by Ian H. Rowlands, Eric Mallia, Julia Shulist and Paul Parker

Developing Smart Tools for Householders:

Making the Smart Grid Work

Electricity services are needed throughout Canadian homes – to power appliances, to provide lighting, to manage room temperature. Residential consumers in the country now account for 32 percent of all electricity demand, and that share has been rising in recent years.[1] Indeed, consumers have come to expect electricity to be readily available and reasonably priced.

While consumers continue to have a need for reliable electricity supply, citizens recognize that there are significant sustainability challenges associated with the same. Systems comprised of large power stations that transform fossil, uranium, and water resources into electricity and then transmit the electricity over long distances to end-users generate environmental externalities (e.g, greenhouse gas emissions), economic challenges (e.g., capital cost overruns), and social tensions (e.g., disputes over land use). A more distributed electricity system – one with a broader portfolio of "fuels" (including renewable resources) generating power closer to loads – is a vision that is becoming increasingly popular; more than that, this emerging vision is being turned into reality in various parts of this country.

In this new kind of electricity system, the residential customer plays a different role. Instead of being a passive – and largely uninformed – consumer of electricity, he or she becomes an active energy manager, making decisions that can serve to advance, simultaneously, a suite of "private" goals (e.g., lower costs for the consumer) and "public" goals (e.g., increased energy security and decreased environmental footprint for

1 Data are from 2009 and are taken from Natural Resources Canada's Comprehensive Energy Use Database (http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/list.cfm?attr=0).

IAN H. ROWLANDS <irowlands@uwaterloo.ca> is a Professor in the Faculty of Environment at the University of Waterloo. He is also the Associate Director (Global Initiatives) of the Waterloo Institute for Sustainable Energy.

ERIC MALLIA is a business manager for Cross-Chasm Technologies (Waterloo, Ontario), a consulting firm specializing in hybrid and electric vehicles. He holds a Master's degree in environmental studies from the University of Waterloo.

JULIA SHULIST is a research assistant and Master's student in the Department of Environment and Resource Studies at the University of Waterloo.

PAUL PARKER is a Professor in the Faculty of Environment at the University of Waterloo. He is also a member of the Board of Directors of REEP Green Solutions.

the community). The consumer, however, can only play this new role if he or she has access to relevant information, as well as the tools to act upon that information accordingly.

The Value of Feedback

Thus, critical to the success of a transformation to a more sustainable electricity system is householder access to feedback regarding their electricity use in ways that are meaningful and useful. One way of doing that is to provide a goal-setting tool – that is, give householders the opportunity both to set their own electricity goal (be it a reduction, a stabilization, or a limited increase in the amount, cost, or carbon footprint of their power use) and to monitor their progress in real-time.

Experience in other parts of peoples' lives suggests that such goal-setting could have positive impacts – fitness activity targets, weight reduction plans, and household savings aims are three examples. Goal-setting can serve to keep individuals focused on improvement, to help them stay disciplined, to provide them with a sense of control, and to sustain their better behaviours over the longer term.

Past experiments in energy studies have revealed that goal-setting holds promise. One study, for example, found that householders who were assigned a goal and received frequent performance-related feedback reduced their natural gas consumption by 12 percent as compared to those without a goal. Another concluded that householders conserved more electricity if they were assigned a difficult conservation goal (a 20 percent reduction) than if they were assigned an easier goal (a two percent reduction). Finally, in a different study, a group of participants were given an appliance-specific goal, a target for electricity usage for their laundry machine. In the end, they reduced their electricity usage by 20 percent on average.[2] Sufficiently intriguing, these results encourage a comprehensive investigation into goal-setting to advance residential conservation and demand management ambitions.

As part of a pilot project in partnership with Milton Hydro Distribution, Hydro One Networks, Energent (a Waterloo-based energy management solutions provider), the Ontario Power Authority, and the Ontario Centres of Excellence, researchers at the University of Waterloo have the opportunity to explore householders' use of an appliance-specific home energy goal-setting tool. The pilot project involves the participation of 25 households in Milton, Ontario (located approximately 50 kilometres west of Toronto). These households are using the "Energy Hub Manage-

Figure 1

One household's goals (both overall and component)

