RESEARCH REPORT

External Research Program

Household Environmental Monitoring Project

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The Household Environmental Monitoring Project

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Abstract

A study group of twenty households was established to test the hypothesis that we can motivate environmentally sustainable behaviour by providing homeowners with a clear picture of their environmental impact, tangible reasons for improvement, and tailored solutions to follow. A report was prepared for each household that compared their consumption of home heating fuel, electricity, water, vehicle fuel and waste generation with others in the study group and recommended the most cost-effective measures to reduce that consumption. This technique succeeded in producing concrete reductions in environmental impact among the study group. On average, 26% of the recommended environmental measures were implemented in the first year, resulting in an estimated greenhouse gas reduction of about 12%, or 2 tonnes per household. In addition, detailed data was compiled on specific households that provided insights into factors affecting environmental impact. Wide variations were found between similarly situated households, demonstrating the potential families have to reduce their individual environmental impact through lifestyle decisions, conservation practices, and energy conscious home improvements.

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Executive Summary

The objective of this research project was to test the hypothesis that we can motivate environmentally sustainable behaviour at the household level by providing homeowners with a clear picture of their environmental impact, concrete reasons for improvement, and tailored solutions to follow.

To test this hypothesis, a study group of twenty households was established in an eighty-five year old community about three kilometres east of the downtown centre of Ottawa, Ontario. Each household completed surveys about environmental attitudes and household practices, and participated in a one week monitoring period which tracked home heating, electricity and water consumption, vehicle usage and waste generation. The research team gathered physical information on each household, previous year utility bills, and arranged for an EnerGuide Home Energy assessment. This information was assembled into a personalized report for each household describing their environmental impact in comparison with other households in the study group and recommending the measures that would most cost-effectively reduce that impact. A community forum of the twenty households was held to discuss results, the value of the process, and potential environmental initiatives. One year after the initial monitoring period, participants provided information on the measures they had implemented as a result of the study, their mileage readings and utility bills for the year following the monitoring period.

The following results were observed through the study process:

- The research project was successful in finding 20 households willing to participate in the study, and in maintaining their participation throughout the study. The information obtained from surveys, monitoring week logs, utility records, site visit, and the EnerGuide assessment, though onerous to gather, was felt by participants and the study team to be worthwhile in order to provide an accurate picture of existing environmental impact and validate any recommendations that were made.

- Participants commented that they became much more aware of their consumption and environmental impact by taking part in the study and were, as a result, motivated to make changes to their behaviour and physical surroundings. This assessment was supported by the recorded results which showed that across the twenty participating households, 26% of the recommended environmental measures were implemented in the first year, resulting in an estimated average greenhouse gas reduction of about 12%, or 2 tonnes per household and .77 tonnes per occupant.

  A comparison of utility bills for the year before and after the monitoring week also showed reductions in consumption in most areas. However the extent of reduction is difficult to quantify in this way because many of the environmental measures were implemented part way through the year and because weather conditions varied significantly between the two years. Heating energy use dropped an average of 9% across the study group, in a period where the number of heating degree days was 1% lower. Water use in the year after the monitoring week dropped by 14%. Electricity use was 9% higher, however this occurred in a year where hot summer weather resulted in 2.23 times the cooling degree days of the previous year and therefore much higher than usual air conditioning demand. Vehicle emissions were 3% lower, although very difficult to compare accurately since the previous year results depended on only a one week mileage record.

- Participants evaluated this environmental monitoring technique as more useful to them than the major existing government sponsored projects, the One Tonne Challenge and EnerGuide program. They felt it provided them with a more accurate, personalized assessment and set of recommendations than the One Tonne Challenge, and a more comprehensive picture of their total environmental impact than the EnerGuide Home Energy assessment alone. However, a majority of participants stated that the most effective way for the government to reduce environmental impact would be to legislate higher mandatory environmental standards for house construction, car fuel efficiency, appliances, equipment, packaging etc. rather than relying on voluntary programs of any kind.

