"We've Never Done That Before:" Making Energy $mart Homes Out of Existing Homes In Westchester County, NY

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ABSTRACT

The New York State Energy Research & Development Authority (NYSERDA), in partnership with Westchester County, NY, Consolidated Edison and ECONnergy, has launched an innovative pilot program to test how homeowners change their use of electricity under time-of-use rates, as well as how they make decisions about operating their homes. The Westchester $mart Homes Pilot (WSHP) will collect 15-minute data on electricity use in existing homes. Selected homes will also receive sensors to measure indoor/outdoor temperatures, and boiler and air-conditioner runtimes. All homes in the Pilot receive a comprehensive whole-house energy assessment under NYSERDA's Home Performance with ENERGY STAR®, program. The Westchester Pilot is the first test in the New York State residential market of: remotely read, interval metering; non-utility time-sensitive variable rates; and integration of advanced metering, Home Performance with ENERGY STAR®, and in-home sensor technology.

This paper describes how the final system was designed and is beginning to be implemented in the field. When fully deployed, NYSERDA and its project partners anticipate that the Westchester $mart Homes Pilot will enable each homeowner to know: how much electricity they used in each time block; how much they paid for electricity in each block; and how the performance of energy systems and changes in temperatures affected that usage and those costs.

Introduction

The Westchester $mart Homes Pilot (WSHP) is designed to test the influence of daily time-sensitive pricing and energy efficiency improvements on residential energy usage. Using a whole-house energy assessment and remotely read advanced metering and sensor technologies, the goals of the Pilot are to 1) provide homeowners with a package of energy efficiency solutions, 2) document the energy savings benefits homeowners generate from implementing the energy-efficiency recommendations, and 3) give residential customers near-real-time interval metering data and variable electric rates to test the theory that variable pricing will influence them to shift their electricity usage from higher to lower cost periods.

Program Design

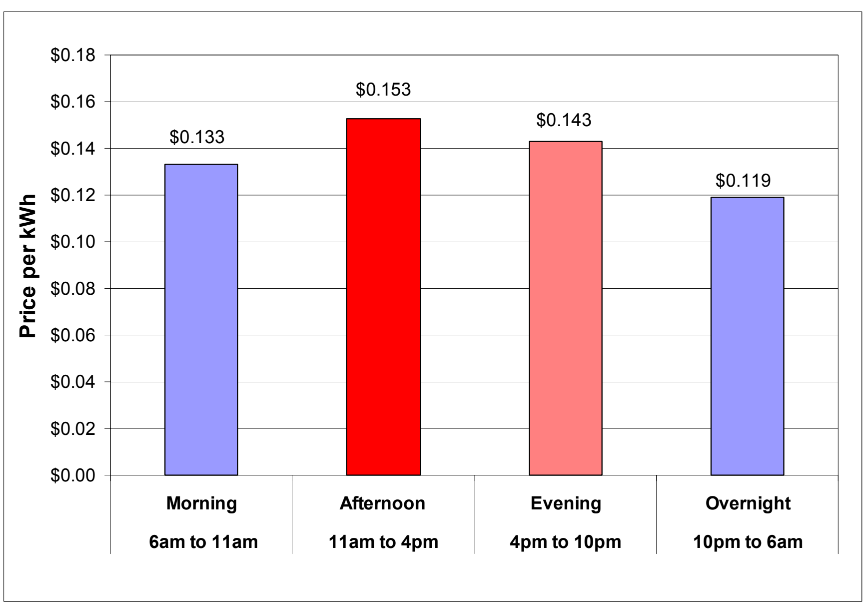
The two-year Pilot officially kicked off in the summer of 2003 as a partnership between NYSERDA, Westchester County, Consolidated Edison and ECONnergy. ECONnergy is supplying electricity for the Pilot, which is open to 150 of their customers in Westchester County, New York. Con Edison continues to provide transportation and delivery of the electricity. Each customer in the Pilot receives an advanced interval meter that measures electricity in 15-minute increments and is remotely read each night. Participants also receive a comprehensive, whole-house performance analysis through NYSERDA's Home Performance with ENERGY STAR® Program. In a test of sensor technologies, 10 selected participants also receive remotely-read sensors in their homes that measure indoor/outdoor air temperatures and runtimes on heating and cooling equipment.

