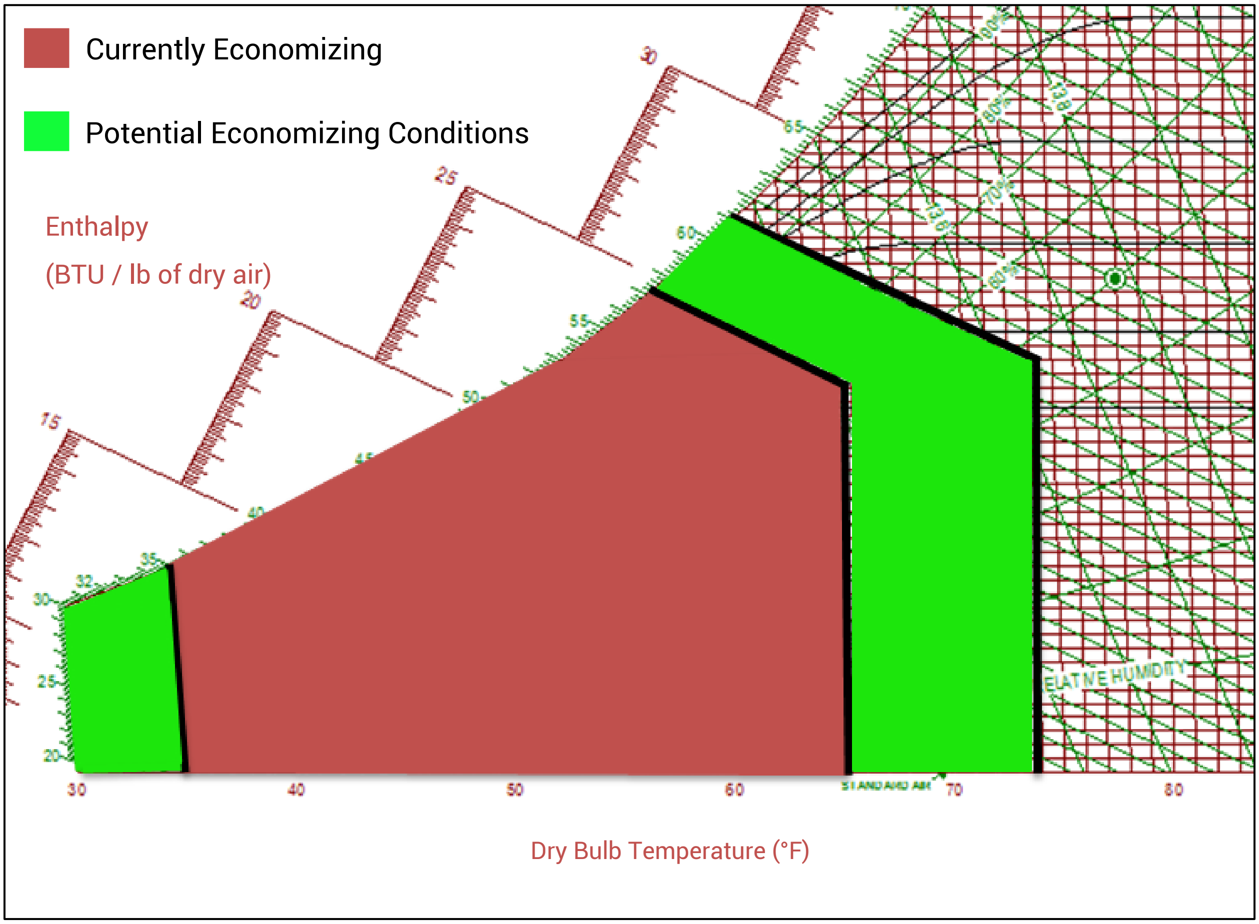


Figure 12 - Suggested Economizers Settings (Source: EZENICS)

Description – Through the use of an economizer fault it was discovered that all of the sample locations could take advantage of expanded economizing thresholds. Upon looking at the control logic for the RTUs it was discovered that the economizing thresholds are from 35 – 65°F and there is an enthalpy maximum of 25 BTUs/lb of dry air. Based off of interior comfort thresholds the economizing thresholds could be expanded to operate from 30 to 74°F with an enthalpy maximum of 27 BTUs/lb of dry air. These threshold modifications would be applicable for RTUs nationwide and would result in substantial savings. The additional outdoor conditions suitable for economizing are shown in green on figure 12, above.

Impact – By taking advantage of additional economizing hours, compressor energy can be saved which reduces the energy consumption of the RTUs.

Fix – Globally modify the economizing thresholds in the building management system.

