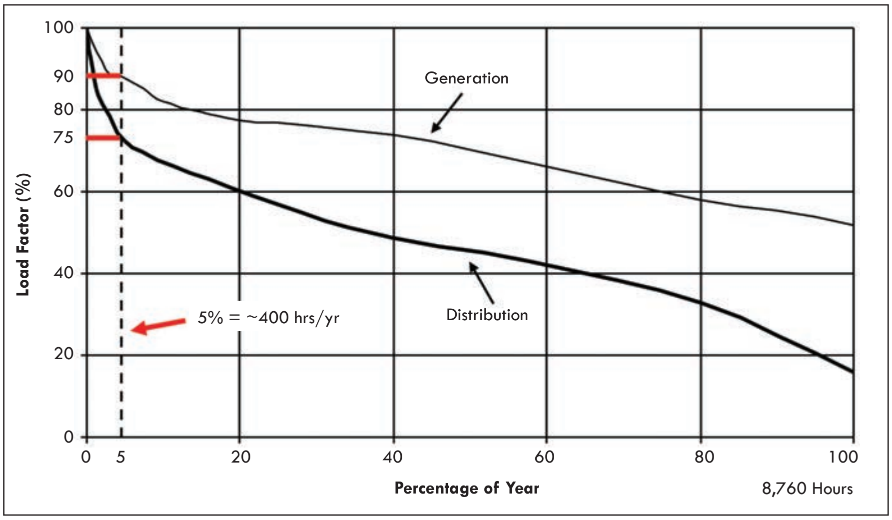

Figure 1: Value of demand response: lower peak demand reduces infrastructure investments. Hourly loads shown as fraction of peak, sorted from highest to lowest. Twenty-five percent of distribution and 10% of generation assets (transmission is similar), worth 100s of billions of dollars, are needed less than 400 hours per year.

Appliances & the Smart Grid

By Tom Catania

Led by ENERGY STAR's application to major home appliances and lighting, the ENERGY STAR label became one of the most recognized brands in the public inventory of market transformation tools. Manufacturers and retailers routinely trade consumers up to the ENERGY STAR-rated models and leading consumer magazines and the media encourage consumers to select these, typically, more highly featured and more expensive products.

Public utilities and state governments invested billions of dollars in consumer incentives, encouraging the choice of the most efficient products. Since 2005, the federal government has offered substantial manufacturer tax credits for specified major appliances produced in the United States that exceed ENERGY STAR levels.*

From Product to System Efficiency

Figure 1 demonstrates the substantial percentage of the nation's power generation, transmission and distribution infrastructure that exist to serve about 5% of the hours in the year—often referred to as "peak demand."

The United States utility grid is an aging $700 billion machine that will require trillions of dollars of new investment over the coming decades. However, the timing, degree and environmental friendliness of that future investment can be positively affected by a more predictable and evenly spread energy demand curve.[1]

Arguably, adding a material amount of episodic renewable energy to the grid can only be cost effective if the grid becomes both less sensitive to the variability inherent in renewable sources such as wind and solar, and if those episodic generation sources have "stored demand" available to be served when wind and solar are most economically available.

When a device connected to the grid consumes power has become as significant for our national energy policy as *how much* power that device consumes. Smart and connected appliances, broadly deployed, would be one of the nation's most cost-effective ways to reduce peak demand and enhance the value of renewables on the grid. An analysis by the appliance industry estimates that virtually the entire projected growth in peak demand expected for 2030 in the United States could be avoided with full implementation of smart appliances.[2]

Early in the development of the concept of a "smart" utility grid, appliance manufacturers began to ask themselves what effect a smarter grid and efforts to take

*In 2009, as part of the government's effort to stimulate the economy, a Cash for Appliances program drove consumers into the stores to purchase appliances to lower their monthly utility bills, and to purchase other items in multiproduct retailers such as Sears, Lowes, Home Depot and Best Buy. The appliance industry had a strong first half in 2010 when most states implemented the Cash for Appliance program, but the housing industry and general economic recovery continued to lag and industry performance declined in the second half of 2010.

demand response from commercial and industrial applications to individual residences might mean for home appliances.