- Including a number of households from the same community and providing comparisons between these households proved useful in motivating participants and helping to put their environmental impact in perspective. Very large differences in consumption rates and greenhouse gas emissions

were recorded between quite similarly situated households, illustrating how much effect lifestyle decisions, conservation practices, and energy conscious home improvements can have. Households with both higher than average and lower than average environmental impact were motivated to make further efforts to reduce environmental impact. Only one household among the study group indicated that they did not appreciate the comparisons that were made and that they did not intend to implement any of the recommendations. Surprisingly, the following year utility bills for this household showed some of the most significant reductions in heating, electricity and water use among the study group, suggesting their participation in the study could have had more impact than they acknowledged.

- The differences between household environmental impact were startling. Home heating fuel, electricity, and water consumption per occupant was 5.5 to 7.5 times greater in the highest consuming household compared to the lowest, with average consumption about 2.5 times the lowest recorded level. Vehicle emissions and waste production were even more variable, with highest levels at 11 to 21 times the lowest levels, and average levels at about 6 times the lowest levels. The total greenhouse gas emissions per occupant was 5.5 times greater in the household with the highest environmental impact compared to the lowest. These variations indicated that, for at least this population group, it is not accurate to assume individual Canadians are producing greenhouse gases at roughly similar rates, or realistic to ask them to cut emissions by the same amount.

- The average greenhouse gas emissions recorded among the study group was 5.4 tonnes per person, very close to the One Tonne Challenge estimate of over 5 tonnes per Canadian. However, the percentage of this total derived from automobile use, home heating and electricity among the study group differed from the Canadian averages set out in the One Tonne Challenge. While the Canadian average is stated as 50% emissions from transportation, 40% from home heating, and 10% from electricity use, the study group breakdown was 30% transportation, 50% home heating, and 20% electricity. This is reasonable for a community of older homes where low levels of insulation and air tightness result in increased heating costs, and where convenient access to downtown, shops and public transportation encourages lower than average automobile use. These results suggest that the kinds of environmental initiatives that will make the most difference could vary significantly between communities.

- There were several common factors among the households with the highest environmental impact per occupant. The floor area per occupant was generally higher than average, most owned two vehicles, at least one of which was a large fuel inefficient vehicle, they drove more than the average, and they tended to be homes with one or two occupants over 40 with no children living in the household. These lifestyle factors appeared to have more impact than the environmental features we think of most often like the quality of the building envelope or energy efficiency of appliances and fixtures. Strategies to encourage wise use of space, house downsizing as families age, and reduced vehicle size and use, are an important part of efforts to reduce environmental impact. A few households with very high consumption had a disproportionate effect in raising the average environmental impact of the study group.

- At the beginning of the study, 11 of the twenty households were already producing less than the One Tonne Challenge goal of 4 tonnes of greenhouse gas emissions per person. Four households were operating at less than 3 tonnes per person. These homes tended to be modestly sized for the number of occupants, they had been carefully renovated to increase insulation values, air tightness, and energy efficiency of appliances and fixtures, car use was low and/or they owned very efficient vehicles, and the owners were consciously adopting conservation practices. Although these four households were already performing well compared to typical levels, in each case the owners elected to implement 30% - 40% of the measures recommended to them to bring their greenhouse gas emissions down to between 2 and 2.5 tonnes per person. For many Canadian households it appears feasible to achieve targets well below the One Tonne Challenge goal.

Of the approximately thirty environmental measures with a less than thirty year payback that were recommended to various households, thirteen were implemented by 20% or more of the households. These included the electricity saving measures of replacing incandescent with compact fluorescent bulbs,

activating energy saving settings on computers, installing ceiling fans, and reducing air conditioning use. The most popular heating energy reduction measures included increasing air tightness of the building envelope, and insulating foundation walls, above grade walls, and hot water tanks. Vehicle emissions reductions through lower vehicle use and ethanol blended gasoline were implemented by one third of households. The most frequently adopted water savings measures included replacing toilets with water saving models, installing kitchen faucet aerators, reducing sprinkler use and installing rain barrels. All households were already recycling and 90% composting at the beginning of the study.