To participate in the Pilot, customers first answer a web-based survey regarding electricity-consuming appliances and their willingness to shift load to lower-priced time periods. During the first two months of their participation, customers continue to be billed on ECONnergy's fixed rates, but also receive a "shadow bill" that shows what their bill would have been under the new variable rates. Armed with information on their hourly electricity consumption, and the daily cost of four energy time blocks available the day before over the Internet, customers can begin to plan how to shift load. The website provides daily, weekly and monthly comparisons so that customers can see the effect of their load shifts.

Electricity Rates: WSHP versus Utility

As a retail access provider in New York, ECONnergy can experiment with rates that do not require approval by the New York Public Service Commission (NYPSC). The new variable rates used in the Pilot are designed so that the customer is subject to the time sensitive variability of New York Independent System Operator (NYISO) Day Ahead Market (DAM) prices. As shown in **Figure 1**, the rates were organized into four blocks over a 24-hour period. The four blocks were chosen to allow the customer to experience (and take advantage of) variable rates, but in a manner less complicated than if the rate were to change every hour as in true real-time pricing. The time blocks chosen were morning (6am to 11am), afternoon (11am to 4pm), evening (4pm to 10pm) and overnight (10pm to 6am). The starting and ending times for each block will remain fixed all year, but the price within any particular block varies daily, depending on the DAM prices. The goal of this rate structure was to offer residential customers the choice of a

Figure 1. Variable Electricity Pricing Sample

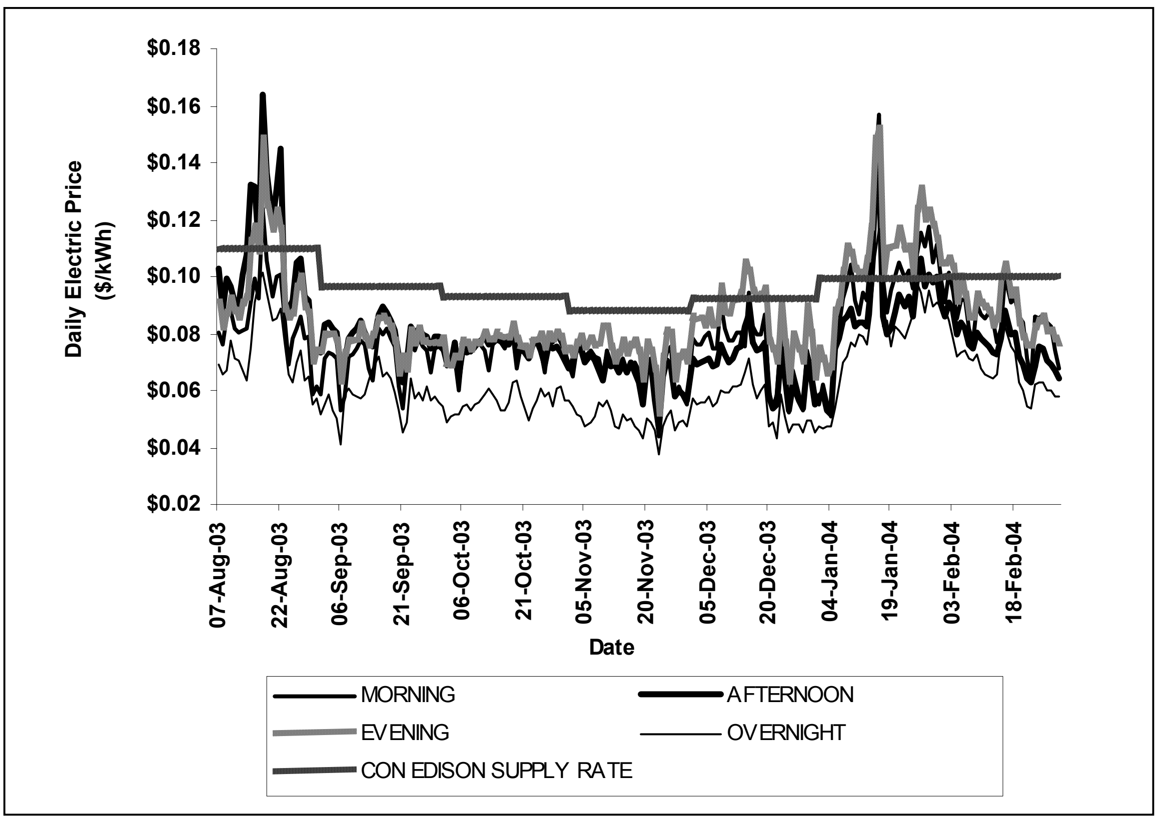


time-differentiated rate structure that more closely links wholesale and retail markets than the traditional utility flat rate structure.

