CONSUMER "WHITE GOODS" IN ENERGY MANAGEMENT

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Background:

Whirlpool Corporation (see www.WhirlpoolCorp.com.) is the world's leading manufacturer and marketer of major home appliances. Whirlpool is not a newcomer to energy technologies and earned the designation of ENERGY STAR® Appliance Partner of the year for four years in a row. Whirlpool has also received numerous other local, state, national and international energy efficiency and environmental awards over the last ten years.

With a commitment to energy aware appliances, Whirlpool Corporation launched a next-generation energy research project in 2001. Over the last several years Whirlpool has explored multiple home energy management concepts to demonstrate how appliances can play a role in future home energy management systems. The Advanced Electronic Applications group at the Whirlpool R & E Center continues on-going home energy management studies. To date this has included consumer focus groups, a demonstration of a total home energy management system concept, stand-alone Time-of-Use appliances, curtailable appliances, variable-demand capacity appliances, and a home energy monitoring system pilot.

As a result of this research, it has become apparent that energy intelligence within the electronic control is a more desirable approach than a simple on-off control. The motivations are from both the customer expectations point of view as well as from a technical perspective. Customer satisfaction will drive up the success of the energy program. Internal knowledge of the appliance/device components, process status, and capabilities, will enable effective energy management within the device. Upon receipt of an external energy signal from a utility company, the electronic appliance control should be empowered to respond appropriately based on a number of internal parameters.

As an appliance manufacturer, Whirlpool has continually refined and perfected the processes performed by residential appliances. The first goal is to provide consumers with the cleanest clothes, spotless dishes, and maximum convenience at reasonable cost. Secondly, the 'learning' from these on-going efforts extends to energy demand management. The focus of this document is to share our understanding of technologies and issues surrounding energy management of consumer "white-goods". We sincerely hope the information shared in the pages that follow provide value and mutual understanding to the utility industry.

Issues in managing energy consumed by 'White Goods'

A cross functional effort required

To realize benefits of energy management in 'white-goods', there are unique consumer issues to be researched. A solo effort has limitations compared to the benefits enabled by a cooperative effort of the energy industry, government, and consumer goods manufacturers with a focus on the needs and expectations of residential consumers.

How much energy can be managed?

Appliances are often referred to as the 2nd or 3rd largest energy user in the residential environment. This may be true, but looking at the sum total energy from a group of appliances doesn't imply that this energy consumption can be harnessed and managed with a single effort. Rather than looking at the aggregate sum total as if it were a single entity, we must look at each appliance individually. Each appliance type is used for a different purpose at different times of the day and we still need to meet the consumer performance expectations for each product. Each consumer may have differing interactions with the appliance and the consumer products involved. We need to understand how much of the appliance power can realistically be affected, at what time of day, during what phase of the process, and at what cost.

Consumer impact questions

- How will future extended residential energy management systems interact with the residential consumer?
- What is considered acceptable?
- What is considered as a lifestyle intrusion and forced compliance?

White goods as process-oriented devices

Previous work has focused on residential devices that do not interact directly with the consumer. These other devices (e.g. water heater, HVAC, and pool pumps) do not perform a consumer process on personal consumer goods. Consumer reaction and interaction issues must be studied relative to automated demand response and the interaction with a consumer appliance that, in turn, operates upon a consumer product. For example:

- ranges, ovens, and cook-tops process food
- refrigerator / freezer preserves food
- washer & dryer process clothing
- dishwasher performs a cleaning process on dishes

These consumer products (food, clothing, and dishes) have to be placed/removed by the consumer. An interrupted process could leave dirty dishes, dirty clothing, or food that has been improperly prepared or preserved. On a micro scale as compared with industrial customers, appliances execute critical processes. An interruption of the process could result in damage to a consumer product or unsatisfactory performance of the process.

A particular appliance device may be able to reduce some or all of the load assuming the control is allowed to have energy decision-making authority.

Cost justification

How do we justify the cost of involving appliances in energy management? The cost of development, higher product cost, and communication technologies need to be justified. The amount of energy that can be saved in a curtailment situation for example may not by itself justify installation of the infrastructure necessary to implement this single-purpose system. However, as an addition to a system that also addresses energy management for devices such as water heaters, pumps, and HVAC, the incremental cost may be reasonable.

"We'll control the appliance at the circuit or wall socket."

You may have seen this approach listed on presentation materials on home energy management systems. A simple approach has been successful for certain devices that can be energy-managed without consumer concern. However, most appliances should NOT be controlled externally via a simple power on/off means. Devices that perform a process on consumer goods cause both consumer and technical concerns. There are a number of significant issues regarding external appliance control including:

- Damage to consumer products. An example is causing laundry to soak for an excessive amount of time while certain detergents or additives (such as bleach) are in the tub.
- Restart issues - many products will not properly restart after they have been forced to pause by turning off the power. Most of these reasons are for safety requirements.
- There are safety issues in starting or re-starting a paused process in certain appliances. Some consumer processes require user intervention to start.
- Fresh water and additional consumable products such as detergent may be needed to continue after a process interruption.
- The process may not complete the task effectively if halted for an unknown duration.
- Consumer acceptance issues and concerns
- Causing an undesired temperature change would result in ineffective cleaning action in a wash process since temperature is a key element in removing certain types of stains.
- Inadequate temperatures may not safely cook food items.

