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WHITE PAPER

Using Wireless Sensors for Energy Monitoring Improves Efficiency and Reduces Energy Costs

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Using Wireless Sensors for Energy Monitoring Improves Efficiency and Reduces Energy Costs

How the SensiNet® wireless sensor network is transforming building energy management.

Summary

Wireless mesh sensor networks are truly a transformational technology for building energy management, and SensiNet® offers the flexibility, reliability, and scalability required to take building energy management to the next level.

In addition to offering remote monitoring capabilities which eliminate the costly, labor-intensive on-site work by field personnel, SensiNet provides instant access to accurate, reliable real time data. This dramatically improves the ability to see trends, catch problems before they cause real damage and make the right decisions to optimize energy utilization.

At a time when engineering practitioners at all stages of building analysis are feeling the pressure to reduce costs by improving the efficiency of energy use, SensiNet is an extremely effective addition to every toolkit. With SensiNet, companies are able to reduce operating costs, improve productivity and more readily comply with regulatory requirements.

A New Technology Transforms Energy Management

Increasingly complex building energy design and management control systems, rising energy costs and the push toward environmentally friendly structures have driven the building energy management industry to a fever pitch. All around the country building energy practitioners—facility managers, consulting engineers, and designers—are actively looking for ways to trim energy costs and optimize utilization.

Whether preparing to apply for Green Building designation, creating a building energy model, performing building commissioning or even just trying to decide whether to finally replace that old boiler, gathering accurate data is at the very core of any energy analysis. After years of struggling with outdated data logging technology that required repeated, costly site visits, real time remote monitoring and reporting has become possible with innovative self-configuring radio networks.

At the center of this dramatic transformation of building energy management are wireless mesh sensing networks. Quick to install, flexible enough to be moved from site to site and easy to manage, wireless sensing networks continuously collect a wide range of information, such as boiler operating parameters, indoor and outdoor temperature, and fuel consumption. The collected data is passed over the network and made available via the Internet for instant assessment and analysis.

Leading the way in the development of this innovative technology is Sensicast Systems, Inc. Its patented SensiNet technology delivers superior reliability, even in the harshest environments, and delivers unmatched flexibility. In most cases, a SensiNet system typically is installed for two to four weeks and, upon completion of the analysis, is easily removed and installed in another building. Deployed in countless buildings through the United States and Europe, SensiNet allows practitioners to visualize performance in real time on-site or remotely. This dramatically enhances the efficiency and accuracy of building energy audits and also serves as an all-around building diagnostic tool. By

implementing SensiNet, companies are able to reduce operating costs, improve productivity and more readily comply with regulatory requirements.

This paper examines the application of SensiNet in some specific applications of building and facility energy management. Several major categories of energy engineering and facility management are examined and installations using different end node configurations are shown.

The Challenge of Data Collection and Analysis

Building energy practitioners utilize many tools to assist in design, commissioning, operation, and troubleshooting of building energy and envelope systems. The ultimate goal is to improve efficiency and deliver measurable cost and resource savings. One tool considered indispensable in the energy engineer's toolkit is the data logger.[1] Data loggers are leave-behind devices that gather different types of signals from temperature to occupancy to light levels. The data is collected and analyzed when possible to determine the cause of a problem or irregularity. These devices are utilized in a variety of ways and represent a way to gather data that is not available through the buildings own sensors or to analyze specific rooms or pieces of equipment.

Traditional data loggers require regular manual interaction and frequent site visits to collect the data, which drives up the cost of doing business significantly. Once collected, the data must then be consolidated before it can be assessed. SensiNet, on the other hand, continuously and automatically sends data across the network. With self-configuring and self-healing capability, SensiNet can adjust to network disruptions and require minimal, if any, maintenance during operation.

In addition, SensiNet offers graphical user interfaces that allow for simple or complex analysis and real-time data viewing, with the added ability to go remotely to the Internet when a connection is available. End nodes can be moved, added, or removed as necessary and set to the sampling interval necessary for the task.

SensiNet even offer the ability to share the collected data with third-party software packages, including an OPC data socket that enables data to be easily transferred into popular instrumentation packages, such as LabView. LabView is a standard data acquisition interface that permits the user to create quick, customized, data representation and calculations and is standard in universities and engineering laboratories.