In 2006, for example, Whirlpool Corporation did a demonstration project in conjunction with the Pacific Northwest National Laboratory that showed that a smart dryer could detect, without human intervention, frequency variation on a utility grid that would presage a power outage, and virtually instantaneously, interrupt the 6,500 W dryer heating elements for up to 10 minutes, while keeping the clothes tumbling and unwrinkled. This was an important capability because critical peak events on the grid that are associated with power outages are typically short in duration—10 minutes could mean a lot to the grid, but matter little to the consumer. Absent readily accessible demand response, to ensure the reliability of the system, utilities must maintain substantial power generation even when it is not needed as a "spinning reserve" that can be brought immediately online if the aging grid hiccups.

If new demand response capable appliances could be developed that reduce peak demand and could also substitute for more expensive and wasted spinning reserves, the societal benefits of this capability could exceed the value of an incremental improvement of the efficiency of an individual product in a home.

Importantly, and strategically for the home appliance industry, creating this new more socially valuable capability in its products also presented a better long-term business proposition than the expensive pursuit of taking out the last watt of energy from already efficient products. After the latest round of energy standards are in effect and the ENERGY STAR levels associated with those products are put in place, in some products the incremental energy efficiency improvements at the margins save consumers only pennies per month. Even before the newly agreed standards and ENERGY STAR levels go into effect, *Figure 2* illustrates the declining consumer cost savings at the highest efficiency levels. Although it varies by product for manufacturers, the cost of achieving bleeding edge efficiencies can be exorbitant.