A survey of participants indicated that top priorities in making decisions about home upgrades were improving comfort and lowering operating costs, with reducing environmental impact and improving air quality ranked as lower priorities. The major obstacles to reducing environmental impact were seen as financial cost and lack of time and knowledge to evaluate and implement environmental measures. In keeping with this emphasis on practical, cost effective measures, the majority of the environmental measures that were implemented were those that the household report identified as high priority, with a less than 10 year payback period. Those with a payback period of more than 10 years tended not to be adopted in the first year, including more expensive items such as window replacement, solar hot water heating systems, or upgrade of appliances.

These results indicated to the research team that the monitoring technique was of value in two ways. The technique succeeded in producing concrete reductions in environmental impact among the study group. In addition, detailed data was compiled on specific households that provided insights into factors affecting environmental impact and the types of initiatives that have the most potential to reduce that impact.

The following are potential avenues for further investigation in order to build upon and test the results obtained in this study:

- Continue to monitor the original study group to determine if the environmental reductions are lasting, and if the environmental momentum generated by this group can be used to influence the surrounding community.

- Simplify and standardize the monitoring technique so that it is a more economical and easy to use tool for a wider market.

- Repeat the monitoring process in order to test its effectiveness in different kinds of communities, and to gather information on how environmental impact varies between communities with different housing types and ages, income levels, urban design features and urban locations.

Résumé

Cette recherche avait pour objectif d'éprouver l'hypothèse selon laquelle il serait possible de susciter un comportement écologiquement durable à l'échelle des ménages en leur brossant un tableau clair de leurs répercussions sur l'environnement, des raisons justifiant une amélioration et des solutions tout indiquées à mettre en œuvre.

Pour vérifier cette hypothèse, un groupe d'étude de 20 ménages a été établi dans une collectivité vieille de 80 ans située à environ trois kilomètres à l'est du centre-ville d'Ottawa, en Ontario. Chacun des ménages a participé à des enquêtes portant sur les attitudes par rapport à l'environnement et sur les pratiques domestiques, et à un suivi d'une semaine au cours duquel on a enregistré l'énergie consommée pour le chauffage, la consommation d'électricité et d'eau, l'utilisation des véhicules et la production de déchets. L'équipe de recherche a recueilli des informations physiques sur chaque ménage, sur les factures antérieures liées aux services publics, et a pris les dispositions nécessaires pour faire effectuer une évaluation énergétique ÉnerGuide pour les maisons. Ces informations ont été colligées dans un rapport personnalisé portant sur chaque ménage, lequel décrit les répercussions de leur comportement sur l'environnement, comparativement à d'autres ménages dans le groupe à l'étude, et recommande la mise en œuvre des mesures les plus efficientes permettant de réduire ces répercussions. Les chercheurs ont organisé un forum communautaire réunissant les 20 ménages afin de discuter des résultats, de la valeur du processus et d'initiatives environnementales potentielles. Un an après la période initiale de suivi, les participants ont fourni des renseignements sur les mesures qu'ils avaient mis en œuvre dans la foulée de l'étude, les kilomètres parcourus en voiture et les factures des services publics au cours de l'année qui a suivi l'étude initiale.

Voici les résultats obtenus au cours de l'étude :

- Les chercheurs ont réussi à trouver 20 ménages qui étaient d'accord pour participer à l'étude et à maintenir leur participation jusqu'à la fin de l'étude. Bien que les renseignements obtenus des enquêtes, de l'examen des enregistrements hebdomadaires, des comptes de services publics, des visites à pied d'œuvre, et de l'évaluation ÉnerGuide aient été difficiles à recueillir, les participants et l'équipe d'étude estiment que le jeu en valait la chandelle, si on voulait arriver à brosser un tableau précis des répercussions sur l'environnement et de valider les recommandations qui avaient été formulées.

