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Emerging Technology Program

1022: Home Energy Management System Utilizing a Smart Thermostat

Final Public Project Report – Executive Summary

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Full Report

The following executive summary is made publicly available by Nicor Gas as part of their Emerging Technology Program (ETP). The detailed Nicor Gas ETP report is available to qualified state and utility run energy efficiency programs upon request. Please contact the Nicor Gas ETP administrator at NicorGasETP@gastechnology.org to find out how to access the full report.

Executive Summary

Introduction

Nicor Gas conducts an Emerging Technology Program (ETP), as part of its Energy Efficiency Program (EEP), to assess new or underutilized technologies that have the potential to realize natural gas savings through new EEP offerings to the 2.2 million customers in the utility's Northern Illinois service territory. The Gas Technology Institute (GTI) provides program implementation for the Nicor Gas ETP. This report summarizes the findings from a home energy management system (HEMS) pilot utilizing a "smart" thermostat and the resulting energy savings potential for Nicor Gas residential customers.

Background

Conventional programmable thermostats provide homeowners the ability to set a schedule for heating (and cooling) setpoints. Such thermostats have an established heating savings of 6.2% in the Illinois Technical Reference Manual (TRM). An emerging class of "smart" HEMS provides for additional heating (and cooling) savings potential through the use of internet connected thermostats that access cloud based software. That software utilizes algorithms to learn homeowner comfort preferences and home thermal responses to automate further setback of thermostat setpoints while meeting homeowner comfort requirements. A proactive energy efficiency technology using Software as a Service (SaaS) was utilized in a pilot of smart HEMS technology in Nicor Gas service territory, with joint participation by Commonwealth Edison (ComEd). It should be noted that the structure of this pilot presented certain constraints on the type and level of detailed information available for the performance evaluation. The Nicor Gas ETP had no physical data acquisition presence in the pilot homes and had access only to datasets available from the SaaS provider's smart thermostat installation and operation protocols. These constraints will make themselves evident in the results.

Results

Site selection for the pilot was completed through an online recruitment process on the Nicor Gas website. A total of 104 smart HEMS thermostats were installed in 92 homes, each with one to three central, forced air furnaces. The pilot assessment was conducted over the 2013/2014 heating season (and 2013 cooling season). Due to poor internet connectivity at many of the sites, the initial data analysis and results were based on a total of 76 thermostats in 65 homes. Of these 65 homes, 63 had central air-conditioning (AC) and accounted for 71 thermostats.

Further detailed analysis revealed that while the relative percentage of furnace runtime savings of two stage and modulating furnaces were found to be consistent with that of the one stage furnaces, the absolute therm savings for these staged and modulated furnaces could not be determined since detailed runtime information on the individual stages of operation or modulation were not available. These additional 11 homes with 14 thermostats were also removed from the dataset.

Finally, several additional thermostats and homes were removed from the dataset for a variety of reasons: discrepancies in furnace operation to gas use found by performing a utility billing analysis, uncertainties in the thermostat operation in conjunction with old 50% AFUE furnaces, and in one instance, human error in the input of furnace capacity data. Removal of these additional 5 homes with 8 thermostats yielded a final dataset for evaluation of 54 thermostats in 49 homes. Of these thermostats, 52 had connected cooling capabilities in a total of 47 homes with central AC. Details on the removal of thermostats from the dataset are provided later in this report.

Given the limited number of homes in the pilot, the findings from the monitoring were augmented by modeling results to meet the more robust needs for TRM content development to quantify the additional heating savings of smart HEMS thermostats over conventional programmable thermostats. Heating (and cooling) energy savings were calculated as follows:

1. 2013/2014 Monitored Savings
    - Energy savings derived from pilot data directly.
2. 30-Year Weather Average Savings
    - Energy savings derived from pilot data directly and normalized to the 30-year average data for O'Hare International Airport.
3. EnergyPlus Modeling
    - Monitored smart HEMS performance was modeled to represent savings for 15 typical Chicagoland homes representing over 80% of the single family home inventory under a typical weather year for O'Hare International Airport.