Through a Program website, Pilot participants have access to their hourly electricity usage on a day-after basis. Using this information and the current block rates posted on the site, they are able to make the next day's energy use decisions. Customers are also notified via e-mail by approximately 4 pm of the price in each of the four blocks for the following day. The e-mail notification also includes helpful energy saving tips and information on the cost of running appliances. Since the Pilot's inception in the summer of 2003, pricing within any of the four rate blocks has varied widely. **Figure 2** shows the changing rates for each block from August 2003 through February 2004, along with the Con Edison electric supply rate for Westchester County over the same period. In the peak summer months of 2003, the rate differential varied as much as $0.07 per kWh, indicating the significant volatility in the wholesale price of electricity during periods of high demand.

The key conclusion to draw from this price analysis is that *minimal risk* can yield *attractive returns*. Pilot participants run the risk that prices will occasionally be higher than the utility tariff rate, but this risk exposure is only for limited periods. If the homeowner pays attention to changes in the variable rate and takes reasonable steps to shift load through a combination of automatic means (e.g., programmable thermostats, pool pump timers) and behavioral changes (e.g., running dishwashers and clothes washers when prices are likely to be lowest), they stand to benefit financially without a great deal of effort on their part.

Figure 2. Westchester Daily Electric Supply Prices

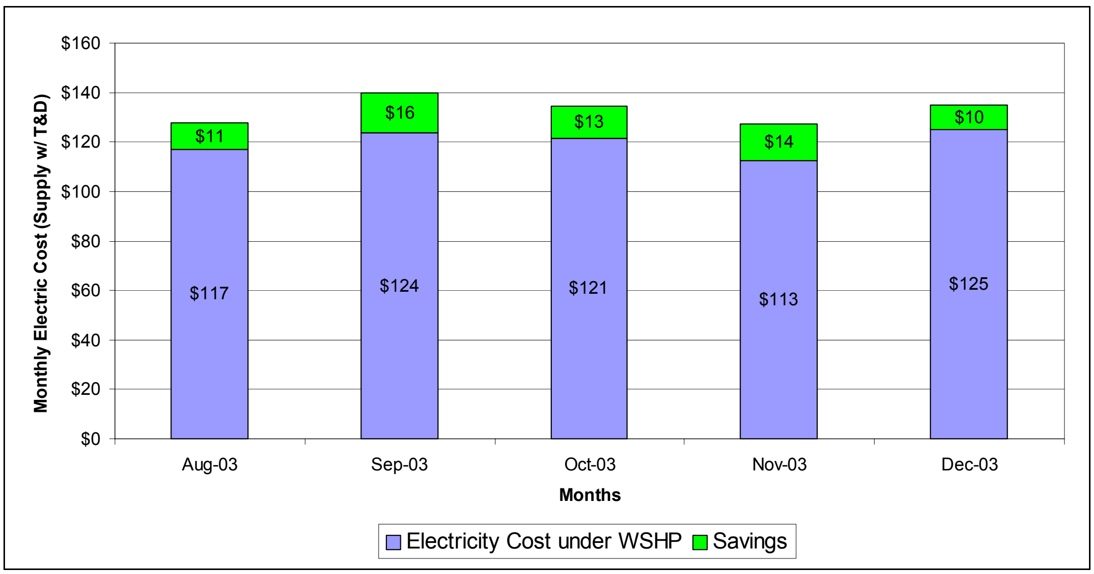


Projected Results

By early summer in 2004, we expect to be fully subscribed with 150 participants. Participants are in the process of scheduling Home Performance with ENERGY STAR® assessments, implementing assessment recommendations, receiving advanced meters, and adjusting to the variable nature of their new electric rates.

Once all participants are fully engaged in the Pilot, we predict that each participant will enjoy energy cost savings averaging about $650 per year, as follows. Electric and fossil fuel energy efficiency measures implemented as a result of a Home Performance assessment have resulted in an average annual cost savings of about $500[1]. We believe that the daily variable pricing will cause additional savings by prompting the homeowner to re-evaluate and change the way they use electricity, shifting their usage in response to price. These changes in behavior are projected to lower electric bills by an average of $150[2] per year, taking into account that part of the savings would be offset by the fact that the home will now have better insulation and more efficient heating and cooling as a result of the Home Performance assessment. **Figure 3** illustrates this projected price responsive savings for a Pilot participant's usage during the first five months of the pilot, August to December 2003.