Safety in energy managed appliance restarts

The electronic clothes dryer is a reasonable candidate for energy management since it contains a large heating element. You may recall from using your own clothes dryer that you must not only select the temperature/cycle, but also perform a second action to activate the process. If your power goes off, the dryer does NOT start again when the power is restored. You must activate the process again. Requiring the consumer to be there helps to ensure that a child has not crawled into the dryer in the mean time. Each appliance type may have a unique safety concern that must be addressed if its process is to be altered.

Convenience and the consumer override.

Assume the consumer has an important engagement in 30 minutes. An article of clothing needs to be dried right away. We have found that our customers expect the convenience of an override at the appliance, not at the other end of the house or over the internet. Following this guideline will encourage acceptance of energy managed appliances.

Consumer lifestyle impact:

Consumers have, over years of unrestrained energy consumption, grown accustomed to having energy when they desire it. Whirlpool Corporation conducted two consumer focus group sessions. One was conducted in the North suburbs of Chicago Illinois. A second was held in San Jose California. The moderator guided a discussion on energy management followed by sample screens of an energy management and consumption visibility tool.

"Headlines" from consumer focus group sessions:

- Primary motivations for consumer to save energy:
  - to "save money" (CA/IL)
  - to "do my part to protect the environment" (CA/IL)
  - to avoid blackouts or the threat of blackouts (CA)
- Energy is an entitlement - “I shouldn’t have to worry about it” (general)
- “We feel trapped into high energy costs.” (CA)
- Energy management may require a lifestyle change since consumers have to interact with appliance products.
  - Resistance to lifestyle changes (IL)
  - Already made energy-related lifestyle changes (CA)
- “We must decide how we want to spend our energy allotment today?” (CA)
- Until it hit’s their pocketbook significantly (> $40 / month), many consumers are not willing to change their lifestyle to manage energy.
- Being able to see and pinpoint areas of home electricity use was a welcome concept idea viewed as a consumer advantage. Response to the concept of a home energy monitoring tool:
  - “Would be useful for me to see energy use by device / room / etc.”
  - “A convenient consumer decision making tool, rather than forced compliance”
- “We want to save energy where it makes sense but don’t let it control our lives.”

One key that seemed to be apparent is that consumers don't want to think about energy or be forced to change their lifestyle. Consumers expect a comfortable solution with a minimum of inconvenience. Whoever is the bearer of news to the contrary, is subject to consumer disdain and ridicule. Note that a disgruntled residential utility customer is usually still a utility customer. However a disgruntled appliance customer has a more convenient choice to become an ex-customer. Therefore an appliance manufacturer has a lot at stake when introducing energy management concepts.

"Show me the energy..."

In the course of the focus group discussions, the participants realized that managing energy used by their appliances might imply a lifestyle change because of the potential impact on when they should use appliances. With this realization in mind, the consumers gave energy usage visibility a higher priority than automation of energy management. Consumers liked the idea of being able to see their home energy consumption broken down by circuit or appliance. This theme of education & visibility was a motivator for the energy monitoring system Whirlpool developed and is currently piloting.

Whirlpool Corporation energy research and pilot projects

Stand-Alone Time-of-Use Appliances

Whirlpool developed pilot appliances that have the daily Time-of-Use segments updated into the control. The consumer has the option of starting the appliance now, or, pressing the delay button to have the appliance automatically start at a time then TOU rates are lower. This interface is quite easy for the consumer to understand.

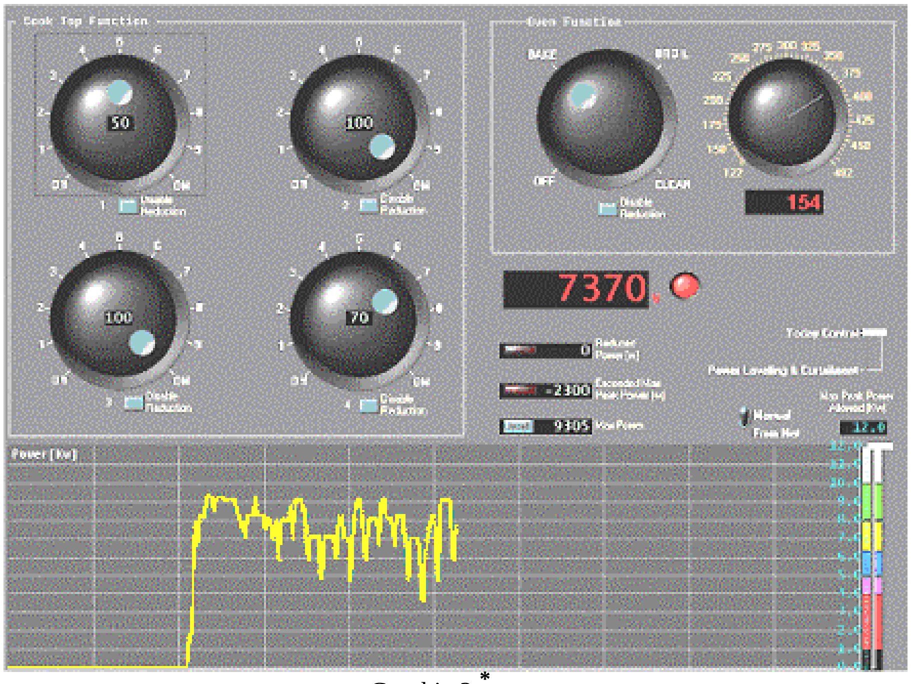
Several homes in the Benton Harbor area have been set up to utilize the local time-of-use electric rate and equipped with the pilot TOU appliances including a washer, dryer, and dishwasher. The control panel lets the consumer conveniently delay operation of their appliance until the energy prices are lower (off-peak rate). An LED lets the consumer know if the rate is currently on or off peak (see graphic 1 below). To delay until off-peak, the consumer can press a button and another LED illuminates to let them know that this appliance will start at a later time.