Most commercial buildings and many residential buildings use a Building Management System (BMS) to optimize the use of energy by the building. A BMS or a Direct Digital Control (DDC) is central station, usually computer controlled, which uses sensors and actuators to improve the efficiency of a building. The BMS may have facility management functions in addition to the energy control functions. Some of these systems consist only of a primary energy source control with some temperature and distribution monitoring but more modern systems can measure hundreds of data points and employ advanced algorithms for more complicated energy savings.

A primary use of data loggers is to analyze conditions that are not measured by the Building Management System (BMS) already in place, or must be measured at intervals that are very short compared to the BMS sampling rate. SensiNet can also fulfill the sensing function for set-up of a BMS then be removed and set up elsewhere, thus saving additional control system measurement points. Often data from a BMS is extractable but only in delimited files that are unique to the system and must be analyzed with a spreadsheet. SensiNet, however, offers much greater flexibility for analysis, trending and integration with third-party software.

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[1] Handbook of Energy Audits, 6th ed. Albert Thumann, William Younger, Fairmount Press, Lilburn GA, 2003, p. 87.

The SensiNet Approach

Sensicast Systems, Inc., a provider of cost-effective intelligent wireless sensor solutions, has been at the forefront of the move to wireless sensor networks. While there are several methods for delivering these capabilities, the Sensicast approach has proven exceedingly effective in monitoring buildings in the United States and throughout Europe.

The Sensicast network features battery-powered end nodes that measure 4-20 mA and 0-10V signals, in addition to the RTD and room temperature end nodes. This allows for many types of transducers to be measured and comparisons of events and temperatures to be made, such as HVAC equipment switching and temperature trends.

Sensicast's flagship product, SensiNet, is a leave-behind set of sensors with a central access and communications point. In a typical application, SensiNet will remain installed in a building for up to four weeks and provide remote access to the boiler operating parameters, indoor and outdoor temperatures and fuel consumption. This data is passed through a web-based data visualization system for detailed analysis of performance parameters like energy intensity, heat factor and average indoor temperature. The data can be valuable in detecting operational irregularities like short-cycling and thermal balance problems.

During the installation, the boiler mechanic or consultant may tune the boiler to operate at optimal conditions in coordination with the Weatherization specialist. Upon completion of the analysis period, the entire system may be removed and installed in another building.

SensiNet uses robust wireless network communication to gather signals from sensors (from one to 1000s) placed throughout a building. Each node of the network is battery operated and connects to a sensor that measures the desired quantity. Each node communicates with other nodes to form a LAN that brings all data back to a central collection access point.

SensiNet's patented technology delivers 100% data reliability and is a self-managing, self-healing network. Sensors can easily moved by technicians as needed, without requiring technical planning or system reconfiguration. Once the network is established, the access point is connected to the wireless SensiNet Services Gateway which sends data via cellular communication to a standard database on the system host. The web-based browser accesses the data and makes it available for analysis by the specialist.

SensiNet Applications in Building Energy Analysis

SensiNet is being used in a myriad of building energy management applications. There are several branches of energy management analysis that are differentiated primarily by when the work is done during the life of the building and whether or not it involves an outside agency or in-house facility management. These are:

- Energy Audits and Energy Modeling
- Commissioning (Cx)
- Retro-Commissioning (Rx)
- Measurement and Verification (M&V)
- Operations and Maintenance (O&M)
- Design Feedback Data

A moderately large set of SensiNet end nodes can be used flexibly in all the applications described below with different interfaces built, on-site if necessary, in a short period of time. The price of a system like this is less than the cost of an infrared camera.

SensiNet Application: Energy Audits and Energy Modeling

The phrase "energy audit" is commonly used to describe an energy study that may be a quick walk-through of a facility or a detailed computer model of the potential savings of alternative energy efficiency measures. There are three general levels of building audit: a walk-through audit; a general audit; and an Investment Grade Audit.

Most authorities on energy auditing recommend the use of data collection systems and wireless sensor networks are particularly well suited for this task.[2] Most sources agree that the use of single measurements of conditions are not representative and encourage the gathering of as much data as is possible. For example the monitoring of a few days of boiler operation can yield data about its control set-up and reveal problems such as short cycling, a common inefficiency.