5.2.2 Outdoor Air Temperature Sensor Issue (Duluth, MN)

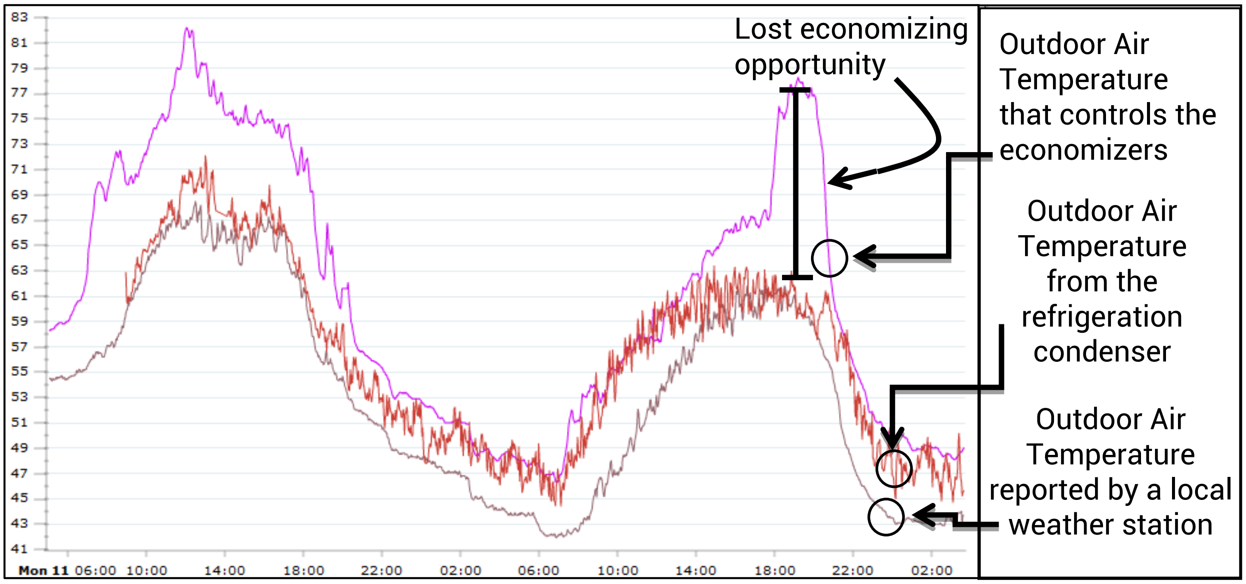


Figure 13 - Wrong Outdoor Air Temperature Sensor Placement (Source: EZENICS)

Description – At first, one might think the outdoor air temperature sensor is bad, but the overnight temperatures, when compared to the temperature measured by the outdoor air temperature sensor, are very close. The problem was the temperature sensor that controls the economizing was mounted on the west side of the building. The direct afternoon sunlight caused increases in the outside air temperature readings. The large peak caused by the direct sunlight can be seen in figure 13, above.

It is logical to assume that the roof of a building will be warmer and increase the on site temperature readings over those of a sensor at a weather station. However, the refrigeration system outdoor air temperature sensor, mounted near the condenser on the roof, confirms the temperatures of the weather station. Also, the slightly elevated overnight temperatures are perfectly normal because of the thermal mass of the building.

An embedded RTU level diagnostic would not have been able to identify this issue or others like it because the machine is acts as a closed loop. Therefore, if the RTU is fed an outdoor air temperature, it believes the temperature and acts accordingly. In this instance, the fault is not on the unit, but the temperature sensor that supplies the information.

Impact – The temperature sensor feeds information to each of the RTUs. If the outdoor air temperature is above their temperature limit, they will not economize. This problem will occur regardless of enthalpy or temperature controlled economizers because enthalpy is a calculation that utilizes relative humidity and temperature.

Fix – Move the sensor to the north side of the building to eliminate the temperature gain caused by direct sunlight.

5.2.3 ERV Wheel Inefficiency (Santee, CA)

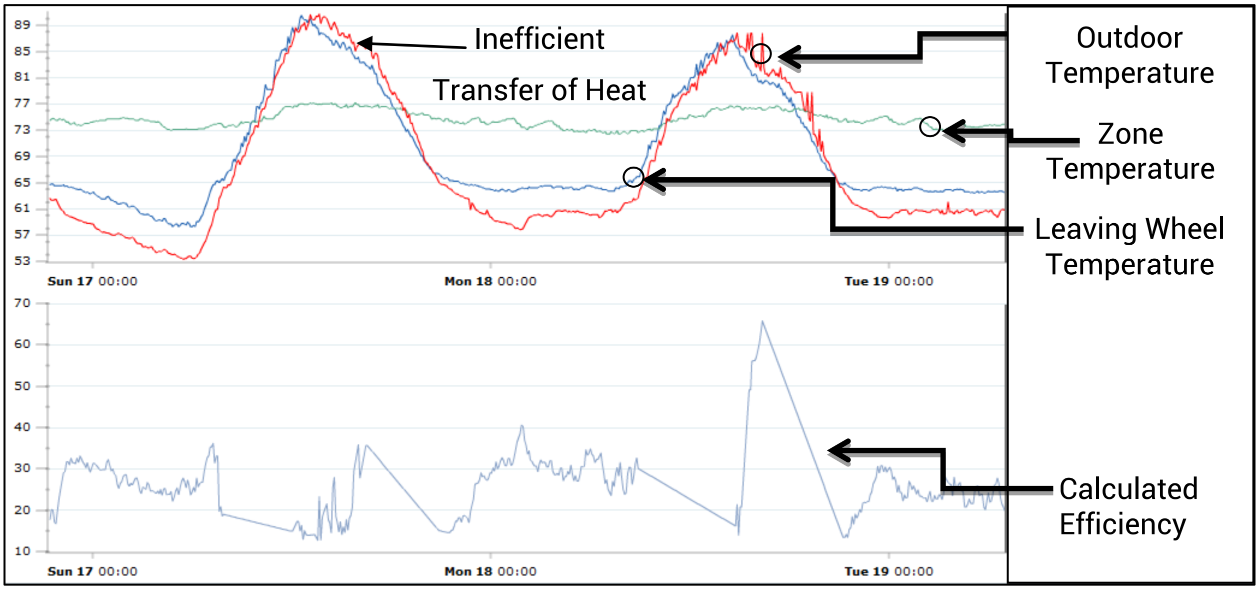


Figure 14 - ERV Wheel Inefficiency (Source: EZENICS)