Graphic 1 *

Variable Power Appliances without performance compromise

Whirlpool has produced a **load-leveling range/oven** appliance prototype. Intelligence applied in the control algorithm can control the internal components in a way that energy peaks common in traditional control methods are eliminated. The concept prototype oven is controlled from a computer that is used as a replacement for the control board. This allows us to experiment with control algorithms and display additional information from sensors on the computer screen.

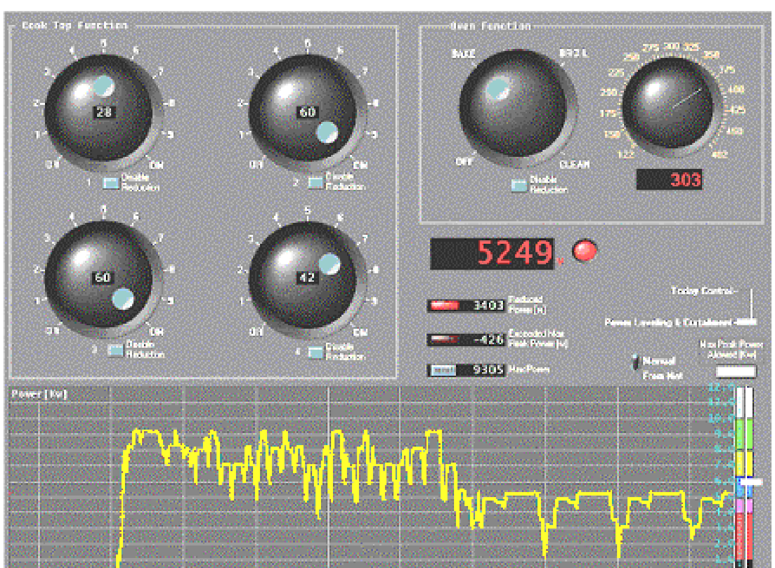
The oven can be operated in the historic analog mode where each burner applies power any time it is needed to bring the temperature back up to match the current user dial setting. On graphic 2 below we see the power use over time.



Graphic 2 *

All four burners are on at various levels. With no energy logic activated, the jagged graph is the typical energy profile of an oven and burners. In the screen-shot above we see the energy consumption is 7,370 watts. At this point the oven temperature has reached 154 degrees while pre-heating to a target of 375.

Graphic 3 below was captured several minutes after the oven was switched into an energy load-leveling mode. Here the heating element in the oven and the halogen burners are cycled by the microprocessor to ensure that all heating elements are never consuming power simultaneously.



Graphic 3 *

Note from the right half of graph 3 how this has flattened out the peaks although the oven cavity temperature continues to rise and has now reached 303 degrees. This load leveling has been achieved without negatively impacting performance. By sharing the energy appropriately in a round robin fashion, a managed level of energy is consumed with minimal consumer impact.

Graphic 4 *

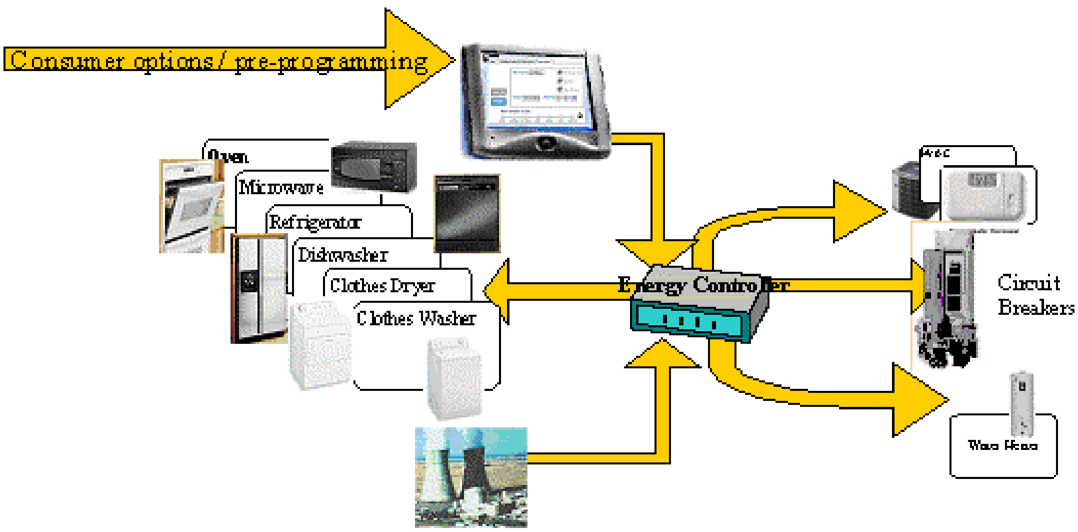
As shown in the photo above, you can visually see the flicker of the burner activations. However the actual heat to the pots on the stove is a steady source of heat.