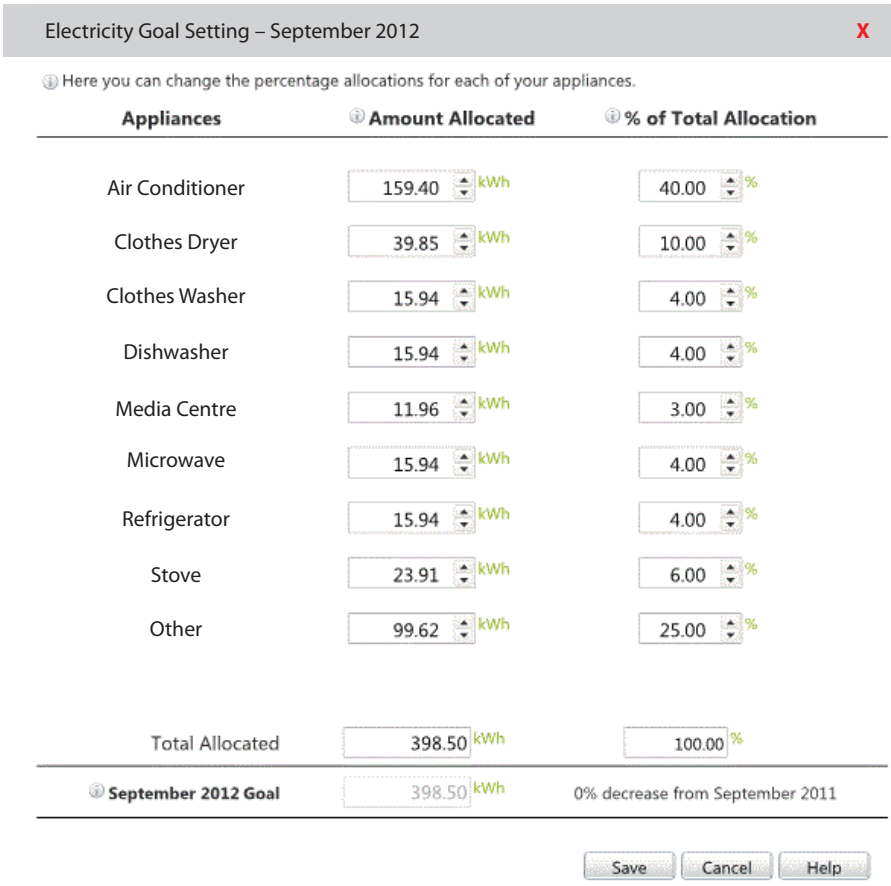
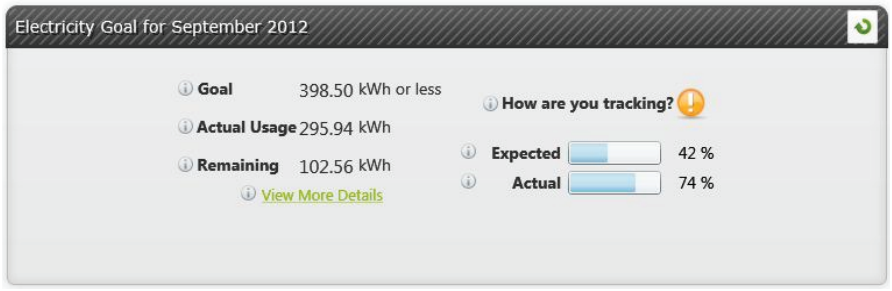


Figure 2

One household's progress towards its overall goal



2 J. H. Van Houwelingen and W.F. Van Raaij, "The Effect of Goal-Setting and Daily Electronic Feedback on In-Home Energy Use," *Journal of Consumer Research* (Vol. 16, 1989), pp. 98-105; L. Becker, "Joint Effect of Feedback and Goal-Setting on Performance: A Field Study of Residential Energy Conservation," *Journal of Applied Psychology* (Vol. 63, 1978), pp. 428-433; and L. McCalley and C. Midden, "Energy Conservation through Product-Integrated Feedback: The Roles of Goal-Setting and Social Orientation," *Journal of Economic Psychology* (Vol. 23, 2002), pp. 589-603.