- Les participants ont indiqué que le fait de participer à l'étude leur avait permis de prendre la mesure de leurs habitudes de consommation et de leur impact sur l'environnement, et par conséquent, étaient davantage motivés à apporter des changements dans leur comportement et dans leur milieu environnant. Cette évaluation est corroborée par les résultats obtenus qui montrent que sur l'ensemble des 20 ménages participants, 26 % des mesures écologiques recommandées ont été mises en œuvre dans la première année, ce qui engendré une diminution d'environ 12 % de gaz à effet de serre, soit 2 tonnes par ménage ou 0,77 tonne par occupant.

  Une analyse comparative des factures des services publics avant et après la semaine de surveillance indique également que des réductions de la consommation ont été réalisées dans la plupart des domaines. Cependant, l'étendue de la réduction est difficile à quantifier de cette façon, car nombre de mesures de réduction des impacts ont été mises en œuvre en cours d'année, alors que les conditions météorologiques ont varié de manière importante d'une année à l'autre. L'énergie consommée pour le chauffage a été retranchée de 9 % globalement pour le groupe à l'étude, au cours d'une période où le nombre de degrés-jours de chauffage a diminué de 1 %. La consommation d'eau dans l'année après la semaine de suivi a diminué de 14 %. La consommation d'électricité a augmenté de 9 %, surtout en raison de l'été très chaud, ce qui a entraîné une augmentation des degrés jours de refroidissement qui se situent à 2,23 fois ceux de l'année précédente. Il en a résulté une utilisation plus importante qu'à l'accoutumée du climatiseur. Les émissions provenant de véhicules automobiles ont été réduites de 3 %, bien qu'il s'agisse d'une comparaison peu précise puisque les données de l'année précédente ne couvrent qu'une semaine d'utilisation.

- Les participants ont jugé cette technique de surveillance environnementale plus utile que les programmes à grand déploiement parrainés par le gouvernement comme le Défi d'une tonne et le programme ÉnerGuide. Ils étaient d'avis que la présente technique leur fournissait une évaluation et des recommandations personnalisées plus précises que ceux du Défi d'une tonne, et un meilleur portrait d'ensemble de leurs répercussions globales sur l'environnement que celui généré par l'évaluation ÉnerGuide pour les maisons. Une majorité de participants ont toutefois indiqué qu'une façon plus efficace pour le gouvernement de réduire les impacts sur l'environnement serait d'imposer par réglementation des normes environnementales plus sévères à l'égard de la construction des maisons, de l'efficacité en carburant des voitures, des électroménagers, des équipements, des emballages, etc., au lieu de s'en remettre à des programmes volontaires de toutes sortes.

- Le fait d'inclure un certain nombre de ménages provenant de la même collectivité, et d'établir une comparaison entre ces mêmes ménages s'est avéré un atout qui a motivé les participants, et qui leur a permis de mettre en perspective les répercussions sur l'environnement de leurs activités quotidiennes. D'importantes différences de consommation et d'émissions de gaz à effet de serre ont été enregistrées entre ménages dont la situation est très semblable, ce qui illustre jusqu'à quel point les décisions en matière de cadre de vie, les pratiques d'économies et les améliorations axées sur les économies d'énergie peuvent influer sur les résultats. Les ménages dont les impacts sur l'environnement étaient soient supérieurs ou inférieurs à la moyenne ont été encouragés à redoubler d'effort pour diminuer les impacts sur l'environnement. Un seul ménage du groupe à l'étude a indiqué ne pas avoir apprécié les comparaisons qui ont été effectuées, et qu'il avait l'intention de mettre en œuvre aucune des recommandations. Étonnamment, les factures des services publics l'année suivante pour ce ménage révèlent qu'ils ont réalisé certaines des réductions les plus importantes de chauffage, de consommation d'électricité et d'eau au sein du groupe à l'étude, ce qui implique que leur participation à l'étude pourrait avoir davantage de répercussions que le ménage ne le reconnaissait.