Figure 3. Projected WSHP Participant Electric Savings from Variable Rates



[1] New York State Energy Research and Development Authority, Albany, New York. 2004. "Home Performance with Energy STAR Program Monthly Report for February 2004." The estimated savings is an average taken from a population of 4,260 households in which energy efficiency upgrades have been implemented.

[2] This is an average predicted cost savings for a home in Westchester County that has central air conditioning, electric cooking, electric clothes dryer, refrigerator, and pool. Model assumes a 17% shift in usage from morning and afternoon blocks to evening and overnight blocks, and has taken into account that savings derived from load shifting will be approximately 25% less in homes that have implemented energy efficiency recommendations as a result of a Home Performance assessment, compared to homes that have not implemented such upgrades.

The Benefits of Smart Home Data

We expect that the Westchester Pilot interval metering data and temperature/runtime data will benefit participants, rate makers and NYSERDA. Participants will receive timely energy use data, combined with variable rate signals, that we hope will spur them to use energy when it is cheaper and thus save money. Rate makers will be able to use the data to help them fine-tune rates so that consumers shift loads away from critical peak periods. And NYSERDA will be able to use the data to evaluate the effectiveness of their residential energy efficiency programs, perhaps modifying them to maximize energy efficiency and demand shifting, and even create new programs to benefit the ratepayers of New York.

Collecting Interval Data in Homes

To implement the Pilot, a combination of organizational, hardware and software systems were needed including:

- Cooperation from the local utility, Con Edison, and the NYPSC.
- An infrastructure to collect the interval electric-use data and prepare time-of-use (TOU) bills for each homeowner on a monthly basis.
- All the equipment necessary to collect and transmit revenue-grade data for billing.
- Additional equipment necessary to collect and transmit data from heating/cooling equipment.

It should be emphasized that if this pilot program had included only the collecting of data for the purposes of a study, the whole effort would have been much simpler. The part of this work that proved to be truly challenging and exciting was developing the technical infrastructure to produce revenue-grade, TOU utility bills and energy-use data within a heavily regulated industry.

Pilot Technical Specifications

During the early development of the Pilot, criteria were established first for the technical specifications of the metering equipment to be installed (the specifications for monitoring heating/cooling equipment came later):

- <u>All data available in 15-minute intervals.</u> This would allow almost any kind of data analysis—30 minute, one hour, demand, day-to-day—as desired, through the use of algorithms in the database after the data is collected.
- <u>Data must available on a daily basis.</u> Once a month would not be good enough for the homeowners or NYSERDA researchers to be able to quickly see the impact of consumer behavior changes, and real-time data collection would be more intensive than needed. Real-time data is important for activities such as control of a building heating/cooling system, but is not often needed for homeowners who only spend about $5-$10 a day for utilities.
- <u>Revenue-grade equipment.</u> Both the NYPSC and Con Edison required the metering equipment to be revenue-grade as defined by ANSI Standard C-12. This generally means

an accuracy of plus-or-minus one percent for electronic meters, which were used to develop the interval data. Also, the transmission of the data from each home to the meter-reading company could not introduce inaccuracies.

- Replicability. The ultimate goal of the Pilot was to implement similar approaches throughout the state. This meant using only off-the-shelf technologies.
- Use telephone lines. Operation in homes with no broad-band Internet connection was also important. Though it would have been easier to enroll only customers with broad-band connections, this would have severely limited the expansion of the Pilot until all homeowners obtain broad-band connections.
- Convenience. Homeowners need web-enabled access to data. Once the 15-minute interval data was collected and transmitted to a central database, it had to be accessible to each homeowner so that they could easily see—in a graphical format—how they were using energy and how much it was costing them.
- Cost. The Pilot started with about 150 homes, and reasonable cost was also important.