Figure 3

One household's progress towards its component goals

Appliances	Allocated	Actual Usage	% of Allocation Used	Tracking
Air Conditioner	159.40 kWh	150.66 kWh	95 %	
Clothes Dryer	39.85 kWh	42.14 kWh	106 %	
Clothes Washer	15.94 kWh	2.92 kWh	18 %	
Dishwasher	15.94 kWh	4.52 kWh	28 %	
Media Centre	11.96 kWh	29.06 kWh	243 %	
Microwave	15.94 kWh	4.90 kWh	31 %	
Refrigerator	15.94 kWh	15.19 kWh	95 %	
Stove	23.91 kWh	9.90 kWh	41 %	
Other	99.62 kWh	123.93 kWh	124 %	

ment System," a web-based energy management tool that allows them to monitor their disaggregated electricity consumption in real-time and to control that same consumption on the basis of their priorities and constraints – a patent-pending optimization model generates their own "ideal" energy schedule that they can access via their own web-based dashboard from wherever convenient.[3]

The Goal-Setting Tool

Included in the system's toolkit is a goal-setting tool. These pilot participants have the opportunity to establish a monthly electricity goal for their household. Using the previous year's equivalent month as a baseline, they first decide what metric most concerns them – is it energy consumption in terms of kilowatt-hours or energy cost in terms of dollars and cents or carbon impact in terms of kilograms of greenhouse gases? They then decide how a household-wide goal will be distributed across the major electricity end-uses in their home. Figure 1 shows one household's goal – both overall and individual components – after these steps have been completed.

It is, of course, one thing to set a goal, and altogether another to monitor it in order to try to meet it. Deployment of smart meters in Ontario means that real-time electricity consumption information is now available. The challenge is to package that mass of data generated in ways that are meaningful to the busy residential customer. As part of their Energy Hub Management System, pilot participants are able to access real-time information that shows them whether or not they are on track to meet their goal. Figure 2 shows how one household is provided with a succinct summary of their situation, while Figure 3 "drills down" into the details, revealing which end-uses are contributing to their success or failure in meeting their own goal.

Staying with this particular household, a review of its initial targets (Figure 1) and its subsequent usage (Figure 3) reveals how the tool could catalyse conversations regarding residential electricity usage. Because this household's end-use consumption data are not available from the previous year, default estimates are used as the starting points. In this case, above-expected consumption by, in particular, the media centre might encourage further discussion by the occupants regarding their overall conservation strategy.

Indeed, experience across the 25 pilot participants' homes is proving to be invaluable to advance learning – to understand better how to make technologies work practically "on the ground" and to appreciate further which tools individuals will select from the proverbial "energy management toolkit" in order to use the system and hopefully to advance energy sustainability. A couple of other households' experiences with the goal-setting tool reveal the different ways in which it can incent a culture of conservation.

Two Households' Experiences

One household – a couple with two young children living in a relatively small row house – is using the tool to understand their overall consumption, in both energy terms and cost terms. They set monthly goals and then check back periodically. While they have not always achieved their goals, they have experienced a steady decrease in their total amount of electricity consumed: between March and June 2012, their monthly consumption went from 528 kWh (March) to 377 kWh (June).

This was in spite of summer being the typical peak demand season as air conditioners are turned on and as the number of cooling degree days grew from 12 in March to 171 in June.[4] Therefore, the tool may have encouraged them to take action.

A second household – a couple with two older children living in a larger detached house – is using the tool to understand better how their various end-uses are contributing to their overall consumption. When

3 See <www.energyhub.uwaterloo.ca>.

4 Degree day calculations are for Toronto Pearson Airport (approximately 35 kilometres northeast of Milton, Ontario) and are taken from <www.degreedays.net> (with a base temperature of 15.5 degrees C).

5 This value is for a 2008 model and is taken from Natural Resources Canada data <http://oee.nrcan.gc.ca/equipment/appliance/10333>.

6 Ontario Energy Board. <www.ontarioenergyboard.ca/OEB/Consumers/Electricity/Your%20Electricity%20Utility>.

they login to the portal, they "drill down" to the individual appliances, both to monitor power consumption at the end-use level and also to distribute their overall goal differently among diverse end-uses. The tool, for instance, appeared to help them manage the electricity consumed by their clothes dryer (one of the appliances subject to a goal shift): while an average "newer" model might be expected to consume 76 kWh a month,[5] their clothes dryer only used 45 kWh a month in both July 2012 and August 2012.

Next Steps

This project is lending further support to the belief that different people will use energy conservation and demand management tools in different ways. While we can be told that there are "average values" for households' electricity behaviour patterns (e.g., consumption of 800 kWh a month with 18 percent of that during peak periods),[6] there will be relatively few "average households." Instead, occupants have different characteristics, and they interact amongst themselves in different ways. As such, it is critical to explore how innovative tools are actually used by people, families, and groups in real-life situations. With such learning, technology can be developed and deployed in ways that allow us to move to a more sustainable future. MW

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