- Les différences d'un ménage à l'autre au chapitre des impacts sur l'environnement ont été saisissantes. La consommation de mazout, d'électricité et d'eau par occupant a été de 5_ à 7_ fois plus élevée dans le cas du ménage qui a le plus consommé, comparativement à celui qui a le moins consommé, et dont la consommation moyenne se situe à environ 2_ fois le niveau le plus bas enregistré. Les émissions de véhicules et la production de déchets affichaient des variations encore plus grandes, le niveau le plus élevé se situant entre 11 et 21 fois les niveaux les plus faibles, et dont le niveau moyen se situe à environ 6 fois les niveaux les plus faibles. La production totale de gaz à effet de serre par occupant en ce qui a trait au ménage affichant le niveau le plus élevé d'impact sur l'environnement a été de 5 fois plus importantes que le plus faible. Ces variations nous indiquent, du moins en ce qui a trait au groupe de population actuel, qu'il serait erroné de supposer que les Canadiens moyens sont responsables de la production de gaz à effet de serre à un rythme à peu près semblable, ou qu'il serait irréaliste de leur demander de réduire leurs émissions du même ordre.

- Les émissions moyennes de gaz à effet de serre enregistrées auprès du groupe ont été de 5,4 tonnes par personne, très semblables à l'estimation de plus de 5 tonnes par Canadien avancée par le programme Défi d'une tonne. Toutefois, la répartition de ce total résultant de l'utilisation de l'automobile, du chauffage résidentiel et de la consommation d'électricité différait des moyennes canadiennes prévues par le Défi d'une tonne. Bien que la moyenne canadienne soit répartie comme suit : 50 % des émissions provenant du transport, 40 % pour le chauffage et 10 % engendré par la consommation d'électricité, la répartition des émissions pour le groupe à l'étude était la suivante : 30 % pour les transports, 50 % pour le chauffage résidentiel et 20 % pour l'électricité. Il s'agit d'un résultat prévisible, compte tenu de l'âge des maisons, lesquelles présentent de faibles niveaux d'isolation et d'étanchéité à l'air qui font augmenter les frais de chauffage, et où un accès commode au centre-ville, aux boutiques et aux transports en commun favorise une utilisation de l'automobile plus faible que la moyenne. Ces résultats indiquent que le genre d'initiative environnementale qui serait susceptible de faire une différence pourrait varier grandement d'une collectivité à l'autre.

- Les ménages ayant le plus important impact sur l'environnement par occupant avaient plusieurs facteurs en commun. La surface habitable par occupant était en règle générale supérieure à la moyenne, la plupart des ménages étaient propriétaires de deux voitures, dont au moins une

consistait en un gros modèle énergivore, ils faisaient un usage plus intensif de l'automobile, et les ménages comportaient le plus souvent un ou deux occupants âgés de plus de 40 ans, et étaient sans enfants. Ces facteurs de cadre de vie semblaient produire davantage de répercussions que les caractéristiques écologiques auxquelles nous songeons le plus souvent, comme la qualité de l'enveloppe du bâtiment ou l'efficacité énergétique des électroménagers et des appareils. Les stratégies pour encourager l'utilisation judicieuse des espaces, le fait d'emménager dans une maison plus petite à mesure que la composition du ménage évolue et l'utilisation de petites voitures font partie intégrante des efforts visant à réduire les impacts sur l'environnement. Quelques ménages affichant une consommation très élevée ont produit un effet disproportionné sur les impacts environnementaux moyens du groupe à l'étude.

- Au début de l'étude, 11 des 20 ménages produisaient déjà moins que l'objectif de quatre tonnes de gaz à effet de serre par personne préconisé par le Défi d'une tonne. Quatre ménages en étaient déjà à moins de trois tonnes par personne. Ces maisons étaient habituellement de taille modeste, compte tenu du nombre d'occupants, elles avaient été soigneusement rénovées de manière à améliorer l'isolation, l'étanchéité à l'air et l'efficacité énergétique des électroménagers et des appareils, l'utilisation de l'automobile était faible ou les voitures étaient éconergétiques, et les propriétaires adoptaient sciemment des pratiques d'économie d'énergie. Même si ces quatre ménages affichaient déjà une bonne performance comparativement aux niveaux courants, dans chacun des cas, ces propriétaires ont choisi de mettre en œuvre de 30 à 40 % des mesures recommandées afin de ramener leur production de gaz à effet de serre dans une fourchette de 2 à 2,5 tonnes par personne. Pour nombre de ménages canadiens, il semble donc que l'on puisse atteindre des cibles nettement inférieures à l'objectif du Défi d'une tonne.