Table 1 represents the resulting economics from the above energy savings analyses. The significantly lower heating savings from the monitored results is primarily due to homeowner intervention in the implementation of further thermostat setbacks called for by the smart HEMS software. The EnergyPlus modeling results show heating (and cooling) savings are maximized without homeowner overrides to the smart thermostat's further temperature setbacks.

A natural gas price of $0.807/therm and an electric price $0.107/kWh were applied, per the 2014 pricing assumptions of the Nicor Gas EEP. Electric cost savings include cooling savings as well as year round fan savings from the heating and cooling seasons. The baseline case is that of a programmable thermostat. The installed cost premium for the smart HEMS product over a programmable thermostat is $193.48/thermostat. This is determined based on the professionally installed cost of $223.48/smart HEMS thermostat, less $30/thermostat installed cost for a standard do-it-yourself programmable thermostat. If the smart HEMS thermostat was self-installed, the cost premium would be $93.48.

Table 1: Summary of Energy Savings for Average Thermostat Operation

Average Smart Thermostat Compared to Conventional Programmable Thermostat	Monitored Results	30-Year Weather Average Results	EnergyPlus Modeling Results
Gas Heating Savings (therms/yr)	40	35	89
Gas Heating Savings (%)	3.0%	3.0%	12.0%
Heating Season Fan Savings (kWh/yr)	17	15	62
Cooling Season Fan Savings (kWh/yr)	19	16	58
Electric Cooling Savings (kWh/yr)	200	170	197
Electric Cooling/Fan Savings (kWh/yr)	236	201	317
Electric Cooling/Fan Savings (%)	8.9%	8.7%	10.7%
Service Fee (per month)	$3.58	$3.58	$3.58
Annual Cost Savings less Service Fee	$14.57	$6.82	$62.60
Incremental First Cost Premium	$193.48	$193.48	$193.48
Simple Payback	13.3 years	28.4 years	3.1 years

The monitored results in Table 1 include the user overrides of smart thermostat operation beyond the user programmed setpoints that create negative savings. The monitored results in Table 2 exclude those user overrides that create negative savings. These latter results are provided to show what the potential savings could be if all the homes' programmed setpoint schedules had been more properly defined over the pilot period to represent the actual user desired setpoints.

Table 2: Summary of Energy Savings for Truncated Monitored Results

Average Smart Thermostat Compared to Conventional Programmable Thermostat	Monitored Results
Gas Heating Savings (therms/yr)	55
Gas Heating Savings (%)	4.1%
Heating Season Fan Savings (kWh/yr)	23
Cooling Season Fan Savings (kWh/yr)	25
Electric Cooling Savings (kWh/yr)	239
Electric Cooling/Fan Savings (kWh/yr)	287
Electric Cooling/Fan Savings (%)	10.6%
Service Fee (per month)	$3.58
Annual Cost Savings less Service Fee	$32.18
Incremental First Cost Premium	$193.48
Simple Payback	6.0 years

Additional cost savings from self-installation were also considered. The standard economics for a self-installed thermostat are presented in Table 3.

Table 3: Summary of Economics for Self-Installed Thermostat

Average Smart Thermostat Compared to Conventional Programmable Thermostat	Monitored Results	30-Year Weather Average Results	EnergyPlus Modeling Results
Service Fee (per month)	$3.58	$3.58	$3.58
Annual Cost Savings less Service Fee	$14.57	$6.82	$62.60
Incremental First Cost Premium	$93.48	$93.48	$93.48
Simple Payback	6.4 years	13.7 years	1.5 years

The economics for a self-installed thermostat with truncated monitored results (like in Table 2) are presented in Table 4.

Table 4: Self-Installed Thermostat Economics for Truncated Monitored Results

Average Smart Thermostat Compared to Conventional Programmable Thermostat	Monitored Results
Service Fee (per month)	$3.58
Annual Cost Savings less Service Fee	$32.18
Incremental First Cost Premium	$93.48
Simple Payback	2.9 years

The dataset indicates most of the homeowners utilized the smart HEMS thermostat and its SaaS the entire year. There were some cancellations of the service, but this was typically due to low internet connectivity and the occupant not having the best available control of the thermostat.

While significant changing of setpoints and overrides did occur, for the most part thermostats did provide energy savings while maintaining thermal comfort in the home. Overall, stakeholder acceptance was good.