Description – The sensible wheel in the DHU should transfer heat from the incoming outdoor air to the exhaust air. In figure 14 above, it is clear that the wheel is not transferring any of the heat from the outdoor air to the exhaust air that is the same temperature as the zone air temperature. The efficiency of this heat transfer is calculated on a continual basis. If the efficiency is low, a fault is detected.

Impact – If the wheel is operating inefficiently, the unit may be required to provide more mechanical cooling or heating than would have been necessary. The additional cooling and heating consumes more energy.

Fix – The following are possible fixes for this issue:

1. Calibrate or relocate sensors if they are not reading the temperatures correctly
2. Repair or replace the drive motor, fuses, and/or the drive belts
3. Adjust a slipping wheel drive belt.

5.3 AFDD Tool – General RTU/DHU

Table 14, below shows the number of general RTU/DHU faults. Table 15, on page 33 shows the projected annualized savings of correcting these issues.

Table 14 - General AFDD RTU/DHU Results (Source: EZENICS)

Problem	SDG&E		Nationwide	
	# of Issues on RTUs/DHUs	Avg. # of Issues per RTU/DHU	# of Issues on RTUs/DHUs	Avg. # of Issues per RTU/DHU
Cooling Stage Failure	64	0.13	6,900	0.21
Heating/Cooling Stage Cycling	15	0.03	3,200	0.10
Fan Cycling	42	0.08	4,500	0.14
Indoor RH Sensor	3	0.01	250	0.01
Simultaneous Heating/Cooling	3	0.01	440	0.01
Totals	127	0.25	15,290	0.48

NOTES:
1. 20 Locations (465 RTUs/26 DHUs) in the sample are in the SDG&E service area\
2. There are 1,522 Locations (29,255 RTUs/2,299 DHUs) in the sample

Table 15 - General AFDD RTU/DHU Financial Results (Source: EZENICS)

Problem	SDG&E		Nationwide		Description
	Projected Yearly Savings (kW)	Projected Yearly Savings (kWh)	Projected Yearly Savings (kW)	Projected Yearly Savings (kWh)	
Cooling Stage Failure	$1,900	$15,500	$208,000	$1,033,000	The lack of cooling means fans will operate continuously but the space temperature will stay above the setpoint. The air that is circulated through the RTU will actually warm up because of the heat generated by the fan motor.
Heating/ Cooling Stage Cycling	-	-	-	$16,500	When a heating or cooling stage cycles, additional wear is put on the equipment. This additional wear causes the equipment to fail prematurely.
Fan Cycling	-	$700	-	$74,900	When a fan cycles, there is additional wear on the unit which means it has to be replaced more frequently.
Indoor Relative Humidity (RH) and Temperature Sensors	-	$1,500	-	$120,500	If the indoor RH or temperature sensors have drifted or failed, the sensors can call for dehumidification even though it may not be required. The additional cooling used in the dehumidification process consumes excess energy.
Simultaneous Heating and Cooling	-	$1,400	-	$107,800	The cooling and heating are operating at the same time which wastes energy.
Subtotals	$1,900	$19,100	$208,000	$1,352,700	
Totals	$21,000		$1,560,700		
NOTES: 1. Projected yearly savings are based on local weather patterns that drive actual machine run times, actual machine size, and local utility rates					