Example – Energy Audits and Energy Monitoring

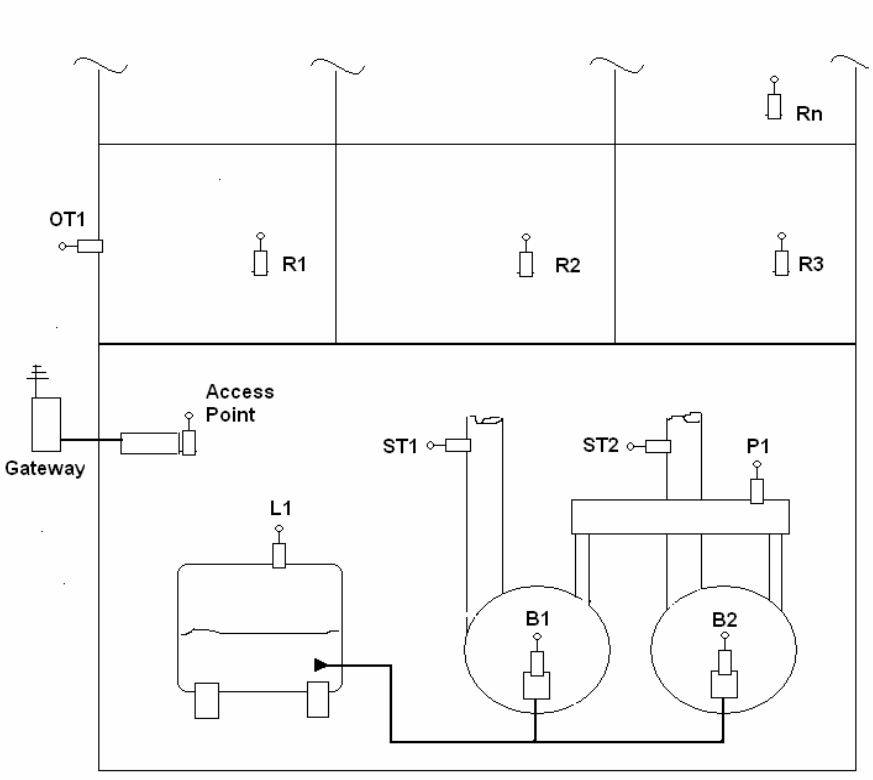

Figure 1: SensiNet system installation diagram.

Figure 1 shows a representation of the components of the SensiNet system installed in a residential building. The SensiNet Services Gateway transmits data via a cellular connection to the data host. The boiler operation sensors B1 and B2 measure the firing of the boiler, ST1 and ST2 measure the stack temperature, and P1 measures the boiler

[2] Ibid, pp. 87 – 113.

manifold pressure. Sensor L1 will measure the tank level for consumption rate. Room temperature sensors R1 – R20 will measure selected room temperatures and OT1 will measure the outdoor temperature.

Table 1 (below) shows the different system points and the wireless network sensor node that is required to measure each sensor output. Repeater and Bridge nodes are required to support difficult orientations and interface with the access point.

Table 1. E-View Proposal System Hardware

Quantity	Description	Output Type	Diagram	Wireless Sensor Network End Node
1	ASP Cellular Gateway		Gateway	-
1	Access Point		Access Point	-
1	Oil Tank Level Sensor	0 – 10V	L1	0 – 10V
2	Boiler Fire Sensors	0 – 10V	B1, B2	0 – 10V
2	Stack Temperature Sensors	RTD	ST1, ST2	RTD
1	Pressure Manifold Sensor	0 – 10V	P1	0 – 10V
1	Outdoor Temperature	-	OT1	Standard Temperature
20	Indoor Temperature	-	R1 – R20	Standard Temperature
2	Repeater Node	-	-	Repeater

SensiNet Application: Commissioning (Cx)

Commissioning is the comprehensive coordination and evaluation of the building operation, quality, and staff by a third party agency to ensure that the building operates as designed and maintains optimal operation in the future. The third party will perform rigorous and systematic operational checks that are not limited to energy but also encompass Indoor Air Quality (IAQ), comfort, and operator training and manuals. LEED certified buildings undergo a Cx process as a mandatory requirement for certification.

While wireless sensor networks are not currently utilized by Cx teams, many experts see this application as inevitability. SensiNet, for example, can perform all of the sensing tasks needed by Cx teams to gather the data that verifies the standards of the Cx plan. Since all data is collected immediately at a central station, the time savings is significant. Plus, a standard GUI for the building aids in statistical analysis and visualization of problems.

Example – Commissioning

In this example (see Figure 2), SensiNet sensors placed in each heating and cooling zone measure room temperature and O_2 level. As the building's HVAC systems and algorithms are evaluated by the commissioning team, data can be recorded and visualized on a single in-building or remote connection. Additional sensors can be added as necessary to measure key points of the primary distribution system.

