AUTUMN 2008 VOL 8.1

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enerInfo BUILDING

CBEEDAC, sponsored in part by Natural Resources Canada via the National Energy Use Database Initiative, is housed at the University of Alberta.

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enerInfo Building is published three times per year by the Canadian Building Energy End-Use Data and Analysis Centre (CBEEDAC) at the University of Alberta.

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CANADIAN Building Energy End-Use DATA AND ANALYSIS CENTRE
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TECHNOLOGY AND ENERGY SAVINGS

Often, technological improvement is accompanied by anticipation of a reduction in the negative impact of our actions on the environment. For example, the incorporation of new technologies in the appliances we use everyday and the adoption of energy-efficient appliances are seen as ways to reduce household consumption of energy. Two recent studies by CBEEDAC researchers examine issues related to the adoption of new technologies, and show that the expected results in terms of reduced environmental harm are not always realized.

David Ryan and Denise Young question the implementation of environmental policies that are motivated by the energy savings determined solely from engineering calculations. They show that the energy savings objectives based on engineering results are seldom achieved because the ultimate behaviour of the agents who make the decision to buy or use the new technologies is not considered.

Vera Brencic and Denise Young investigate the effect of the adoption of time-saving innovations on household energy consumption. While time-saving appliances are often more energy intensive than alternative technologies, the total effect on household energy consumption depends on the activities to which the extra time that is made available from using these technologies is reallocated, and on whether these activities are energy-intensive.

On a different note, another recently completed CBEEDAC study contains an extensive analysis of energy demand models and modelling. David Ryan and André Plourde review energy demand models that have been used to estimate responses to energy price changes, and examine their evolution, advantages and disadvantages.

These studies are briefly summarized in this newsletter. Copies of the full reports are available from CBEEDAC and will shortly be available for downloading from our soon-to-be-released updated website.

Recently Completed CBEEDAC Projects

Modelling Energy Savings and Environmental Benefits from Energy Policies and New Technologies

A number of policy initiatives that are aimed at reducing energy use have targeted the adoption of new technologies, such as compact florescent light bulbs, energy-efficient models of appliances, and programmable thermostats. However, the energy savings that are anticipated from these technologies, typically based on engineering calculations, often fail to fully materialize. This is likely to be due, at least in part, to a failure to take into account the behavioural responses of households and businesses to these technologies. Individual agents make decisions regarding the purchase and intensity of use of new technologies on the basis of economic incentives, and these are not fully included in engineering calculations. As a result, policies often do not attain the benefits that were expected.

In this research project, standard egineering approaches are outlined, and (empirical) microeconomic modelling approaches that can be used to more fully evaluate the expected outcomes of environmental policies that target the widespread adoption of new technologies are examined. The engineering approach focuses on calculations such as Life Cycle Costs (LCC) and the Payback Periods (PP), which are relatively easy to implement. Specifically, engineering information on energy-use characteristics is combined with energy price forecasts and capital cost information in order to determine whether or not it makes economic sense for (a product embodying) a new technology to be purchased by the typical consumer. If the technology is economically viable, then the difference between the energy use characteristics of the new and old technologies is used to forecast the impacts of widespread adoption of the technology on energy demand and the associated environmental impacts.

However, these calculations do not reflect certain aspects of the potential end-user's behavioural decision regarding the purchase and use of an appliance, and these factors may modify the expected environmental benefits. For example, the reasons why an agent is considering purchasing a new appliance, the relationship between the intensity of use of an appliance and household characteristics, the characteristics of the currently-used appliance, and the economic constraints faced by the household, can all influence appliance choice and utilization. Therefore, the LCC and PP approaches are unlikely to accurately reflect the true costs and benefits to potential users of new technologies, and hence the potential energy savings are likely to be overstated.

A better picture of realizable energy savings can be obtained by supplementing engineering studies with an analysis of the decision-making processes of households and firms. Unfortunately, human behaviour is difficult to model, and in many cases the limited availability of household- or firm-level data often makes such attempts difficult. Nevertheless, there are cases where economic studies are feasible, as the authors illustrate for the adoption/use decision for programmable thermostats in Canada. In this case, analysis that takes account of human behaviour reveals a substantial difference between the energy savings that could hypothetically be achieved from this new technology and the energy savings that are actually realized.

Time-Saving Innovations and Canadian Household Energy Use

This research project analyzes the effects of the adoption of time-saving innovations on the energy use of households. Two effects can be distinguished. First, the use of energy for basic household needs and maintenance (cooking, cleaning) is likely to increase, as time-saving technologies (such as dishwashers and microwave ovens) are usually more energy-intensive than other options. Second, the reallocation of the extra time made available from the use of these innovations will also influence household energy consumption. This time can be reallocated in a variety of ways: to leisure activities or household chores, to energy-intensive activities, or to less energy-consuming activities. Data from the Canadian Survey of Household Energy Use from 2003, as well as the prices of electricity and natural gas collected by CBEEDAC, are used to explore the extent to which time-saving technological devices have entered into Canadian household use and, via regression analysis, to examine the impact of the ownership of products that embody time-saving innovations on activities and energy use at the household level.