Des quelque 30 mesures environnementales dotées d'une période de récupération de moins de 30 ans et qui avaient été recommandées aux différents ménages, 13 ont été mises en œuvre par 20 % ou plus des ménages. Parmi ces mesures, on trouve le remplacement des ampoules incandescentes par des ampoules fluorescentes compactes, l'activation du mode économie d'énergie des ordinateurs, la pose de ventilateurs de plafond et l'utilisation moins fréquente du climatiseur. Les mesures d'économie les plus prisées en matière de chauffage comprenaient l'étanchéité à l'air accrue de l'enveloppe du bâtiment,de même que l'isolation des murs de fondation, des murs au dessus du niveau du sol et des chauffe-eau. Le tiers des ménages a réduit les émissions des véhicules en utilisant moins la voiture et en ayant recours à un mélange d'essence et d'éthanol. Les mesures d'économie de l'eau les plus fréquemment adoptées comprennent le remplacement des toilettes par des modèles à faible chasse d'eau, la pose d'aérateurs sur les robinets de cuisine, un faible niveau d'arrosage et la collecte de l'eau de pluie à l'aide de barils. Tous les ménages recyclaient déjà et 90 % d'entre eux compostaient les déchets végétaux avant même le début de l'étude.

Une enquête auprès des participants a indiqué que la priorité en matière de décisions visant la rénovation consistait à améliorer le confort et à diminuer les frais d'exploitation, alors que la réduction des impacts sur l'environnement et l'amélioration de la qualité de l'air constituaient des éléments moins prioritaires. Les obstacles principaux faisant écueil à la réduction des impacts sur l'environnement tenaient surtout aux coûts et au manque de temps et de connaissances pour évaluer et mettre en œuvre les mesures. En conformité avec l'importance accordée aux mesures pratiques et efficaces sur le plan des coûts, la majorité des mesures de réduction d'impact sur l'environnement qui ont été mises en œuvre avaient trait à celles que le ménage avait qualifié de prioritaires, et dont la période de remboursement était de moins de 10 ans. Les mesures qui affichent une période de remboursement de plus de 10 ans n'étaient pas habituellement adoptées dans la première année, y compris les éléments coûteux comme le remplacement des fenêtres, les installations solaires de production d'eau chaude ou l'amélioration des électroménagers.

D'après ces résultats, l'équipe de recherche en a conclu que la technique de suivi a porté fruit sur deux tableaux. La technique a réussi à engendrer des réductions réelles des impacts environnementaux au sein du groupe à l'étude. En outre, des données détaillées ont été compilées sur des ménages particuliers qui mettent en lumière certains facteurs qui influent sur les impacts environnementaux et sur le genre d'initiative qui est le plus susceptible de réduire les impacts.

Voici quelques pistes possibles, lesquelles pourraient être examinées plus à fond, de manière à tirer profit de la présente étude et à mettre à l'essai les résultats obtenus :

- Poursuivre les efforts de suivi auprès du groupe à l'étude afin de découvrir si la réduction des impacts est durable et si l'impulsion ainsi créée pourrait inciter la collectivité environnante à faire de même.

- Simplifier et normaliser la technique afin d'en faire un outil plus économique et facile à utiliser dans un marché élargi.

- Répéter le processus de suivi de manière à en vérifier l'efficacité dans différents types de collectivités, et à recueillir des informations pour découvrir dans quelle mesure les impacts sur l'environnement varient d'une collectivité à l'autre, en fonction du genre de logement et de l'âge, des niveaux de revenus, des facteurs de conception urbaine et de l'emplacement urbain.