Performance can be verified without the need to set up complex routines within the EMS or to analyze files of output data or adding additional DDC points. Perhaps the best benefit of the test rig is the ability to exactly duplicate the test years in the future. The same configuration can look for deterioration in performance or functionality, just like an annual doctor's check-up.

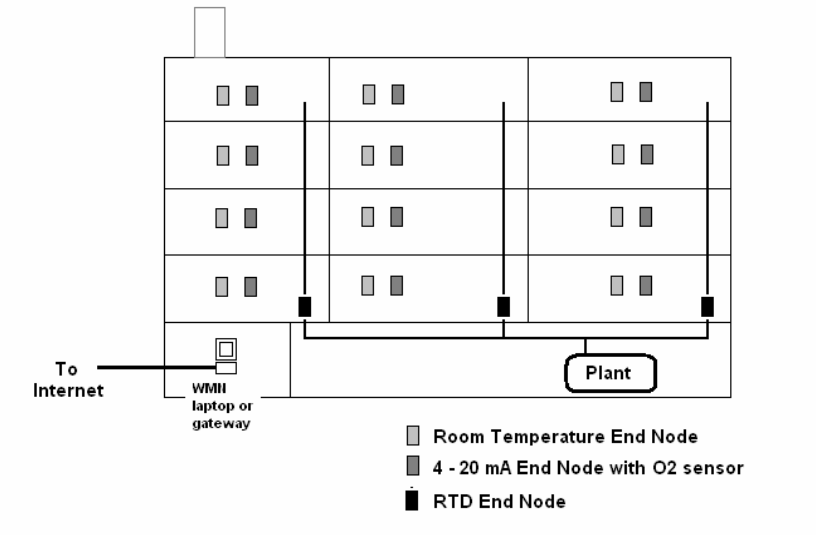

Figure 2. Example layout for a simple commissioning objective.

If the analysis of a particular VAV box is necessary, then additional sensors can be added to the system and the data analyzed using a tabbed page or a separately tabbed LabView screen. (Figure 3.)

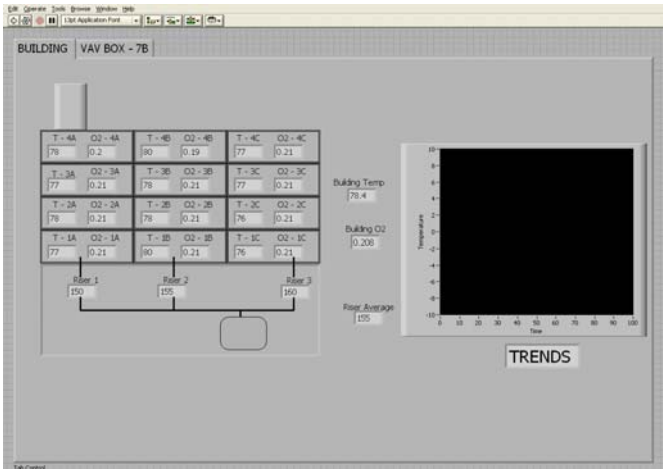

Figure 3. LabView screen for commissioning example in Figure 2.
Constructed in about 30 minutes.

SensiNet Application: Retro-Commissioning (Rx)

Retro-commissioning is the same process as Cx but is performed for existing buildings. In existing buildings, the HVAC system components naturally deteriorate or problems that occur in the course of

operation are often fixed by a band-aid solution. The situation is worsened when employees leave, taking their knowledge of the system with them. The benefits of Rx are easier to analyze since the building has a prior performance record.

The flexibility of SensiNet gives the Rx team the ability to use the same wireless network data-gathering tool for both Cx and Rx purposes. Individual equipment may be monitored and replacements justified as necessary.

SensiNet Application: Measurement and Verification (M&V)

Measurement and Verification (M&V) is a field of energy engineering that usually consults on energy projects after completion to provide third-party verification of performance. It can also be performed similar to an energy audit and result in a recommendation report for upgrades and changes. A cogeneration system installed at a building may undergo a period of M&V to fulfill a contract requirement or, in some cases, the M&V consultant will monitor before and after installation to provide independent data for a performance contract. The Federal Energy Management Program (FEMP) and the International Performance Measurement and Verification Protocol (IPMVP) define protocols for formal contracts.