Metering Equipment Selection

The first phase of metering equipment selection involved choosing the systems needed to gather and transmit the revenue-grade interval electric data. We analyzed a wide variety of systems:

- Existing meters with redundant data-collection devices. Most electric meters used at homes are single-phase electro-mechanical meters that fit into a standard meter base and cost about $30-$40. We evaluated adding redundant interval metering equipment from a variety of companies by putting new meters with current transformers (CTs) on each home's electric service. These types of devices were not chosen because they were not currently approved by the NYPSC as revenue grade.
- New meters with pulse output. New meters could have been installed with a KYZ-pulse output and connected to a data recording system. While this type of system is used in many commercial installations, there are technical issues involving system accuracy that are addressed with relatively complicated software packages. MV-90 protocols are sometimes used, for example, to evaluate if the pulse outputs are being collected accurately, and means of estimating or error-checking are also required. The NYPSC and Con Edison have evaluated these types of systems on a case-by-case basis. For the purposes of the Pilot, it was decided that getting NYPSC approval for such a pulse-output system could be delayed until a later phase, as long as another technical solution could be found for this first phase.
- Existing meters with radio-frequency (RF) devices behind the glass. A trend in single-home metering is for utilities to retrofit their electro-mechanical meters with an RF transmitter inside the glass enclosure of the meter. These NYPSC-approved RF devices optically read the meter dials and transmit the reading to a collector. The RF devices transmit the data approximately a quarter of a mile. The most common utility practice is to use vans to drive through specific neighborhoods and to collect the meter data once a month from these RF transmitters by using receivers in each van. We quickly determined that it would not be practical to collect data daily with vans. A less common industry approach is to install fixed networks of receivers/transmitters on the tops of poles. Small

units can be placed on light poles or garage roofs in townhouse neighborhoods. Larger, more powerful units can be mounted on utility poles. Some of these units relay signals before connecting to a phone line or a cellular phone transmitter. Some pole-top units have a cellular transmitter in each unit. These options looked promising at first but were rejected for this pilot because they all require a minimum density of homes to make the infrastructure of receivers/transmitters cost effective. The first 150 homes were likely to be spread across hundreds of square miles in Westchester County. During future installations with greater participant density, one of these RF approaches could be much more cost effective.

- Powerline carrier (PLC) devices behind the glass. Similar to the RF units above, existing electro-mechanical meters can be fitted with PLC units behind the glass that send signals across utility power lines. This approach requires PLC receivers/transmitters every couple blocks, so the same hurdle of inadequate participant density prohibited this approach for this pilot.
- Advanced meters and telephone modems. The approach finally chosen used advanced meters designed for commercial use, combined with NYPSC-approved modems. The Schlumberger Sentinel meter and the General Electric KV meter both store interval electric data (e.g., each 15 minutes) in a specific tabular format called ANSI C-12.19 tables. Both meters have been tested by the NYPSC and by Con Edison and determined to produce revenue-grade data. Nertec, Inc. produces a device called a TeleReader that receives the ANSI tables from the Schlumberger or GE meters and transmits the data by modem over telephone lines. Since the modem does not affect the data in any way, the NYPSC-approved ANSI tables remain revenue grade. The TeleReader fits inside either meter and uses the current from a telephone line to power the modem while it transmits the ANSI tables over the same phone line. During this pilot we had an existing telephone line at each house spliced at a junction box and an extension telephone line run (usually outside the house) to the electric meter. This configuration worked so that at most houses no installation was required inside the home. There was also no need to replace batteries in the modem unit. Finally, the TeleReader is programmed to dial out only at night (after 2:00 am), and it checks first to make sure the line is not being used so that the homeowner is not inconvenienced. The interval data can then be stored and used each month for TOU billing. This approach turned out to be the best available at the time and has worked well. As advanced metering technologies—similar to all electronic/ telecommunications technologies—are changing and developing with new equipment every month, other good options are likely to exist for future installations.

Technologies for Monitoring Heating/Cooling Equipment

In addition to interval electric data, NYSERDA determined that it is important to supplement electrical data with other consumption data from devices such as gas meters, water meters, heating/cooling equipment or other systems. This process added smart home characteristics to common houses. Many smart homes have been built around the world, but most have been research or demonstration efforts. These often involve construction from the ground up and include high-speed communications systems that can be quite costly. While these types of smart homes may have been ideal for new homeowners, the Pilot was significant in providing the opportunity for learning how to bring advanced capabilities to existing homes.