5.3.1 Cooling Stage Failure (Fresno, CA)

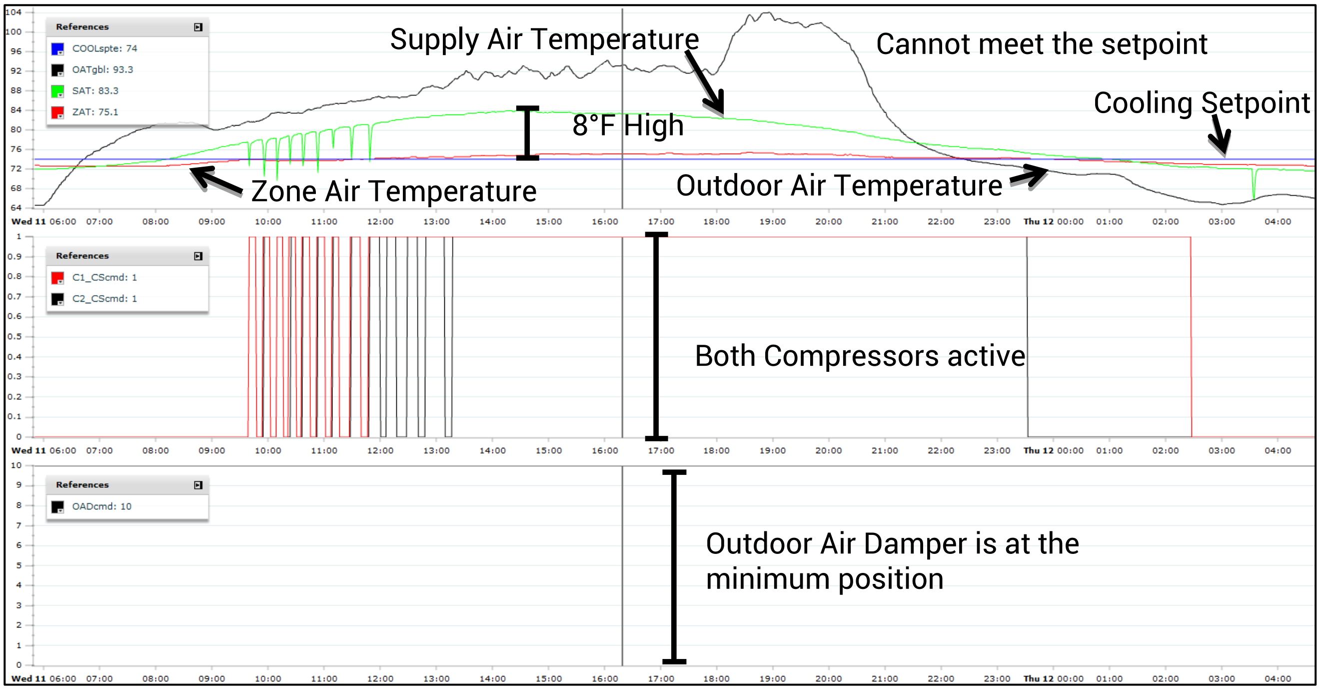


Figure 15 - Inefficient Cooling Coil (Source: EZENICS)

Description – As figure 15, above shows, both cooling stages are active but the supply air temperature is 8°F above the setpoint. This condition leads to the conclusion that the cooling coil is inefficient. Possible causes include a dirty coil and/or low refrigerant charge.

Impact – A cooling stage failure will directly influence client comfort. The supply fan will run continually, consuming energy, while the zone temperature setpoint will remain unaffected. Without the cooling from the vapor compression cycle, the air that is circulated through the RTU will actually increase in temperature because of the heat picked up from the fans.

Fix – A technician needs to investigate the issue to determine the exact cause of the problem. The two most likely scenarios are that either the refrigerant charge is low or the evaporator coils need to be cleaned.

5.3.2 Inside Relative Humidity Variation (Culver, CA)

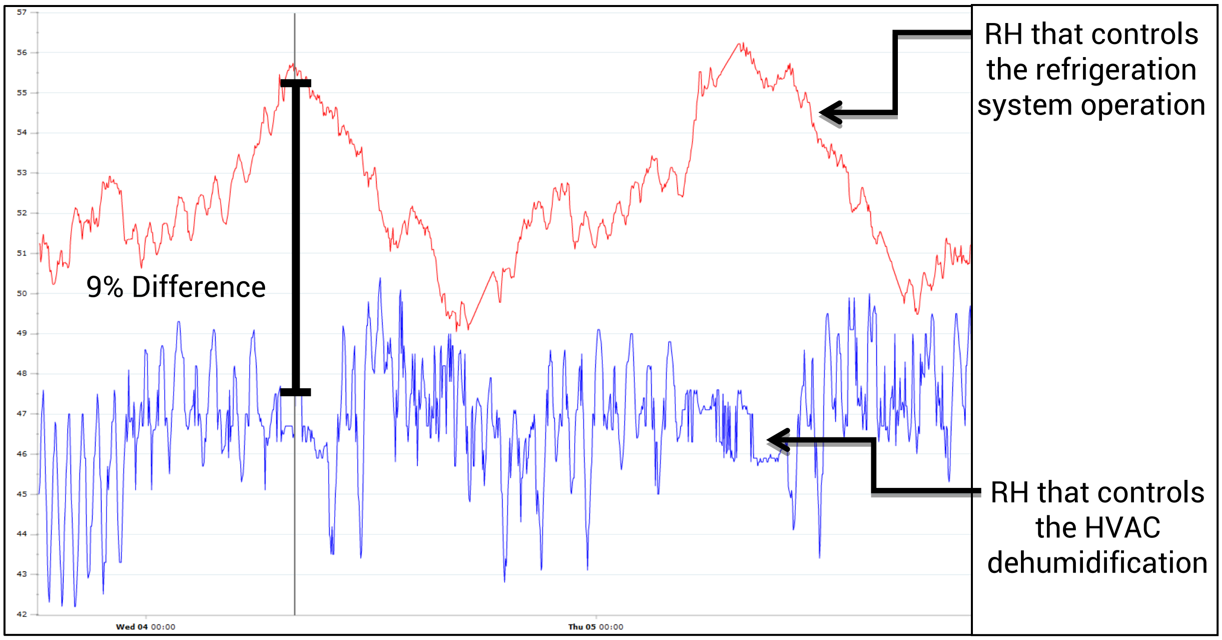


Figure 16 - Inside Relative Humidity Variation (Source: EZENICS)

Description – As figure 16, above shows, the relative humidity driving the dehumidification for RTUs is not in line with the other relative humidity readings. This presents multiple issues:

- If the relative humidity is actually stratified, then the RTUs will be performing the majority of the dehumidification instead of the DHU. The RTUs are not as efficient at removing moisture as the DHU, so more energy will be consumed.
- If the relative humidity is very high throughout the store, but the DHU and refrigeration sensors are poorly placed, then the RTUs will struggle to provide proper dehumidification. The additional latent load will be picked up by the refrigeration system, which is approximately 50% as efficient as a DHU at removing moisture.
- Icing can occur on the refrigeration evaporator coils.
- The anti-sweat heater will not function properly, resulting in excess moisture on the refrigeration cases, which can be a safety hazard for customers and employees if too much moisture collects on the floor.