An additional feature was implemented that allows the maximum energy consumption level to be set by the consumer or (in a communication enabled model) utility company. If, for example, the maximum energy level for this range is set to 3 kilowatts, the range will apply a similar but more restrictive algorithm to continue operating in a reduced power mode. There may be some consumer impact and additional consumer priority logic that comes into play. We could assume the items in the oven cavity are higher priority since the oven recipe may have strict cooking times. It may be more difficult to visually judge whether the cooking is complete in the oven as compared to the items being prepared on the cooktop. The consumer may opt to give the oven priority over the burners. This priority would maintains the oven's programmed temperature while the burners get less of the cycle time and may be operating at a reduced temperature.

The concept proven by this range prototype goes far beyond this single device and should be envisioned at a higher level. Rather than with a single appliance, the same concept could load-level multiple devices or the whole home. Multiple appliances could synchronize their energy demand to eliminate peaks and coordinate a maximum household consumption level. Much of this could be done with minimal or no consumer impact. For example, if the central air conditioner compressor start was delayed for several minutes until the freezer compressor completes it's cycle, consumer impact would be undetectable.

Total Home Energy Management concept prototype

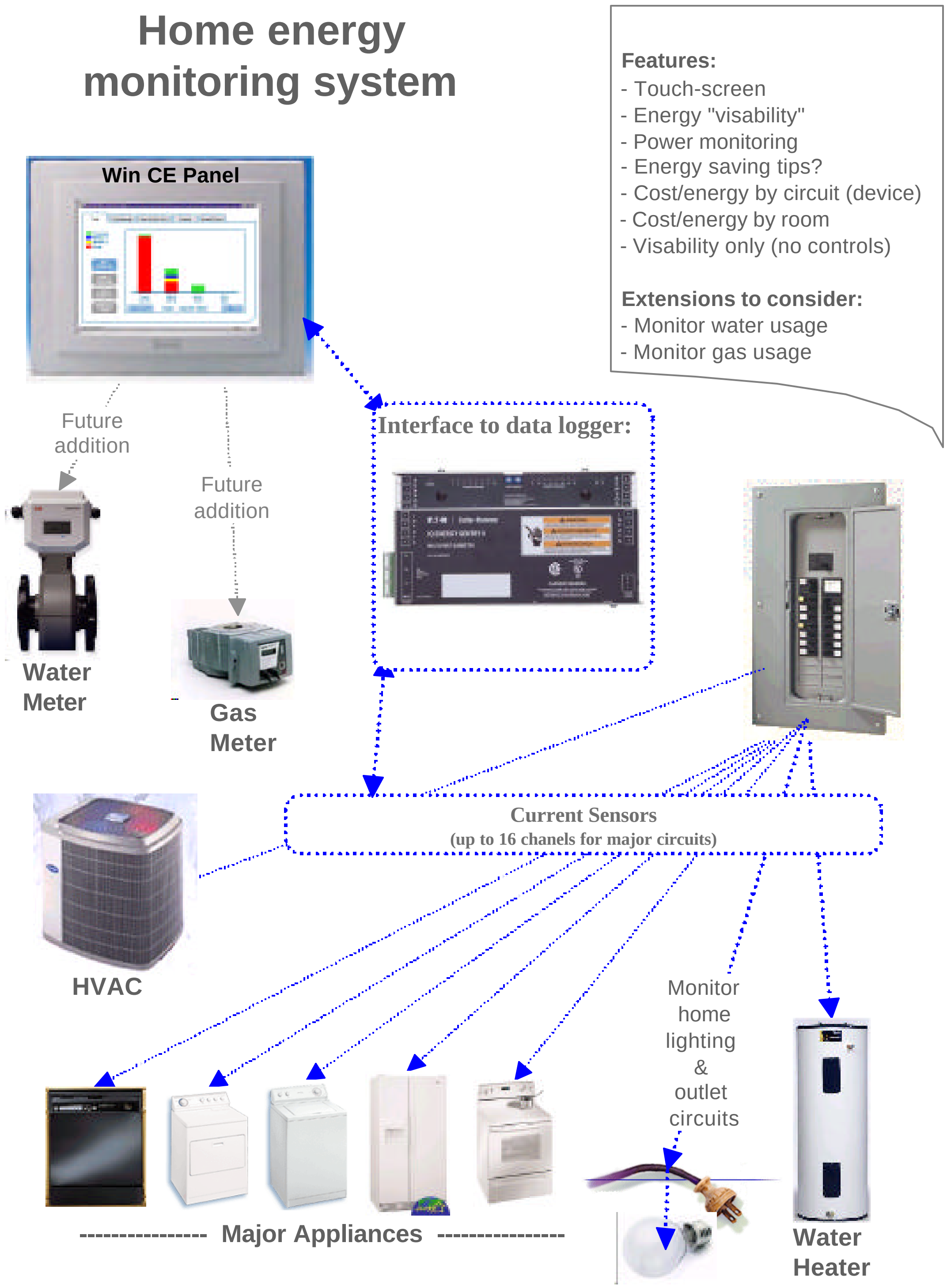
This project was conceived with a goal to manage total home energy utilizing concepts such as TOU, critical peak restrictions, maximum instantaneous demand limitations, and power curtailment issues from outside the home via a standard digital communications mechanism. Consumer research indicated that, among other things, being able to view energy consumption and history is desirable. A concept system was developed demonstrating consumer energy configuration, curtailment, TOU energy scheduling, usage peak avoidance, and visibility via a wireless web tablet. This concept prototype system was developed and demonstrated utilizing a thermostat, water heater, dishwasher, and clothes washer utilizing communications technology via standard residential electric wiring.