The choice of technology will affect both the amount of time that must be devoted to any particular task and the amounts of purchased energy inputs that are required. For example, the use of a microwave to prepare a meal saves time over other technologies. Although a microwave oven uses more energy per minute of operation than a conventional oven, the reduced amount of time required will generally lead to lower energy costs per meal cooked. However, total energy savings will depend on the activities to which households reallocate their extra time and the energy intensity of these activities. For example, the use of time-saving appliances (TSA) may not reduce the total amount of time a household allocates to household chores: for example, the use of a microwave oven could result in an increased number of hot meals cooked at home.

The authors use the number of TSAs adopted by the household as a measure of the intensity of TSA adoption, and then examine how average energy consumption, the average hours per week allocated to leisure appliance use, and the average frequency of appliance use for household chores vary according to this intensity. Based on the results displayed in Table 1 below, household TSA adoption tends to be associated with a more frequent TSA use for household chores (Column (3)), an association referred to as a "household production time rebound effect". For example, households in the bottom 25th percentile of the sample based on the number of adopted TSAs use their appliances almost 19 times per week on average, while those in the top 25th percentile use them just over 25 times per week on average.

Table 1: Energy Use/Time Allocation by Intensity of TSA Adoption

Intensity of TSA adoption	Average electricity use per sq. feet of dwelling heating area (in gj) (1)	Average natural gas use per sq. feet of dwelling heating area (in gj) (2)	Average frequency of TSA use per week (number of loads) (3)	Average intensity of LA use (in hours) (4)
bottom 5th percentile of all households	0.039	0.095	0.000	157.000
bottom 25th percentile of all households	0.036	0.077	18.928	138.024
bottom 50th percentile of all households	0.034	0.068	24.711	133.743
top 25th percentile of all households	0.027	0.056	25.320	132.648
top 5th percentile of all households	0.027	0.056	25.320	132.648

The values in Column (4) indicate that, in contrast, households that adopted relatively more TSAs tend to allocate less time to the use of leisure appliances (LA): 132 hours per week against 138 hours per week in average. However, further research indicates that TSA adoption is also associated with an increase in the amount of time households allocate to using leisure appliances. Households thus appear to adjust their allocation of time to home production as well as leisure activities.

While TSA adoption does appear to change how households allocate their time, in particular toward appliances that require energy, the authors do not find that TSA adoption results in an overall increase in residential energy consumption.

Time-Saving Innovations (Cont'd)

Interestingly, households with more TSAs tend to on average consume less electricity and natural gas per square foot of heated dwelling area. Columns (1) and (2) indicate that households that fell in the bottom 25th percentile of the sample consume about 0.036 (0.077) gj of electricity (natural gas) per square foot compared to 0.027 (0.056) gj consumed by households that fall in the top 25th percentile.

A regression analysis shows that only the adoption of a microwave by high income households and the adoption of a washing machine by low income households seem to affect electricity consumption, in a negative way, and none of the TSAs have a significant impact on residential natural gas consumption.

Importantly, the analysis does not capture substitution for activities taking place outside of the home. Hence the magnitude of the time rebound effects that arise from the households' TSA adoption, and their impacts on energy use, is likely incomplete.

Energy Demand Models and Modelling

The response of consumers to energy price changes has always been a key issue in energy sector analysis. It is not surprising therefore that the price elasticity of energy demand has been estimated using a large variety of models. Since no single model has proven to be better than others in all contexts, many different models continue to be used. This research explores energy demand models and modelling in the context of the historical evolution of the approaches that have been developed and applied. In addition to explaining the key features of selected models and estimation methodologies – which tend to be inextricably linked, the evolution of models, and likely reasons for this evolution, are also examined.

The authors emphasize that there is no "right" model, with models differing according to various circumstances. The authors detail early approaches to modelling and estimation, usually in log-linear form, which were valued for their simplicity, and how their restrictiveness led to the development of more sophisticated models. They also explore approaches involving systems of equations, using flexible functional forms, for both the production-side and the demand-side for energy. Other models are also reviewed, including those that deal with non-stationarity of the variables and their implications for the modelling of energy demand, and those dealing with asymmetric demand responses that began appearing in the mid 1980s. Finally, other aspects of energy demand modelling that are analyzed include the decision to use / intensity of use of energy-using appliances, and the modelling of energy end-use attributable to particular activities when available data only indicate aggregate energy consumption.

BUILDING SERVICES

CBEEDAC has the expertise to provide services to the building sector in the area of data storage and analysis. For more information regarding these services, on becoming a sponsor of CBEEDAC, or about the services provided by other Data and Analysis Centres contact CBEEDAC or see our Web site (www.ualberta.ca/~cbeedac).

CBEEDAC reports are available online in PDF format.

If you house and/or collect data that could become a valuable addition to Canada's Building Energy End Use information system please consider contacting the Centre with your data information.