Selecting Monitoring Points

At first it appeared that it would be relatively simple to monitor—and perhaps even control—many types of equipment in a home. Once the modem was installed at the meter and was operating every night, the plan was to “piggyback” on the electrical data transmissions with other data. The process, however, of developing a workable system was more complex. A wide variety of monitoring points were considered from gas meters to carbon-monoxide sensors to garage-door sensors. As the details of getting all these sensors to store data and communicate effectively over a common phone line began to develop, a short list was developed for the first phase of the Pilot. The points being monitored in the first 10 homes now include:

- Indoor temperature sensor. This allows for the comparison of energy used for heating/cooling with indoor conditions, including the effect of thermostat setback.
- Outdoor temperature sensor. This allows for the comparison of energy used for heating/cooling with outdoor conditions that affect heating/cooling.
- Cooling runtime. The compressor runtime of the central air-conditioning unit (or each stage in the case of two-stage units) is monitored. By knowing the tonnage of the cooling unit, the approximate energy use per 15-minute interval can be calculated in software routines at the NYSERDA database where all data is stored.
- Heating runtime. The furnace or boiler runtime (including each stage for multi-stage units) is monitored. By knowing the capacity rating and efficiency of the furnace or boiler, the Btus of heat added to the house per 15-minute interval can be calculated at the central database.

Retrofitting Existing Homes

The combination of hardware needed to meet all the original Pilot technical specifications above and to monitor heating/cooling systems was much harder to develop than anticipated. Equipment vendors across the US and Canada kept saying things such as, “wow, what a great idea; we’ve never done that before. When you figure out how to connect all the pieces, please call me back and tell me how it works. Our company might want to produce new products.” One person said, “I found a circuit diagram in an electrical engineer’s handbook. If you buy a handful of components at Radio Shack, you can solder together a unit that will do what you need.”

We looked at a variety of data loggers and other systems, but they almost all had problems that were hard to overcome:

- High first cost. Some systems were well over $1,000 each.
- No modem option. Systems either used broad-band only or required a manual download of data.
- No dial-out option. Only dial-in was available for some systems, which would inconvenience the homeowners.
- Incompatibility with sensors. Some systems, for example, were designed for pulse inputs from water and gas meters but would not take inputs from temperature sensors or run-time relays (without going to Radio Shack and being creative).
- Battery powered with no external power. Some systems would require battery replacement each year at each home.

After months of investigation, we found a system from the Obvius Corporation in Portland, Oregon, that had been manufactured for less than a year and that offered tremendous flexibility. Their AcquiSuite system incorporates data logging capabilities with flexible input options, Ethernet or dial-out communications, a software package that stores and graphs the data, and reasonable cost. Each AcquiSuite installation can use a phone-line extension from the same phone box used for the Nertec modem at the electric meter. As explained above, there may be other manufacturers that can provide similar systems now, but during the fall of 2003 when we were rolling out the first phase of the Pilot, it was a relief to find this workable technical solution.

Figure 4 shows a graph of the indoor temperatures from one of the Pilot participants. This temperature data will be used to evaluate the effectiveness of night-setback thermostat settings for both heating and cooling systems by analyzing the 15-minute heating/cooling use at various indoor setbacks for various outdoor conditions.