Graphic 5

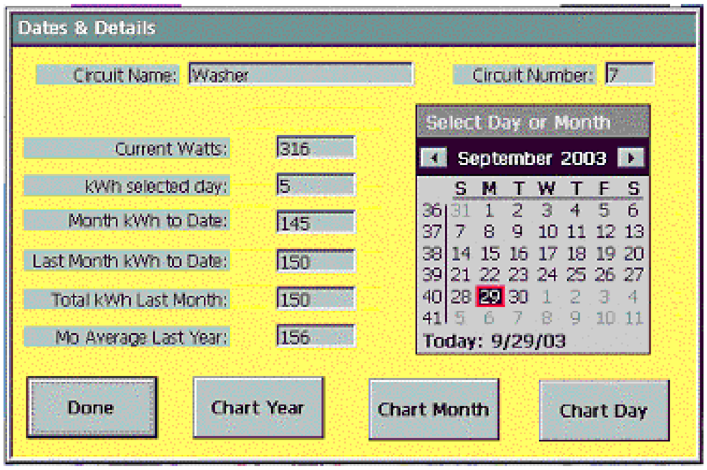
This system (see graphic 5) took advantage of a home network control system with a home gateway and broadband connectivity. An external signal could inform the system of several levels of energy restrictions. The consumer could pre-program the system to respond according to their desires. An external energy signal received by the energy controller indicated normal, restricted, or emergency energy status. The home energy controller could reschedule events such as rescheduling or pausing a dishwasher, changing modes in the washer, change the thermostat setting or turn off the water heater according to the consumer's pre-programmed preferences.

Woodridge Place residential energy management and visibility pilot



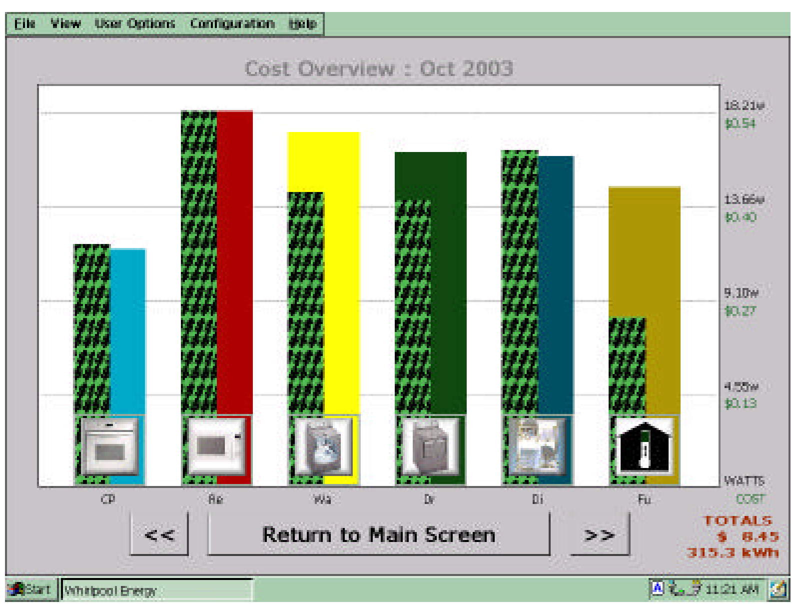
Graphic 6

Whirlpool Corporation developed and placed an energy monitoring system in residential homes in Benton Harbor as an energy pilot program scheduled to operate for several years (2003-2005). The technology entails a comprehensive energy use reporting and tracking screen utilizing sub-metering devices and a 12-inch color touch-screen monitor. The system (see graphic 6 above) gives consumers a visual display of current and past energy consumption. The ability to see and manage where energy dollars are consumed allows consumers to implement their own form of manual energy conservation. Knowing the monthly cost of each appliance provides detail to enable smart energy decisions as shown in several sample screens below.