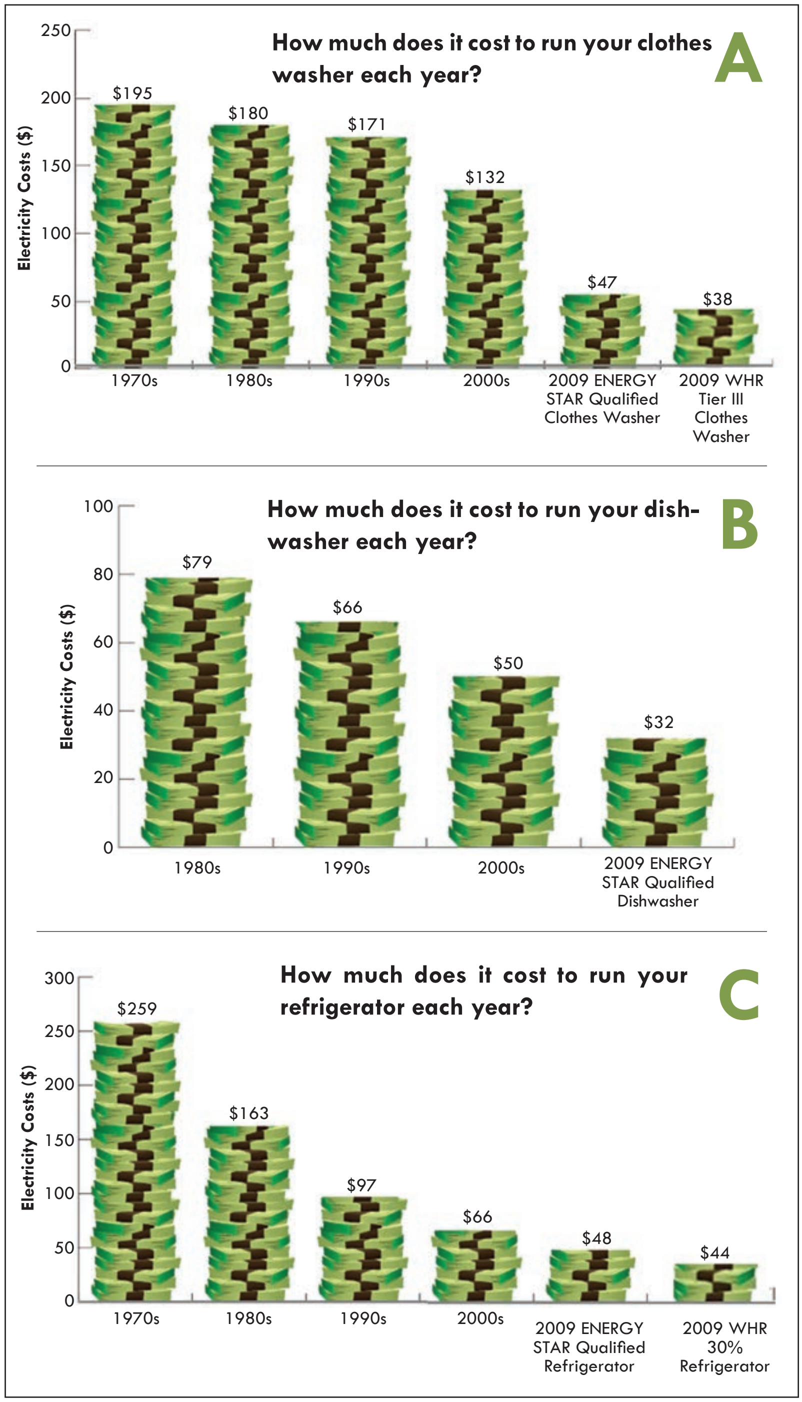

Figure 2: Consumer cost savings decline at the highest efficiency levels. The cost of achieving bleeding edge efficiencies can be exorbitant.

Performance compromises are already beginning to be seen in some super-efficient dishwashers and clothes washers, which are leading to some understandable and, in some cases, bizarre consumer compensatory behavior. Some consumers who find food deposits on dishes are aggressively pre-rinsing dishes, thereby using much more water than any of today's minimally qualifying appliances. Other consumers, seeing no visible water in their super-efficient clothes washer, have taken to throwing in some extra water or overdosing the product with detergent.

Smart Appliances and Standards Negotiations

Pacific Northwest National Laboratory assisted the home appliance industry in providing objective analysis of the relative value of demand response as compared to standalone product efficiency. PNNL's analysis was relied

History of Appliance Regulation

During the last 30 years, the appliance industry has experienced substantial consolidation, concentration and globalization of manufacturers, with similar changes and consequent increases in the negotiating power and leverage of major appliance retailers. Unfortunately for manufacturers, the concentration of suppliers has occurred simultaneously with exploding demand in developing markets. This has had the unusual effect of causing increasing input costs even during the severe recessionary environment.

The deteriorating external economic environment forced the industry to reexamine whether business as usual—continuing to agree to move all products at some future date to the efficiency levels of whatever today's best available technology is—could be economically sustained. In fact, as the data was beginning to show, the societal value of bleeding-edge appliance efficiency was declining, and it risked a variety of unintended consequences (including seriously compromised product performance).

Unlike some industries, U.S. appliance manufacturers have pushed for national appliance energy standards for decades and have performed a series of voluntarily negotiated rulemakings that set ever more stringent energy, and eventually water, efficiency standards for appliances. These were tough negotiations, but the industry had the benefit of a favorable National Appliance Energy Conservation Act, which explicitly required a balancing of consumer, environmental and industry impact before a standard could be adopted. Furthermore, the Act, in addition to preempting state appliance energy standards, required the Department of Energy to take into account the cumulative regulatory burden on the industry of having to invest in meeting standards for more than one product at once.* Regardless of whether the DOE was led by a Republican or Democrat in the White House, neither side of the negotiations over energy efficiency standards (and there were often several "sides" represented) tended to view a failed negotiation as a preferable outcome.**