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1. Introduction

Through federal initiatives such as the One Tonne Challenge, individual Canadians are being asked to reduce their personal environmental impact and greenhouse gas emissions in order to help our country meet its Kyoto commitment. In surveys over the last decade, 90% of Canadians have indicated they feel a great deal or fair amount of concern about the state of the environment[1]. Recent research has provided a wealth of general and specific information to support more sustainable living. Yet, over the same period, the percentage of Canadians who believe they have a personal responsibility for protecting the environment, or that they can do something to help the environment has dropped.[2] Canadian greenhouse gas emissions continue to increase rather than decrease as required under our Kyoto commitment. This research project proposes a technique to convert the general concern and interest in environmental protection to actions at the household level within a community context.

The largest component of the Canadian housing inventory, with the greatest overall environmental impact, is the occupant-owned dwelling in existing communities.[3] For Canada's established residential neighbourhoods, improved sustainability depends primarily on incremental upgrade of the housing stock by homeowners, occupant lifestyle choices, and municipal planning decisions that support lower impact living. Unlike large organizations, individual households do not have available to them the specialized knowledge and organizational framework to convert the myriad of available environmental information into practical solutions that suit the particular physical and lifestyle characteristics of their household. This research project tests the hypothesis that we can motivate environmental action by providing households with a clear picture of their impact, concrete reasons for improvement, and tailored solutions to follow.

2. Research Plan and Method

2.1 Review of Related Literature

In order to arrive at a monitoring technique for recording the environmental impact of households and recommending the most productive measures for reducing that impact, existing environmental research and monitoring methods were reviewed to ensure the current research would be built upon other successful practices and data. Two major federal government sponsored programs, the EnerGuide Home Energy assessment and the recently introduced One Tonne Challenge, were found to be particularly relevant. The EnerGuide method served as a model of a successful technique for measuring an existing housing state, recommending upgrades, and presenting benefits to be achieved by homeowners. The One Tonne Challenge program served as a general source of information and recommendations for reducing environmental impact, as well as a national level benchmark for the individual results to be gathered in our study.

The following is a summary of previous research, divided into categories of motivational techniques, environmental monitoring tools, analyses of environmental projects, and resource conservation techniques. A bibliography attached as Appendix 1 includes a complete listing of material reviewed with a brief description of each source.

2.1.1 Motivational Techniques for Encouraging Sustainable Behaviour

Previous research into methods of building environmental awareness, obtaining commitments from participants and providing incentives for change has shown how community-based social marketing

[1] Environics International Ltd., Canadians and The Environment, 1997.
[2] Environics International Ltd., 1998.
[3] Single detached dwellings accounted for 58% of existing Canadian housing stock in 2000, Statistics Canada, Canadian Statistics, Housing Stocks, 2000.

tools can help community groups implement resource reduction programs within their neighbourhoods (Cullbridge Marketing and Communications, 2005, McKenzie-Mohr, D. and Smith, W, 1999).

The strategies suggested in these sources form the basis for the techniques we used to motivate more sustainable behaviour. Study participants were selected who were willing to commit to monitoring personal behaviour and to consider recommendations for change. Requirements and benefits to participants were clearly communicated throughout the process by known members of the neighbourhood, who made themselves available to answer participants' questions and listen to feedback. By tracking consumption patterns within the same small neighbourhood, community norms were established to foster a sense of friendly competition. Incentives in the form of resource and cost savings increased the potential total amount of sustainable efforts made by the whole community. Prompts in the form of a post-report questionnaire, community forum, bulk purchase of environmentally friendly products, and a one-year follow-up helped to remind participants of opportunities for further improvement.

2.1.2 Environmental Monitoring Tools

A broad range of monitoring tools is available to help homeowners and building decision-makers reduce resource consumption, a significant number of which come from Canadian sources. These include design tools for building professionals, tools that examine individual household consumption in relation to resultant effects on a global scale, tools created by the federal government to aid individuals in their personal reduction efforts, and those assembled by local community groups. While much useful information was gathered from our review of these existing tools and incorporated into our technique, no one existing monitoring tool was found that provided the level of detail and combination of household environmental impact from heating, electricity, water, waste and personal transportation that we were trying to achieve.