Graphic 7

Consumers may select a calendar day, month, or year as shown in graphic 7 above. Comparisons and trends lead toward managed results.



Graphic 8

The example screen in Graphic 8 above both compares the different appliances, as well as showing the impact of a time-of-use rate.

Data will be gathered from this pilot over the next several years on both sub-metered consumption histories as well as in consumer feedback interviews. This should confirm or deny the focus group feedback regarding the desire to see energy consumption as a way to manage personal energy consumption related cost.

Future plans may include the addition of water and gas metering onto the monitoring system. This will allow better correlation between appliance gas, water, and electric consumption.

So how can we involve white goods in energy management?

Now that we've covered some of the research, issues, and consumer impact concerns, let's look at how appliances can successfully manage energy. Consider an example where a smart dryer, with energy management logic in the electronic control, can respond to a demand management signal. In this implementation the intelligent appliance control can respond by taking whatever measures are feasible considering the capabilities of the internal components and the current state of the machine process. The clothes dryer control may turn off only the heating element representing over 6,000 watts leaving the 450-watt drum motor running. This could be in response to either a curtailment signal or a grid stability (spinning reserve-type reasons). Internal dryer moisture sensors extend the tumble time appropriately to compensate. A simpler approach for a curtailment period may be to go ahead and finish the current process, but disable the start of another process until after the curtailment or price peak ends.

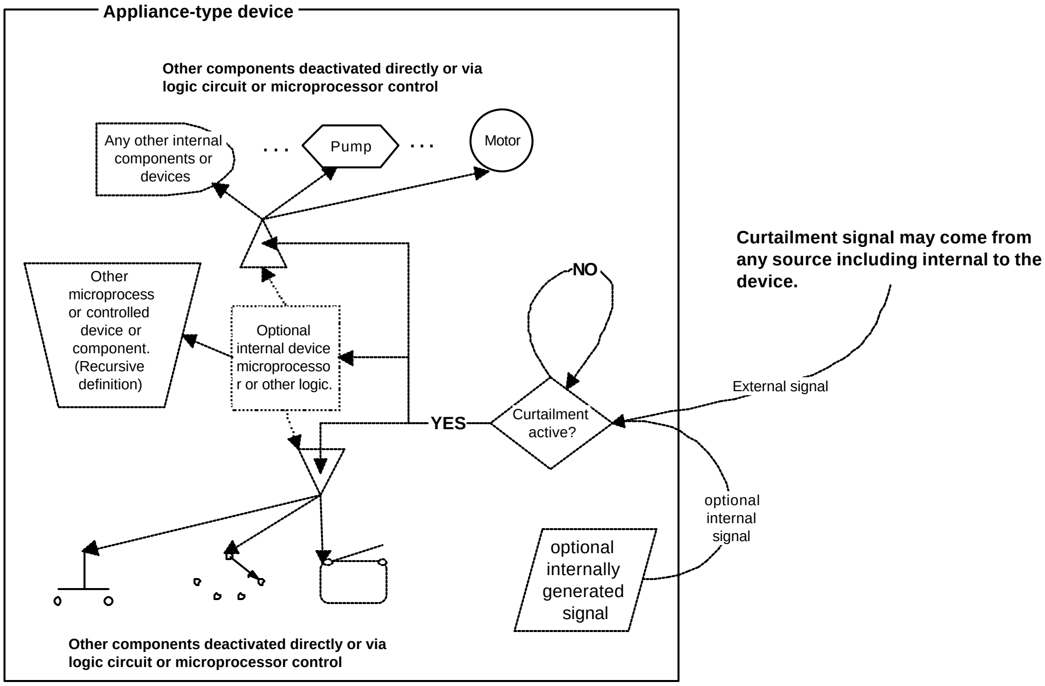
This scenario lets the device control maximize energy saving while minimizing consumer disruption and eliminating damage to consumer products. The electronic appliance control can apply internal knowledge of the device components, process status, and capabilities, to manage energy effectively. The control system managing the appliance process can control the pumps, motors, heating elements etc to temporarily reduce energy in a way that is acceptable to the consumer. (See graphic 9 below) In this way, the appliance manufacturer is able to achieve an energy load reduction in an appliance without a complete halting of the consumer process.

Upon the detection of an energy issue or receipt of a demand management signal, the options left to the discretion of the imbedded device control module may include:

- Restrict use of the device
- Limit certain capabilities of the device
- Wait until later to activate the device
- Do nothing due to risk of damage to consumer goods.

The amount and type of energy savings depends on:

- Options selected by the consumer
- Current machine state
- Type of internal components under the control of the microprocessor
- The severity of the energy restriction communicated to the device



Graphic 9

In the example of a clothes dryer, the dryer control responds as appropriate for the current state of the device. For example:

- turn off the internal heating element that can consume up to over 6,000 watts
- reduce the heat/temperature in the dryer cavity
- automatically extend the drying time to compensate for the reduced energy mode
- allow consumer override at the control panel

Characteristic features in managing appliance energy

The term energy management can take on various meanings depending on the context of the conversation. At one time we were only referring to making the device perform its process using less energy. Current discussions involve a more orchestrated approach to handle the changing parameters involved. Research into ways to make the appliance use less energy in general will continue, while this discussion is focused on a list of advanced appliance energy management characteristics. These characteristics may be addressed individually, or a single product may implement more than one of these characteristics:

(A) Grid Friendly

The instant load shedding for a brief period (several minutes). This could be a simple Boolean (Yes/No) signal.