Figure 4. Screen Capture of Indoor Temperature Data

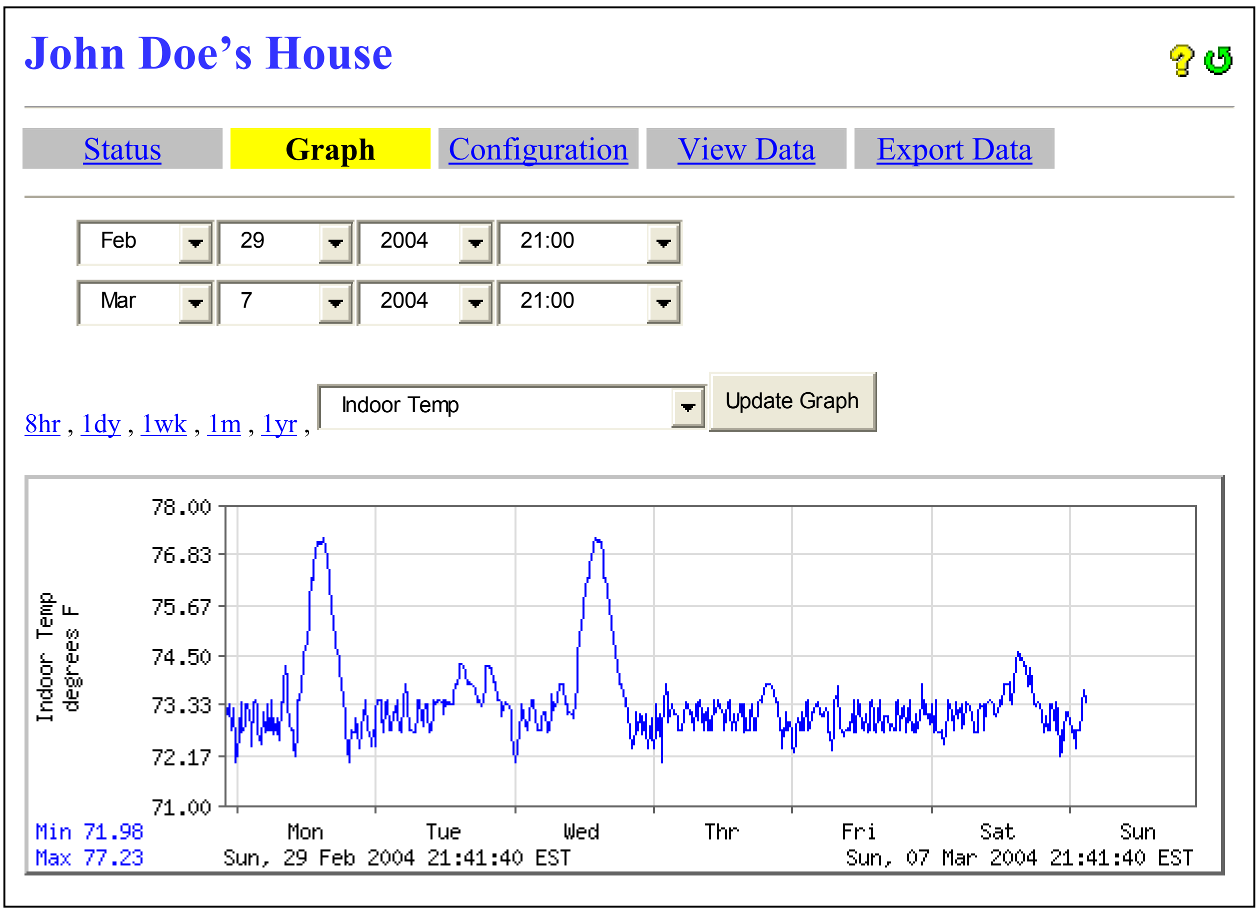
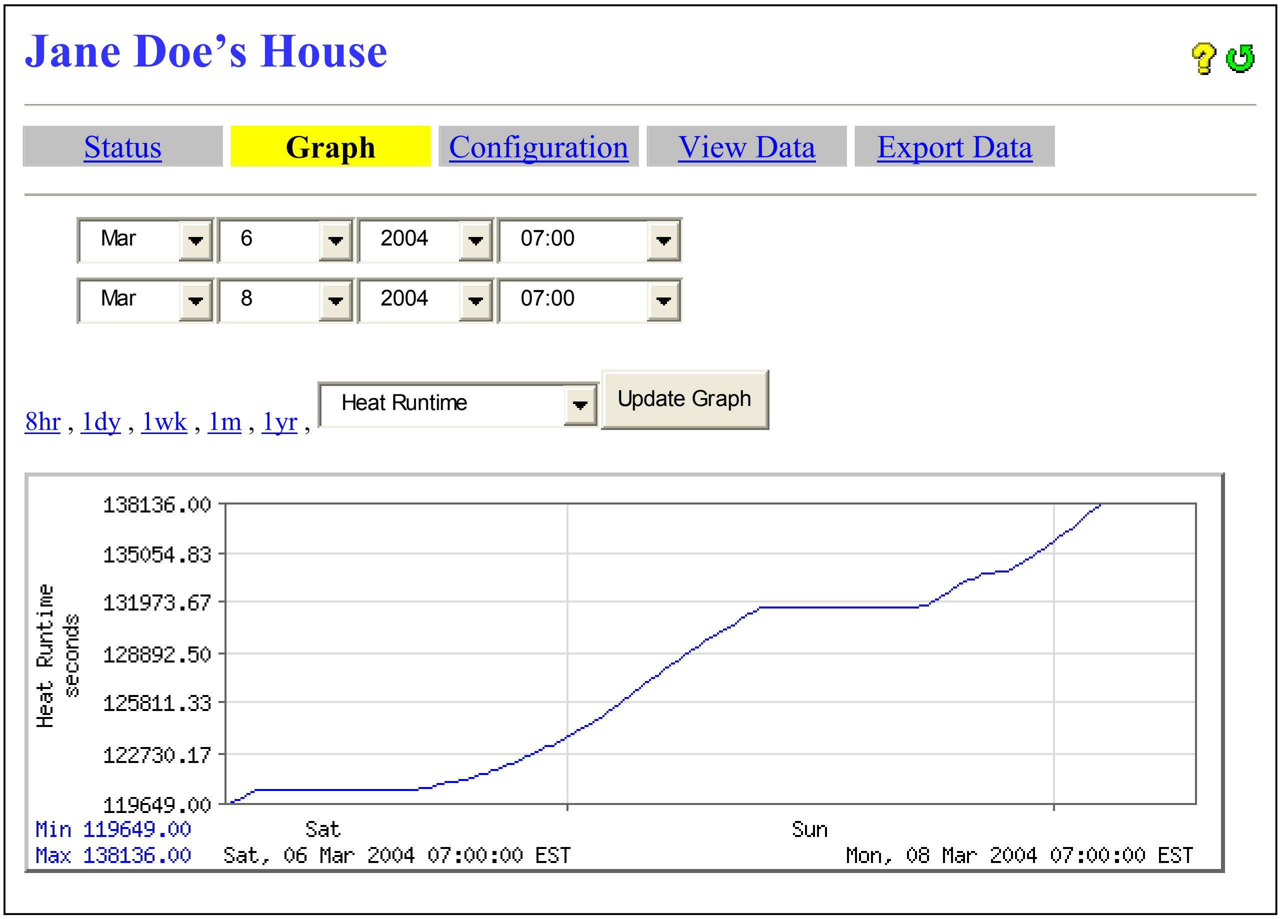