Energy and water efficiency standards became a fairly predictable part of the business planning cycle, and a manufacturer that successfully innovated on this dimension was rewarded in the marketplace. The government, and the quasi-governmental utility sector, also played an important role in enabling an economically sustainable business case for investments in appliance energy efficiency.***

*Some examples of major regulatory burdens affecting the appliance industry include: the Montreal Protocol (required refrigerator manufacturers to change refrigerants and insulating blowing agents multiple times); a variety of new energy standards (differing in substance and timing among a variety of countries); U.S. Clean Air Act and other environmental air and water quality regulations that imposed factory costs; local, national and international material content restrictions and codes such as ROHS, REACH and extended producer responsibility obligations like the EU's Waste Directive.

** There was one "just say no" episode during the history of appliance regulation. Following the Republican sweep of the House of Representatives in the mid-1990s, the industry succeeded in persuading Congress for a period of time to defund the DOE's ability to implement the refrigerator standard previously passed into law. The industry was split in testimony before the Congress, and it almost led to the demise of the Association of Home Appliance Manufacturers.

*** There were substantial variations among appliance product categories in the ROI for high efficiency products. Clothes washers were probably the biggest success story with consumers being willing to pay substantial premiums for the newest high efficiency models because, in addition to costing less to operate, they had more capacity and were gentler on clothes as the agitators were eliminated. Refrigerators are at the other end of the value spectrum, and manufacturers suffered from the cost of improved energy performance, and the Montreal Protocol-based retooling requirements related to moving away first from ozone-depleting substances and later from materials that contributed to global warming. The environmental benefits for refrigerators were beneath the appliance skin, and only manifested themselves to consumers in the form of thicker walls and doors.

on by all parties to the standards negotiations throughout the process.

It completed an extensive analysis that showed that for all the major appliances (which were a part of the then-current round of standards negotiations in 2010) the societal and environmental value of demand response capability in these appliances exceeded, by at least 5%, the value of traditional individual product efficiency.[3]

Again, to make a long story short, the industry and the energy-efficiency advocacy community (in exchange for agreeing to a new future set of mandatory appliance standards, changes to test procedures and extended energy tax credits) agreed to jointly petition the Environmental Protection Agency (responsible for policy direction of the ENERGY STAR program) to incorporate demand-response capable, connected appliances into the ENERGY STAR program.[4]

This agreement, and the EPA's subsequent decision to apply the concept in the refrigerator ENERGY STAR specification, is a simple, but powerful, public policy. As was mentioned earlier, refrigerators are caught in a terrific cost-price squeeze.† This is a product category where every penny of cost is significant, and where the products are already extremely energy efficient. Today's 24 ft^3 (0.68 m^3) refrigerator is as efficient as an 8 ft^3 (0.23 m^3) model from 1950, even though many energy-consuming features have been added in that same time period.

Refrigerators that meet the demand response/connected specification can still earn the ENERGY STAR designation even if they are 5% *less* efficient than a non-smart refrigerator. The product cost savings associated with the lower level of energy efficiency help manufacturers pay for adding the new capabilities.[5]

Refrigerators are an excellent product to inaugurate the new connected capability because the system benefit will

†Several U.S. refrigerator factories have been closed in recent years, substantial production has moved to Mexico and antidumping actions have been filed against foreign importers of refrigerators into the United States.

be offered with virtually no impact on the consumer. Connected refrigerators will come into the home with a built-in deferral of their 500 to 700 W daily defrost function outside of the nation's traditional peak demand times of day. Every home with any sort of broadband capability (90% of U.S. homes today) will enjoy this benefit regardless of whether their grid is smart or their home has a smart meter.

As utilities begin to dynamically communicate with the homes on a daily basis, offering time of use rates, requesting and financially rewarding consumer responses to critical peaks by changing their consumption, and as more renewable generation or electric vehicles require more sophisticated demand response—these smart refrigerators will be ready to adapt their performance to these future requirements.