Impact – RTUs will consume more energy due to excessive dehumidification. Potentially, the anti-sweat heaters will not perform properly. The refrigeration system will remove the excess moisture at higher cost.

Fix – There are two solutions to this problem. The sensor may need to be recalibrated. In this case, the solution is to send a technician to recalibrate the sensor. If the sensor calibration is not an issue, it is likely that the sensor needs to be relocated. In this event, the technician should relocate the relative humidity sensor that controls the RTU's operation to an appropriate location.

Similar to the outdoor air temperature problem, this issue may go undetected if the fault detection was embedded on a whole unit level.

5.4 Total Impact

The OG and AFDD tool results for the 20 buildings in SDG&E service area have been grouped together in Table 16, below.

Table 16 - AFDD Result / Financial Summary - SDG&E (Source: EZENICS)

Problem	# of Issues on RTUs/DHUs	Projected Yearly Savings (kW)	Projected Yearly Savings (kWh)
Incorrect Schedules	34	-	$8,000
Incorrect Setpoints	148	$5,000	$42,800
Non-Optimized Economizer Settings	482	-	$29,000
OAT Sensor Readings	368	-	$23,900
ERV Wheel Inefficiency	1	$970	$1,500
Cooling Stage Failure	64	$1,900	$15,500
Fan Cycling	42	-	$700
Indoor RH and Temperature Sensors	3	-	$1,500
Simultaneous Heating and Cooling	3	-	$1,400
Subtotals	1,145	$7,870	$124,300
Grand Total		$132,170	

The OG and AFDD tool results for the buildings nationwide have been grouped together in Table 17, below.

Table 17 - AFDD Result / Financial Summary - Nationwide (Source: EZENICS)

Problem	# of Issues on RTUs/DHUs	Projected Yearly Savings (kW)	Projected Yearly Savings (kWh)
Incorrect Schedules	25,800	-	$5,325,000
Incorrect Setpoints	25,500	$366,000	$1,122,000
Non-Optimized Economizer Settings	30,700	-	$1,900,000
OAT Sensor Readings	26,900	-	$3,532,000
ERV Wheel Inefficiency	200	$80,000	$325,000
Cooling Stage Failure	6,900	$208,000	$1,033,000
Heating/Cooling Stage Cycling	3,200	-	$16,500
Fan Cycling	4,500	-	$74,900
Indoor RH and Temperature Sensors	250	-	$120,500
Simultaneous Heating and Cooling	440	-	$107,800
Subtotals	124,390	$654,000	$13,556,700
Grand Total		$14,210,700	

1. $350 Million is the total of all the utility bills for this sample during 2011. The total includes demand and consumption charges. Based off of the demand charges in table 3 on page 5, the demand charges account for approximately 25% of the utility bill and the remaining 75% of the bill is consumption charges. $13,556,700 of the savings was in consumption.
2. The energy consumed by the HVAC equipment is a relatively small percent of the overall energy consumed. Based on a subset of locations that were examined, on average, the HVAC equipment, which predominantly consists of RTUs and DHUs, accounts for approximately 33% of the energy consumption.
3. According to the EPA, $1 of energy savings equates to $59 of product sold at retail stores. This means based on retail profit margins, an incremental $59 of product would have to be sold to result in the same profit impact as savings $1 of energy. Many new locations would have to be built and successfully in business to equal the profit impact that these energy savings result in.

Table 18 - RTU/DHU Percent Savings (Source: EZENICS)

Total Energy Bill	$350,000,000
Consumption Charges (75% of total energy bill)	$262,000,000
RTU Consumption (33% of Consumption Charges)	$86,625,000
Identified Consumption Savings	$13,556,700
% Savings of RTU Energy Consumption	15.6%
Pounds of Bananas that must be sold to produce the same savings	799,800 Tons

5.5 Demand Response Optimizer

Table 19 - Demand Response Optimizer Results (Source: EZENICS)

Bid Type	SDG&E		Nationwide			
	# of Locations Enrolled (% of those in the SDG&E area)	Average Event Bid	# of Locations Enrolled (% of total)	Average Event Bid	Total Number of Events	Total Capacity Saved
FSL*	-	-	330	80 kW	72	51 MW
GLD**	20	57 kW	641	72 kW	43	13 MW
NOTES: *Firm Service Level (FSL) **Guaranteed Load Drop (GLD)						

Of the sample locations used in this study, there were 125 buildings enrolled in DR programs in 2008. The operators of these buildings were solely utilizing the Demand Management Optimization Module to centrally manage the events that took place in a variety of locations/utilities in the US with a variety of aggregators. By 2012, the portfolio of buildings enrolled in DR programs expanded to 914. In the SDG&E service area there were 10 locations enrolled in DR in 2008; by 2012 the number of locations increased to 20.

