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Demonstration and Evaluation of a Non-Invasive, Low-Cost, Strap-On Sensor For Natural Gas Meters

Sean Pachuta (NREL)

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For more information contact:

Sean Pachuta
National Renewable Energy Laboratory
Sean.Pachuta@nrel.gov

GSA's Green Proving Ground program and DOE's High Impact Technology Catalyst program enable federal and commercial building owners and operators to make sound investment decisions in next generation building technologies based on their real-world performance.

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I. Introduction

The U.S. General Services Administration (GSA) is interested in installing internet-connected gas submeters or sensors to better understand gas consumption in its portfolio of buildings. GSA, in partnership with the National Renewable Energy Laboratory, conducted a demonstration to assess a specific strap-on sensor technology. This technology was implemented at two separate GSA facilities located in Dallas, Texas. This demonstration evaluated hardware and software installations and integrations, data integrity and accuracy, and included an economic analysis.

This demonstration evaluated a natural gas strap-on sensor technology provided by the vendor Vata Verks, which produces a noninvasive, strap-on sensor solution. The company was founded with a mission to conserve water (and eventually natural gas) cheaply and simply, as explained on its website. The product intends to streamline submeter deployments for natural gas and water by eliminating most hardware costs while allowing for the easy integration of sensor data into other systems, such as the building automation system (BAS), and removing tenant and building disruption. This demonstration evaluated the product features when used on a natural gas utility meter.

II. Technology Overview

The solution evaluated is a non-invasive, strap-on sensor designed and marketed to reduce installation time and simplify automated gas or water meter upgrades. The sensor technology straps a sensor probe onto the side of a gas or water utility line at the utility meter. The probe measures oscillations within the magnetic field from the movement of the utility meter and flow through the line. The recorded data are then sent to a sensor that calculates the consumption and further transmits the data to a Java Application Control Engine (JACE) Internet of Things controller, BAS, or on-site gateway. Some product features, as stated by the vendor, include the following (Vata Verks 2021):

- **Accuracy of Product:** For natural gas, 1%–2% error for temperature compensated meters, For water, 0%–1% error for temperature uncompensated meters
- **Data communication options:** Modbus Transmission Control Protocol (TCP), Modbus Remote Terminal Unit (RTU), Message Queuing Telemetry Transport (MQTT), Pulse, Hypertext Transfer Protocol (HTTP) Push, and onboard logger, with more coming
- **Resolution:** It is meter dependent, but it can be measured and adjusted to the customers' needs. Upgradability is available to make the sensor probe 100 times greater than the standard high resolution.

This sensor technology is compatible with many types of gas and water utility meters. On the gas end, the product is compatible with rotary, diaphragm, and most turbine gas meters. On the water end, it works with positive-displacement, single-jet, multi-jet, piston, and compound meters.

To install the sensor probe, it is simply strapped onto the utility meter, and the probe will read oscillations in the magnetic field and transmit information to a sensor up to 200 feet from the probe. This sensor then pushes information to equipment, such as a pulse counter, JACE, or BAS, where users can then integrate and view the consumption data.

III. Test Bed

An assessment of the technology was conducted for the demonstration period from November 29, 2021, to April 30, 2022, at two separate GSA facilities in Dallas, Texas. These locations are in GSA's Region 7. Table 1 shows information on the test bed locations.

Table 1: Test Bed Locations

Building Name	Building Location	Building Size (ft^2)	Building Use Type
A. Maceo Smith Federal Building	525 S. Griffin St. Dallas, TX 75202	198,403	Office
Terminal Annex Federal Building	207 S. Houston St. Dallas, TX 75202	253,112	Office

A. DESCRIPTION OF DEMONSTRATION SITES

A. Maceo Smith Federal Building: The A. Maceo Smith Federal Building is a 9-story building located in Dallas, Texas. Originally built in 1971, it was acquired by GSA in 1983.

Figure 1: A. Maceo Smith Federal Building

Image from GSA

Terminal Annex Federal Building: The Terminal Annex Federal Building is located in Dallas, Texas. The office building, built in 1937, consists of five stories and a basement.

Figure 2: Terminal Annex Federal Building

Image from Library of Congress

IV. Performance Objectives

Three performance objectives were included in the scope of this demonstration, each with success criteria. Table 2 details these objectives.

Table 2: Performance Objectives

Performance Objective	Success Criteria
Strap-on sensor accuracy	Less than +/-3% error for more than 90% of the time
Installation and integration	<30 days for installation and integration
Cost-effectiveness	Similar in cost or less expensive than previous options used by GSA, which have ranged from $10,000–$30,000

A. STRAP-ON SENSOR ACCURACY

The accuracy of the sensor was determined by comparisons of the sensor data with weekly manual utility meter reads. The data quality was a consideration and was reported, ideally having a low number of data dropouts; more than 90% of the time during the assessment, the meter must have data flow. The success criteria of this performance objective covered the time frame from November 29, 2021, to April 30, 2022, and the sensor must be within +/-3% of the utility meter.