Appliance response:

- continue process but trim major load such as heating element

- may be able to halt the entire process for a short period of time
- appliance control may override at a certain duration point to ensure the success of the process

(B) Load Leveling / Peak Leveling

Achieve level energy consumption by controlling or eliminating peaks (spikes/surges) in load consumption (as in the load-leveling oven discussed earlier). This is done by coordinating the energy use at the component level. Load leveling may not reduce the total energy consumed in kWh. However by maintaining a level and predictable energy demand, we reduce the maximum power that must be available to meet the temporary peaks.

Load leveling can be sub-categorized into several levels of complexity

B1 - Internal - such as in the load-leveling oven
B2 - External coordinated among devices or homes and communities
B3 - Coordinated peak limitation. The concept where a home is required to keep the maximum consumption below a given level (for example < 5kw).

(C) Curtailment

Method to reduce electric capacity requirements during periods of peak demand. These peak capacity management issues vary by region and season occurring a relatively small number of times during the year. Curtailment (as opposed to grid friendly) assumes a longer duration that may extend multiple hours. Communication to the appliance could be Boolean or multi-level. Appliance response could include:

- Appliance will not start a new process during this time (unless the consumer overrides the curtailment)
- A running process is switched to a lower power mode (for example a lower drying temperature on fabric or dishes)
- Disabled options such as defrost, ice-maker or ice crusher in a refrigerator

(D) Time-of-use (TOU)

- delays start of appliance until off-peak time-of-day unless user overrides manually
- reminds consumer of the price impact or TOU restriction

Some final thoughts and data:

A residential appliance in the 'White Goods' category may not be an ideal candidate for a stand-alone solution to residential energy management. Appliance energy isn't the low hanging fruit that is as easily managed as a water heater. But white goods can represent a significant contribution according to the statistics:

- With very few exceptions, every home in America has one or more appliances. (101.3 out of 101.5 million households have a refrigerator)
- Appliances average roughly 1,771 watts each (avg. of Dishwasher, Microwave, Refrigerator, Clothes Washer, Clothes Dryer, Cooking, & Freezer)

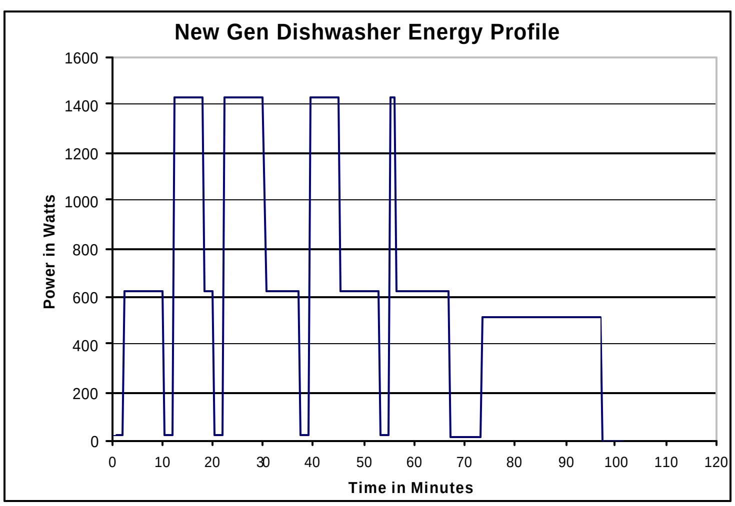
- Each home has an average of 4.67 appliances

Consider the list of appliances represented in the charts below.
(Household data taken from 1997 U.S. Gov. census reports.)

Total US households	101,500,000		
Appliance	**Typical Watts**	**% of U.S. Households w/this Appliance**	**Total U.S. Appliances of this type ...**
Dishwasher	1400	50	50,750,000
Microwave	1500	84	85,260,000
Refrigerator	900	100	101,500,000
Clothes Washer	500	78	79,170,000
Clothes Dryer	4500	55.9	56,738,500
Cooking	3000	65	65,975,000
Freezer	600	33	33,495,000
Totals:	**12,400**		**472,888,500**
Average Watts:	1771		
Avg #Appl/Home:	4.659		

Table 1

Applying the percentage of homes with each appliance type to the total number of U.S. households approximates the total number of appliances of each type as shown in the rightmost column of table 1 above. Note that the "Typical Watts" column does not represent a steady state in every case. While most of the run time of a refrigerator tends to be a consistent state, the dishwasher changes over time as demonstrated in graphic 10 below.



Graphic 10

The amount of load reduction possible depends on the current state of the dish cleaning and drying process and the capabilities and sensors contained in the specific model.

In the chart below (table 2) we've applied the typical kWh consumption of each appliance to arrive at an approximation of the annual kWh attributable to each type of appliance. Note that these are approximations as the actual consumption is affected by variables such as model, age, location, and household type in addition to the average weekly/monthly use of each appliance.