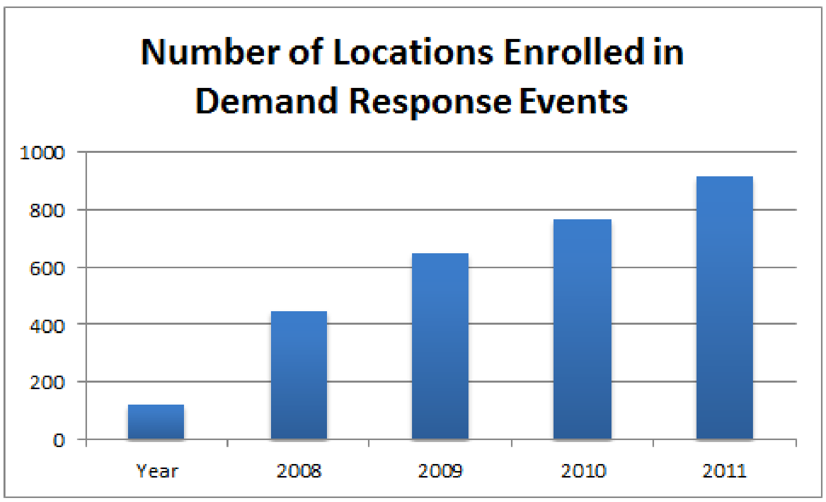


Figure 17 - Demand Response Enrollment (Source: EZENICS)

During 2011, successful DR events generated over $2.5 million in revenue for the sample of locations nationwide. Buildings in the SDG&E service area generated over $35,000 in 2011. The DR revenue was generated by a centralized team of 4 individuals.

Table 20 - DR Revenue Generated in 2011 (Source: EZENICS)

Nationwide	$2,500,000
SDG&E	$35,000

The size of the stores in the sample and the amount of equipment within each store vary greatly, resulting in a demand variance of 200 kW to 1200 kW with an average of 450 kW. The average kW amount was used in the following graphs and statistics.

Within the sample buildings, there were two types of DR bids: Guaranteed Load Drop (GLD) and Firm Service Level (FSL). The savings for locations with an FSL bid are much higher due to the increase in event frequency. Clients have increased the size of their bids significantly as a result of using the Demand Management Optimization Module which enables client confidence to pursue more aggressive curtailment strategies through AFDD and OG assessment of operational and environmental conditions providing maximized bidding potential and event performance across a portfolio of buildings. In 2012, 64 Megawatts of energy were curtailed.

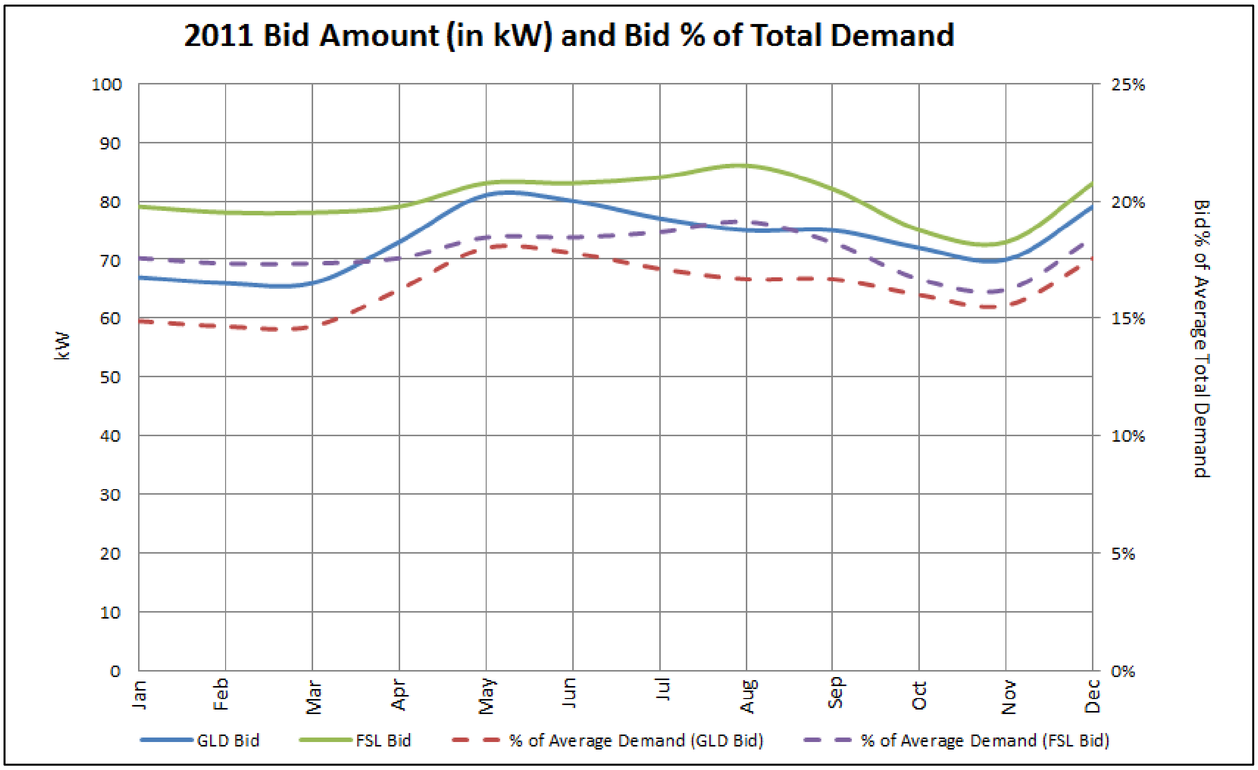


Figure 18 - Demand Response Bid Information (Source: EZENICS)

