**Residential Energy Efficiency Programs, Household Characteristics, and Energy Consumption**

by

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**Abstract**

In the residential sector in Canada, the major uses of energy are for space heating purposes, water heating and lighting. In view of the significant share of this sector in total energy consumption, and hence in greenhouse gas emissions, policy analysts have long touted the need for increased residential energy efficiency. Of course there are several ways that this increased energy efficiency can be achieved. These include imposing higher energy efficiency standards on new buildings and appliances, programs to increase consumer awareness of their energy consumption, GHG emissions, and measures that they can take to reduce them, and programs to encourage residential retrofitting to improve the thermal qualities of a residence as well as the energy efficiency of major appliances such as space and water heaters that are in place. The focus of this paper is on residential retrofitting programs and their effect on energy consumption.

While these measures all appear to be obvious ways to increase energy efficiency in the residential sector, recent research has shown that engineering estimates of the energy that will be saved through introducing products that embody newer energy-efficient technology are not always fully realized. In part this may be due to rebound effects, where increased efficiency is offset to some extent by induced higher levels of usage. However, it can also be due to many other factors, such as less than full utilization of the energy-saving features of the new technology (such as with programmable thermostats that are not programmed). In other cases over-estimates of energy saving associated with new technology occur because the take-up of the new technology is slower than expected, possibly due to costs associated with the new technology that were not anticipated but which become widely known, such as reliability issues, higher costs of replacement parts, and even aesthetic concerns (such as with compact fluorescent lights). Whatever the reasons, the net effect is that the energy that is saved is less than anticipated, and in order to understand the extent to which this is likely to occur, it is necessary to take account of behavioural factors, that is, the fact that the actual energy savings will be the result of the interaction between human behaviour and the change in the energy efficiency properties of the new technology.

A difficulty with empirically determining the actual energy savings by taking account of human behaviour is that the required sample information is often not collected. In the particular example that motivates the analysis in this paper, the Canadian EnerGuide for Houses (EGH) program, all the data that are obtained are based on engineering information. Under this program, homeowners voluntarily participated at their own expense (although in some cases with a subsidy) in an initial home energy audit and were subsequently provided with a set of energy-saving retrofit recommendations. They were free to undertake as few or as many of these as they wished, and subsequently could voluntarily undertake, again at their own (in this case considerably lower) expense, a second home energy audit. Based on the home energy auditor's assessment of the energy saved as a result of their home retrofitting, the homeowner was then eligible for a grant that was an increasing function of the energy that was saved. The data that were collected during these two home energy audits forms the EGH database. While these data are very detailed on house characteristics, including its general location, almost no information concerning the house occupants was collected. In fact, even the energy consumption data, and the change in energy consumption measure that is used to determine grant eligibility and the size of the grant, are based purely

on engineering considerations.  No attempt was made to collect actual energy consumption data from the house occupants.

In view of this, it is not possible to use the EGH data to directly calculate the *actual* energy savings associated with home retrofitting activities under the EGH program.  Nevertheless, as we demonstrate in this paper, the available EGH data, along with supplementary demographic and socio-economic information which we obtain from the Canadian census and match by location to households that undertook retrofits as part of the EGH program, can be used to model and subsequently estimate the roles of various socio-economic and demographic factors, as well as house characteristics, in household energy consumption.  To do this we begin by noting that the energy consumption measure contained in the EGH dataset can only depend on house attributes, and in particular cannot depend on characteristics and behaviour of household occupants (perhaps other than a few simple measures like household size), as this information is not used by the energy auditors in determining the *estimated* amount of energy consumption.  Indeed, this is true both for energy consumption based on the initial audit which depends on pre-retrofit house characteristics, and energy consumption based on the follow-up audit which depends on post-retrofit house characteristics.  However, the homeowner *decisions* of whether to participate in the audit, whether to make any retrofits, and if so how much retrofitting to undertake, all depend on these factors.  Consequently, as we demonstrate in this paper, energy consumption *after* the retrofits – as determined by the second household energy audit – although itself an engineering measure, is necessarily a function of these household characteristics as well as the efficiency characteristics of the house *prior* to the retrofits.  Further, estimation of this function will no longer be tantamount to simply recovering an imperfect estimate of the formula used by the energy auditors to assess energy consumption.  Rather, it will yield information on the roles of these different factors in determining household energy consumption.

Of course, the decision to undertake any retrofits, like the decision of how much retrofitting to do, are endogenous, and this needs to be taken into account in the estimation procedure.  We do this by using results from the literature on treatment effects and sample selection.  Specifically, we estimate an equation describing the probability of undertaking retrofits, and use estimates based on this equation as instruments in our subsequent estimation of the roles of both house characteristics and occupant characteristics in determining energy consumption.  Preliminary results confirm the importance of household occupant variables such as income, the level of education, and the age distribution, as well as house energy characteristics such as the level of insulation, furnace efficiency, and floor area.  This type of information, concerning the interaction of household and house characteristics in determining residential energy consumption, would be expected to be particularly useful for policy makers and energy analysts in their efforts to better assess the extent of the energy savings that are likely to actually be achieved through the use of various programs like EGH that are designed to encourage increased residential energy efficiency.