SensiNet provides a central repository for metering data through networked data collection from multiple electrical meters while simultaneously gathering thermal output data. M&V projects usually result in longer periods of analysis than audits and thus the opportunity for more formal data visualization and instrumentation is greater. A temporary SensiNet network can be set up for certain installations with data gathered over a period days or weeks to provide a clear picture of performance. Once the collection phase is completed, the system can be removed and reused at another location for another project.

SensiNet Application: Operations and Maintenance (O&M)

Operations and Maintenance (O&M) is a practice of constant commissioning that is usually undertaken by internal facility or engineering staff to keep a building operating at peak performance. O&M also involves the preparation of contingency plans for when equipment will need to be replaced or repaired.

With SensiNet in place, measured data can be taken and assessed over the life of the equipment. When the time comes to replace the equipment, the manager is ready to make the appropriate changes. Facility management teams can easily master the use of a SensiNet-based data collection system to evaluate equipment routinely and diagnose erratic behavior.

SensiNet Application: Design Feedback Data

Design and energy consulting engineers are always looking for ways to reduce the initial cost of their designs. Performance monitoring of an HVAC design component in the field allows the design firm to gather data to improve its next design. Installation of temporary SensiNet network with or without BMS or Internet connectivity is unobtrusive and serves this purpose well. For regular use on a certain type of HVAC equipment a spreadsheet or LabView analysis interface can be set up to automate the process.

Example – Design Feedback Data

A common design flaw in fuel-heated residential housing is boiler oversizing. The efficiency of a boiler at partial load conditions is often less than the quoted design efficiency on the brochure. A properly sized boiler should run 100% of the time when the coldest predicted design conditions occur. For example, the design condition may be the coldest night in 10 years with a sustained wind and half of the residents in the shower.

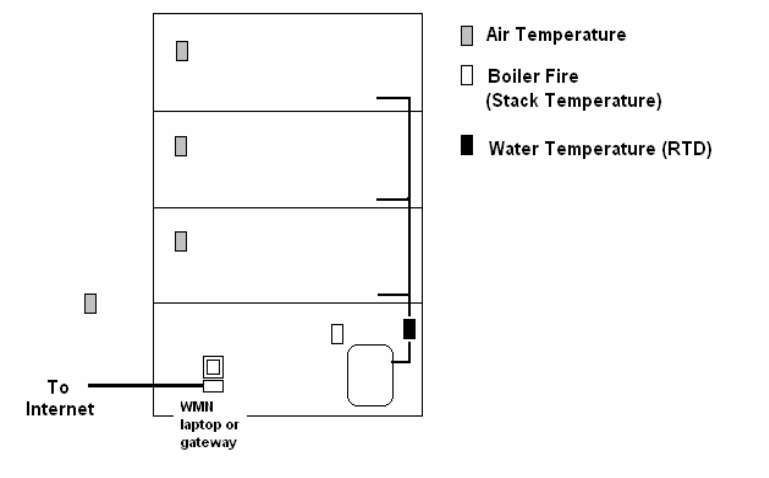

Figure 4. An example layout for a boiler runtime diagnostic test.

By taking field data, the designer can measure the run time of the boiler versus outdoor and indoor temperatures and determine the proper sizing rules for their designs. Since boiler performance is significantly affected by building envelope conditions, the data can drive further improvements to envelope design in order to reduce boiler size to the smallest possible to improve efficiency and reduce upfront costs. Figure 4 shows a sample layout for a common housing type in New York City, a three-unit brownstone in New York City served by a single boiler.

A Sensicast/LabView system can perform this task well and a custom user interface will allow for fast data analysis and repeatability. The LabView interface lets the designer quickly establish trend information. The same form can be utilized to gather a catalog of data and draw conclusions about the sizing and operation of the boiler versus building characteristics.

About Sensicast

Sensicast provides comprehensive and cost-effective intelligent wireless sensor solutions to a wide range of industries. Sensicast's sensing solutions deliver crucial information in real time from environments and processes where data collection is impossible or impractical through wired sensors. Easy to deploy and operate, Sensicast's wireless systems are in operation in plants and buildings across North America and Europe providing robust and reliable monitoring of temperature, process, and energy as well as predictive maintenance. Sensicast provides complete solutions through a network of system integrators and technology partners, its OEM development platform, and directly to end-users.

For more information go to www.sensicast.com, or send an e-mail to sales@sensicast.com