Appliance	Total appliance kWh --- Typical kWh ea home --- Per Month	 Per Year	 | --- Est kWh/Yr --- U.S. Appliances
Dishwasher	22.10	265.20	13,458,900,000
Microwave	15.03	180.36	15,377,493,600
Refrigerator	54.17	650.04	65,979,060,000
Clothes Washer	14.35	172.20	13,633,074,000
Clothes Dryer	126.19	1,514.28	85,917,975,780
Cooking	117.33	1,407.96	92,890,161,000
Freezer	64.83	777.96	26,057,770,200
Totals:	**Totals:**	**4,968**	**313,314,434,580**
Average Watts:			
Avg #Appl/Home:			

Table 2

(Monthly usage has been averaged according a to a variety of studies.)

If we are concerned with curtailable energy, table 3 below is a quick look at the typical wattage represented by this same group of major appliances. The chart below applies typical wattage represented by each appliance type to the census information.

Total US households		101,500,000		
Appliance	**Typical Watts**	**% of U.S. Households w/this Appliance**	**Total U.S. Appliances of this type ...**	**Representing wattage of**
Dishwasher	1400	50	50,750,000	71,050,000,000
Microwave	1500	84	85,260,000	127,890,000,000
Refrigerator	900	100	101,500,000	91,350,000,000
Clothes Washer	500	78	79,170,000	39,585,000,000
Clothes Dryer	4500	55.9	56,738,500	255,323,250,000
Cooking	3000	65	65,975,000	197,925,000,000
Freezer	600	33	33,495,000	20,097,000,000
Totals:	**12,400**		**472,888,500**	**803,220,250,000**
Average Watts:	1771			
Avg #Appl/Home:	4.659			

Table 3

From this we see the actual total number of watts represented by typical household appliances in the U.S. This is an interesting number that may be of limited value in itself although it represents what could, to some extent, become a managed load. To create an estimation of the actual load at any given moment for curtailment purposes requires a lot of additional data including day of week, type of household, season, geographical location, etc.

This is a calculation left up to a particular utility company who has the geographical data and consumer profiles for their region.

Perhaps the notable value is relative to the grid-friendly appliance concept that could enjoy participation by most of the appliance categories. This is a scenario where a mass of appliances could reduce load immediately for a short duration of several minutes upon detection of a grid instability situation. This mass load reduction could address part or all of what is currently handled by spinning reserves.

"How long would it take?"

A concern is often voiced regarding appliances in energy management. The concern may be phrased something like ... "But think how many appliances it would take have a notable impact." One of the key points from these charts is a comparison of the chart above (table 3) with the chart below (table 4). This gives us an indication of the rate of turnover in home appliances.

	Potential ability to bring additional watts under energy management control Yr 2002 sales	 Total Watts
	6,206,800	8,689,520,000
	13,311,400	19,967,100,000
	9,744,300	8,769,870,000
	7,744,900	3,872,450,000
	5,401,900	24,308,550,000
	5,337,700	16,013,100,000
	2,535,000	1,521,000,000
Totals:	**50,282,000**	**83,141,590,000**

Table 4

Based on the sales figures from Appliance Magazine for the year 2002, new appliance sales in one year's time represents over 10% of the total wattage consumed by appliances in the U.S. Without going into a lot of fine detail, we can see that a significant number of appliance watts could potentially be brought under energy managed control reasonably quickly. With annual sales at roughly 10% of the total appliances in use, this seems to show a potential for reasonably quick implementation of a major energy management program.

Financial concepts for consideration:

For a 'white goods' manufacture, it seems difficult to quantify the recovery of additional development costs and product costs in energy management innovations. There is little by way of a feedback loop to prove or disprove the effect. Was revenue generated because of energy features? Or, would the consumer have purchased this model anyway because of other features? Even rebate data doesn't necessarily find its way back to the manufacturer. The more advanced energy concepts as mentioned in this document require additional up-front investment. Cost/value issues arise in any internal discussions regarding energy features. While financial concepts are not the focus of this discussion, here are a few thoughts:

- Consider a rebate structure whereby the consumer submits a $30 rebate card. When this is processed, the consumer receives $30 and the appliance manufacturer receives $20. This revision to the traditional appliance rebate would provide incentives and a mechanism to recoup the cost of the more detailed design modifications required for these advanced energy management concepts.

- Regional annual rebate to the appliance manufacture relative to the number of appliances on the grid containing a grid-friendly technology.

- Other financial incentives where the appliance wattage brought under energy management controls, is utilized to compute value.

About the Author:

At the Whirlpool Corporation Research & Engineering Center, Gale Horst is the Energy Focus Leader of the Advanced Electronic Applications department. In this role he has studied various energy management concepts in the utility industry, participated in U.S. DOE discussion groups, and delivered a number of working concept prototypes including a total home energy management system, a curtailable appliance prototype, and the Whirlpool residential energy monitoring system. The mission of his group is to identify where Whirlpool technologies can deliver energy management solutions through advanced engineering and electronic technology.

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