B. INSTALLATION INTEGRATION

The sensor solution's installation and integration were another performance metric. The product comprised a strap probe that connects to a utility (gas) meter with, per the vendor, simple calibration. The vendor also provides instructions on calibration depending on meter type. The performance objective success criteria were based on having no significant delays in the installation from the product, allowing for simple installation and integration, with clean and accurate data flow. Another requirement was a total time of less than 30 days to install the solution. A focus group was conducted with the operation-and-maintenance team to gather input and conclusions. The focus group was asked questions about the installation and value proposition, with the intention for GSA to receive better feedback on the cost-effectiveness performance objective.

C. COST-EFFECTIVENESS

The cost-effectiveness was evaluated by comparing the cost of the equipment, installation, and integration costs to the costs of similar options to receive gas meter data. The success criteria were met if the solution was found to be similar in cost to other metering or technology options on the market and offered outcomes comparable to what GSA has previously used.

V. Results

Table 3: Performance Objective Results

Performance Objective	Success Criteria	Results
Strap-on sensor accuracy	Less than +/-3% error for more than 90% of the time	Absolute mean error: Terminal Annex Federal Building: 0.77% A. Maceo Smith Federal Building: 0.95%
Installation and integration	<30 days for installation and integration	Terminal Annex Federal Building: 2 weeks (14 days) A. Maceo Smith Federal Building: 6 weeks* (45 days) *The installation was delayed due to circumstances beyond the vendor's control.
Cost-effectiveness	Similar in cost or less expensive than previous options used by the GSA, which have ranged from $10,000–$30,000	Terminal Annex Federal Building: $3,032 A. Maceo Smith Federal Building: $3,072

A. STRAP-ON SENSOR ACCURACY

For both locations, the solution provided accurate readings once calibrated. The process of calibration after installation consists of changing what is called the "k-factor." This allows the user to adjust the sensor to be calibrated to the utility meter with which the sensor probe is attached. For both locations, the gas meters were initially installed during the cooling season, during which time there was minimal gas flow, making calibrations difficult. The vendor instructions for the k-factor calibration/adjustments were also found to be complicated; however, after multiple attempts, GSA was able to achieve accurate sensor readings compared to the utility meter.

Calibration took a significant amount of time; therefore, while the study period lasted 6 months, there were only 2 months of calibrated data available at the end of the monitoring period. Although the sample size is smaller in the short time window, even one inaccurate reading can affect the results; however, this performance objective success criteria was still met. The data showed a difference in accuracy that was greater during less gas flow or warmer outdoor air temperatures.

The utility meter readings, including photos, were taken at specific times, and then they were compared to the sensor interval data. The difference between the two was calculated to find the accuracy of the solution. For the A. Maceo Smith Federal Building, the solution (after adjustments to the k-factor) showed an average error of 0.95%, or accuracy of 99.05%, during the time frame from March 14, 2022, to May 2, 2022. The biggest difference in accuracy was at the end of April, which showed an error of 2.23%. The Terminal Annex Federal Building showed very similar results after the k-factor adjustments. The error from March 14, 2022, to May 2, 2022, averaged 0.77%, or a 99.23% accuracy, with the largest error being 2.03%. This solution achieved GSA's goal of having an error no greater than 3% while also having consistent data flow and no dropouts during the period from March 14, 2022, to May 2, 2022.

B. INSTALLATION INTEGRATION

For this project, the solution was installed using two different methods at the two locations: One used a contractor, and the other used internal GSA staff, yielding different results.

For the A. Maceo Smith Federal Building, the timeline to install and fully integrate the sensor took from October 15, 2021, to November 29, 2021 (45 days). The installation took longer because of minor complications in the process on GSA's end. There were difficulties in GSA getting a proposal for the operation-and-maintenance staff to complete the work. There were also BAS integration complications and difficulties receiving Cisco Identity Services Engine permissions. Although the installation of the meter was quick, there were also issues with the physical installation. The issues were thought to be produced by a faulty probe; however, after careful examination, bad cabling was found, potentially from the contractor hired for the installation. Once this cabling was replaced, there were no more issues. The time spent replacing the bad cabling was not factored into the installation timeline from October 15, 2021, to November 29, 2021, because the sensor was physically installed and integrated, which enabled investigation into the connection issue.