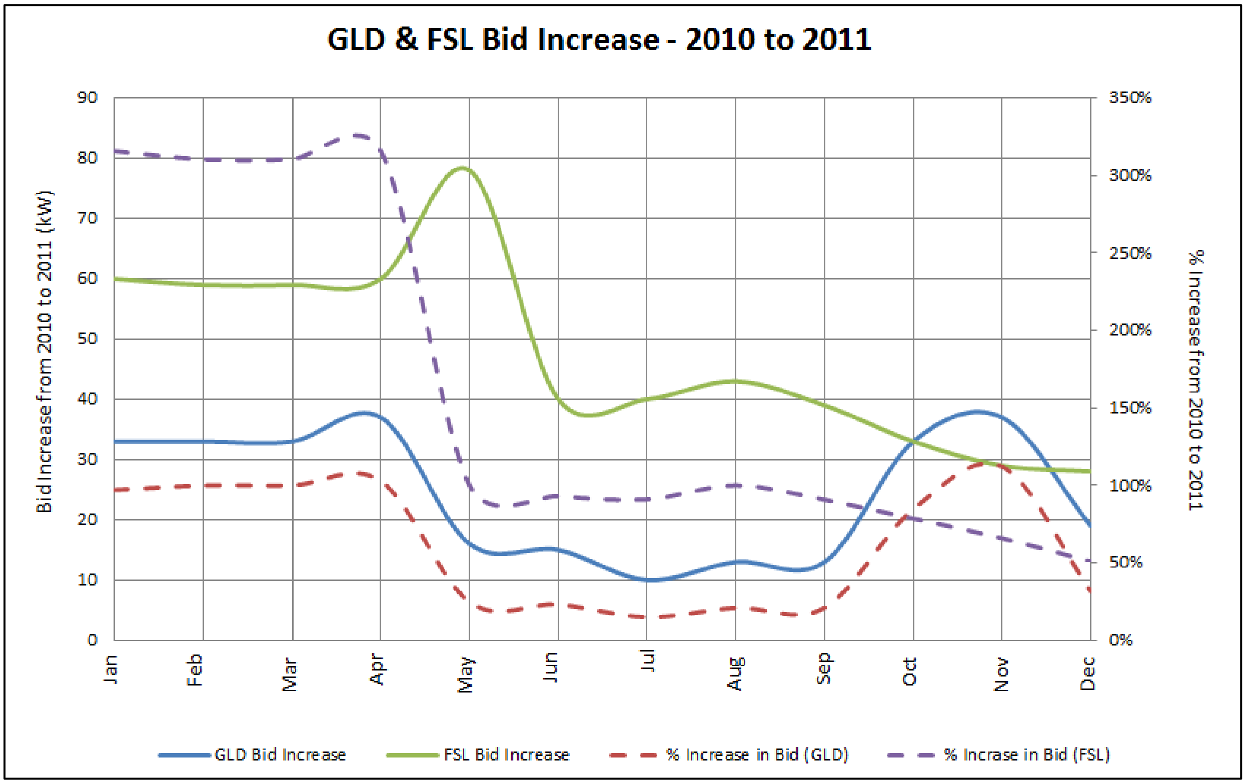


Figure 19 - Demand Response Bid Increase (Source: EZENICS)

Table 21 - AFDD Nationwide Total Summary (Source: EZENICS)

Problem	# of RTUs/ DHUs with the Issue	Projected Yearly Savings (kW)	Projected Yearly Savings (kWh)	2011 DR Revenue
Incorrect Schedules	25,800	-	$5,325,000	-
Incorrect Setpoints	25,500	$366,000	$1,122,000	-
Non-Optimized Economizer Settings	30,700	-	$1,900,000	-
OAT Sensor Readings	26,900	-	$3,532,000	-
ERV Wheel Inefficiency	200	$80,000	$325,000	-
Cooling Stage Failure	6,900	$208,000	$1,033,000	-
Heating/Cooling Stage Cycling	3,200	-	$16,500	-
Fan Cycling	4,500	-	$74,900	-
Indoor RH and Temperature Sensors	250	-	$120,500	-
Simultaneous Heating and Cooling	440	-	$107,800	-
Subtotals	124,390	$654,000	$13,556,700	$2,500,000
Average Number of Issues per RTU/DHU				
Grand Total of All Issues		$16,710,700		

The real challenge for EZENICS has been getting clients to start fixing the equipment issues. When clients were asked for feedback, it was discovered that due to the overwhelming amount of issues despite having severity ranking, duration, quantities, and financial impact it was challenging for the clients to determine where to begin correcting faults. As a result, EZENICS has had to change how the tools display information to clients.