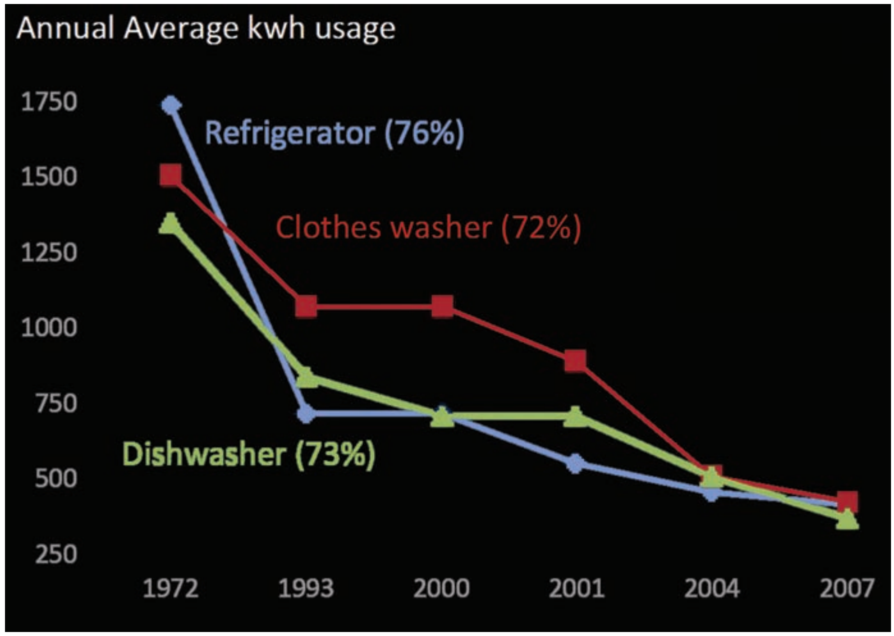

Figure 3: On the current path of efficiency, there are diminishing returns.

It is expected that utilities, who most benefit from the better system management that comes from more the more ubiquitous demand response that connected appliances can offer, will be willing to pay for it. Specifically, utilities are ready to begin to shift their existing and long-standing efficient appliance consumer incentives to the new products with the new connected capabilities.

Connected Appliance Prize

Assuming at a future date 100 million U.S. households have a connected refrigerator, what would that mean to the utility grid (and ultimately the consumer since their monthly bills support the system whether it is efficient [green] or not [brown]?). At a minimum, the grid would have 50 billion W of defrost energy that are no longer required during peak—every day! In a future world of smart appliances on a smart grid, those same 50 billion W become available to renewable generation sources. The consumer's home can indicate to the grid that when you have a renewable resource ready, my refrigerator is ready to use that resource to defrost itself.

A connected dishwasher can communicate that its owner has only specified that the dishes need to be cleaned and ready by 6 a.m. even if the dishwasher was loaded at 6 p.m. The owner chose to have the cleaning occur at either the least expensive, or the greenest, energy time of the evening or early morning.

The connected refrigerator can tell you if a child has left its door ajar, or that your water filter is ready to be replaced, and invite you to accept the manufacturer's reduced price replacement deal. The connected refrigerator will tell your service technician what is wrong with it and guarantee they arrive with the right part, the first time.

The connected dishwasher will notice you selected the hot dry function and explain to you the annual electricity usage and cost that is associated with that choice. In the unhappy event that a snowstorm knocks the power out in your area, your smart home with smart appliances will shorten the outage period. The smart appliances will wait to restart for a sufficient time after the utility restores power. Therefore, the utility can flip the "on" switch sooner knowing that the devices in the home will not surge back into operation immediately and take the grid down again.

In short, connected appliances, gestated through visionary public policy and clever engineering, but borne of system and industry necessity, will soon be delivered into the arms of what is hoped will be an adoring consumer.

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