For the Terminal Annex Federal Building, the timeline to install and fully integrate the solution was much faster because internal GSA employees, rather than a contractor, executed the installation. For this facility, three GSA employees installed and integrated the sensor. The on-site cabling and mounting of the device took 1 day, then the initial BAS programming took place during the next few days. The total installation time was 2 weeks (14 days), with internal staff completing the programming in between other projects and meetings and relearning the Modbus integration. The timeline could have been shorter if the staff did not have competing urgent obligations.

Focus Group

In the focus group, polling results showed a score of 4 out of 5 when rating the installation experience with the vendor's solution versus previous submeter options used by GSA. Some feedback included details such as "mostly had a trouble-free experience with the submeter" and "physical installation was very straightforward." For questions about improvements, the feedback showed that a wireless capability to update, calibrate, and adjust the sensor would be welcomed because the installed solution did not have this feature, so adjustments can be completed only by physically going to the sensor; however, the vendor does offer products with these capabilities, but they were disabled by GSA through the information technology remediation process. Feedback also showed that the ease of installation of these meters was appreciated. Duplicating this at other locations could be as simple as a copy and paste of the Modbus integration if the BAS vendor is the same. Although most feedback was positive, users found that some refinement was needed in the packaging and instructions, but the product worked as intended. For both buildings, the focus group yielded a mix of potential improvements; however, all people involved said they would install the sensor in other buildings.

C. COST-EFFECTIVENESS

The cost-effectiveness of this sensor solution was evaluated and compared with previous submeter installations at GSA's buildings. Previously, GSA installations have typically ranged from $10,000 to $30,000, depending on the installation, integration, and location. With the sensor tested in this project, the cost also varied slightly based on location. The installation at the Terminal Annex Federal Building resulted in a cost of approximately $2,275 for the installation plus $757 of the vendor's equipment, totaling $3,032. The installation at the A. Maceo Smith Federal Building cost slightly more, perhaps because of the contracting method used but the difference is very small. This cost was approximately $2,315 for the installation plus $757 for the vendor's equipment, totaling $3,072. Overall, the sensor solution in the project was significantly less expensive than the previous options.

VI. Summary Findings and Conclusion

Overall, the strap-on sensor performed well, with minor issues and lessons learned during the project. The solution achieved success criteria for the three performance objectives: accuracy, ease of installation and integration, and cost-effectiveness. The lessons learned from this project will help GSA improve internal processes to reduce time and costs if choosing this solution or other similar options.

VII. Deployment Recommendations

The strap-on sensor is a less expensive way to meet the Energy Independence and Security Act of 2007 (Public Law No. 110-140) requirement for advanced metering on covered GSA facilities. The technology could be applicable for facilities where real-time gas readings are needed. The same meter can also measure water, but this functionality was not tested. The strap-on sensor will be advantageous for:

- Buildings that already have integrated BAS
- Whole-building or equipment-specific meters, gas or water
- Buildings that need more granular measurements for policy goals.

VIII. Lessons Learned and Best Practices

- Decide whether this sensor will be installed to a JACE or a network switch. The network switch integration will require more work to ensure that proper permissions are added to allow communications on the GSA network.
  - Internet Protocol assignments and allowlisting should be accomplished in advance of the installation.
    - Ensure there is port availability on a network switch or JACE.
    - Ensure the port is configured correctly for the device.
    - Update the riser diagrams and switch matrix, as necessary.

    - Integrate or prepare the BAS for integration before installation.
- If available, use the BAS subcontractor to complete the integration while the BAS subcontractor is on-site for scheduled visits, and use a contractor to complete the cabling if the BAS subcontractor cannot.
    - Check local laws and regulations on cabling to determine whether an electrician is needed.
        - Using an electrician is allowed for adding an outlet to the enclosure during the installation to provide energy to the sensor.
    - Ensure the contractor is qualified to run cabling.
- When programming the BAS, allow for the k-factor adjustment within the BAS wire sheet to prevent the need to directly connect and physically go to the device for any future updates. The tested device is not internet-capable on a GSA network.
- This solution is not building automation and control network compatible. Modbus was used for this project, but see the Technology Overview section for offered communications of the product.
    - This can be set up with a pulse reader to read at the meter.
- Install during periods when gas or water is consumed.
    - During the project, adjustments to the k-factor could have been faster if there was more gas flow.
        - Calibrating during winter months for compensated gas meters allows for greater accuracy during peak usage.
        - The vendor keeps a library of gas meter k-factors that it will share with installers, negating the need to calculate the k-factor and streamlining the installation. For increased accuracy, additional calibration might be needed.
- Install the device in an enclosure that has a dedicated electrical outlet to energize the device.
- During the test bed assessment, the vendor updated its instructions for the installation and the k-factor calibration based on lessons learned from this evaluation.

IX. Reference

Vata Verks. 2022. "Water and Gas Intelligences for Buildings." https://vataverks.com/.