The greatest change that EZENICS has made in the past year is the inclusion of specific high level business decision rules. These business rules allow management to set criteria so when faults are displayed, they can be acted on immediately by technicians without having to guess what the priorities should be. The reason for these rules is that it is not feasible for clients to fix every issue; there are simply too many. However, there are triggers for facility managers, often comfort related, which will cause them to roll trucks. Once a client inputs their criteria related to the comfort thresholds of a building or the quantity of faults, the faults will be filtered and only the issues that meet those facility drivers will be displayed. At that point, the list of faults becomes a list of actionable items.

During 2011, the OG and AFDD tools identified over 124,390 for the sample of 1,522 buildings. The problems that were identified have a potential savings of approximately $14,210,700. Teams of two or three individuals have used the Automated Fault Detection and Diagnostics (AFDD) and Operational Guidelines (OG) tools developed by EZENICS to realize millions of dollars in actual savings.

The Demand Response (DR) Optimizer integrates the results from the AFDD and OG tools, along with the indoor conditions from multiple locations to allow users to manage concurrent events successfully. The DR Optimizer uses these inputs to create dynamic load shedding strategies. The DR Optimizer has been used across 24 DR markets that include 120 different utility companies to save over 64 megawatts of capacity.

Cowan, A. 2004. "Review of Recent Commercial Rooftop Unit Field Studies in the Pacific Northwest and California." New Buildings Institute, report to the Northwest and Conservation Council and Regional Technical Forum. White Salmon, WA.

ABOUT EZENICS

Ezenics (formerly Sensus MI) is a leader in scalable enterprise facility optimization solutions across disparate systems that continuously analyze data to provide prioritized actionable information and supervisory intelligent control with existing systems and equipment to provide constant energy, maintenance, reliability, and environmental benefits. The Ezenics enterprise optimization platform has over 400 million square feet of property that are continuously optimized across the globe ensuring high uptime and occupant satisfaction while enhancing commissioning, energy efficiency, maintenance, carbon management, and demand management activities.

Founded in Europe in early 2004, Ezenics has experienced engineering and development teams located in offices in Italy, Dubai, Argentina, and Omaha Nebraska that enable 24/7/365 support and uptime with the ability to execute on facilities around the globe.

Industry Leading Domain Expertise

Ezenics is a recognized leader in the energy and HVAC&R market backed by proven client successes, grants, industry awards, and a dedicated university research laboratory.

$1.5 Million California Energy Commission Grant for FDD. 250 CA sites & involvment from all major CA Utilities.	ASHRAE grant for Phase III FDD research involving field impliment with a focus on Centrifigal Chillers.	Italian Regional Innovation Award	Frost & Sullivan's 2006 European Excellence in Technology Of The Year Award

- 2009 and 2010 Buildy Awards for best technology and best implementation
- NREL 2011 Building Optimization Grant

BuilConn Smart Green Sustainable Buildings — ConnectivityWeek Santa Clara, CA June 8-11, 2009

Sensus Machine Intelligence (Sensus MI) and Target Corporation won the annual Buildy Award for **Best Building Connectivity Implementation** at ConnectivityWeek 2009. The award is presented to the integrator, building owner or consultant with the most progressive building, supporting the vision of whole building integration and intelligent buildings.

Buildy awards were determined from attendee voting at ConnectivityWeek, which was the largest annual gathering of industry experts on IT and the energy markets in North America with more than 1200 industry experts.

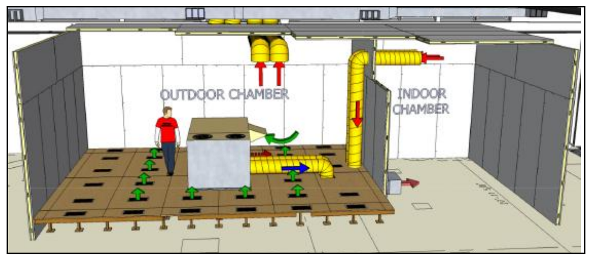
E.U. CASCADE Project

Three million dollar project for Automated Fault Detection and Diagnosis to support energy efficient operation of HVAC-systems in airports public spaces.

http://www.cascade-eu.org/cms/

FDD Lab

The EZENICS AFDD technology is based on real world experience and experimentation from chiller test stands in Italy plus our own innovative 600 square feet dual climatic chamber laboratory in Omaha, NE with 250+ sensors.



Scalable Solutions for all types of commercial facilities

The EZENICS platform allows clients to optimize existing assets in a scalable manner that provide a high net value solution with a low cost. This business philosophy opens up the opportunity for value creation in large complex facilities and the often more neglected smaller retail facilities such as QSRs (Quick Serve Restaurants) and convenience stores. This business model is enabled by the ability to add value without additional hardware and site visits.

Ezenics has a wide range of commercial facilities being continuously optimized.

- Hospitals
- Retail Small & Large Box multisite with and without refrigeration
- Airports
- Data Centers
- Multiple and Single Office Buildings that are owned and leased
- Mixed Use Campus Facilities
- Hotels
- Quick-Service Restaurants
- Convenience Stores

Ezenics solutions are most commonly procured as an ongoing solution with a monthly fee. The objective is to work to ensure that benefits are always far more than the costs on an ongoing basis thus providing instant and continuous payback.

To learn more about EZENICS, visit our website at www.ezenics.com or contact Brian Thompson through email (b.thompson@ezenics.com) or by phone (765)387-4448.