Figure 5 below shows how heating consumption is being tracked. This is one of several available graphical views in the software provided with the data recorders. The data is available over the internet.

Figure 5. Screen Capture of Heating System Runtime Data



Data can also be exported and analyzed in a spreadsheet. **Figure 6** below includes data from a participant's house during February, 2004, when the cooling system was not running.

Figure 6. Sample Data Export to a Spreadsheet

Time (US/Eastern)	Indoor Temp (Degrees F)	Outdoor Temp (Degrees F)	Cumulative Heat Runtime (seconds)	Interval Heat Runtime (seconds)	Cumulative Cooling Runtime (seconds)
2/28/2004 20:15	72.9	46.4	43,050	-	1.0
2/28/2004 20:30	73.0	46.3	43,229	179	1.0
2/28/2004 20:45	72.8	46.0	43,229	-	1.0
2/28/2004 21:00	72.9	45.6	43,418	189	1.0
2/28/2004 21:15	72.7	45.4	43,545	127	1.0
2/28/2004 21:30	72.6	45.4	43,598	53	1.0
2/28/2004 21:45	72.6	45.0	43,788	190	1.0
2/28/2004 22:00	72.6	44.8	43,992	204	1.0
2/28/2004 22:15	72.6	45.2	44,193	201	1.0
2/28/2004 22:30	72.6	44.6	44,398	205	1.0
2/28/2004 22:45	72.6	44.1	44,661	263	1.0
Average/Total	**72.7**	**45.3**		**1,611**	**-**

Conclusions

The installations at the first 150 homes are going well and are anticipated to be completed during the summer of 2004. The additional monitoring equipment in 10 homes is almost complete as of May, 2004. With persistence, it has been possible to get 15-minute data on electricity use, indoor/outdoor temperatures, boiler runtimes and air-conditioner runtimes in existing homes...without spending a fortune. The Pilot took longer than anticipated to get up and running, but it has been a success so far, including a number of New York State firsts:

- First residential remotely read, interval metering project.
- First non-utility, time-sensitive rate offering for the residential market.
- First integration of advanced metering, Home Performance with Energy STAR, and in-home sensor technology.

Over the next six months, NYSERDA and the WSHP team anticipate accomplishing the following:

- Completing all installations.
- Significant analysis of the 15-minute data being collected from participants.
- Possibly using the new data to refine more time-of-use residential rates.
- Determining how to expand advanced metering to other parts of New York State.