Design Tools

Several design tools have been developed to help building professionals identify and reduce the environmental impact of new and existing buildings. With calculations more suited to the requirements of larger projects with substantial budgets, these tools are designed for those who are involved in the creation of large commercial, institutional, or residential projects, and would provide limited benefit for the average homeowner. These include the environmental rating system known as LEED (Canada Green Building Council, 2003), The Commercial Building Incentive Program or CBIP (NRCan, OEE, 2003) and RETScreen (NRCan, CANMET Energy Technology Centre, 2004) which calculates the benefits of several renewable-energy building options such as wind energy and photovoltaic solar cells.

Global Impact Assessment Tools

Tools that examine individual resource consumption in relation to total global supply range from broad, simplified snapshots to more complex analyses. David Suzuki's Nature Challenge (2005) is a web tool composed of six general questions to approximate net effects on air and water pollutants, water use, loss of farms and wetlands and increased greenhouse gas emissions. More detailed assessment methods that employ a measuring tool known as the 'eco-footprint' allow participants to determine if their own levels of consumption exceed their share of the total global productive land area available to sustain the planet and its inhabitants. The principal benefit of this type of assessment for participants is the ability to quickly and easily relate personal decisions such as vehicle purchases and methods of home heating to the contribution to the amount of greenhouse gases produced and natural resources consumed to fulfill individual needs. Several of these tools (Earthday Network, Redefining Progress, 2002, Redefining Progress, 2003) analyze home heating, electricity and water use, clothing and food purchases, transportation fuel use and waste production with varying levels of accuracy. Many of these tools are based on the input of generalized information that provides a less accurate household assessment of existing environmental impact and potential improvement than our research was looking to achieve.

Federal Environmental ReductionTools and Strategies

Several tools provide detailed and accurate sources for resource reduction strategies specific to one category of resource consumption. The EnerGuide for Houses Program is a successful federal program to encourage building envelope and equipment upgrades. Existing home energy efficiency is rated via a blower door test, practical information is provided on techniques, costs and potential savings for the implementation of improvements, and a grant is provided based on measured improvements to the energy efficiency rating. This combination of personalized household assessment and recommendations tailored to the specific characteristics of a particular household served as a model for developing our monitoring technique. Our project also incorporated this program as the primary means of assessing the home energy portion of the total environmental impact of each of the study households, and as an incentive for households to participate in the study and become eligible for federal funding for energy efficient upgrades.

The Anti-Idling Toolkit and Fuel Consumption Guide, both created by Natural Resources Canada (2005), offer ideas for community groups to alert fellow residents of the potential fuel reduction achieved by changing driving habits or purchasing more fuel-efficient vehicles. NRCan provides a booklet containing information on energy-efficient appliance options called the EnerGuide Appliance Directory (2005). Our study employed these extensive and easily accessible sources of information to inform participants of their current consumption levels and potential for improvement.

Over the last decade, the reduction of greenhouse gas emissions has emerged as a dominant environmental effort, and several tools have been developed for Canadians to address reduction strategies contained in the Kyoto Protocol. A detailed data inventory spreadsheet tool created by Partners for Climate Protection (2004) to calculate total municipal carbon dioxide emission levels examines industrial and commercial in addition to residential effects and is geared towards the whole municipal process rather than the individual homeowner. On a more local scale, the Household Greenhouse Gas Emissions Questionnaire (CMHC, 2004) asks participants several general questions about home heating energy, electricity, transportation and waste consumption. Individual results are compared to those of a typical Canadian home. Our monitoring technique builds on this approach by examining causes of variation between neighbourhood residents.

Two recent tools have been developed to address the individual one tonne greenhouse gas reduction requirement contained in Canada's Climate Change Action Plan. The One Less Tonne web tool (Pembina Institute, 2004) encourages users to press a "commit" button in response to a list of recommended actions and displays resultant environmental and cost benefits. Following Canada's Climate Change Action Plan, credit is given for actions taken since 2002. Though frequent air travelers and residents of provinces with higher electricity generation emission levels are encouraged to make reductions greater than one tonne, the tool relies mainly on general recommendations rather than an assessment of existing individual consumption levels to provide incentive for sustainable behaviour.

The Government of Canada's One Tonne Challenge (2005) identifies individual reduction priorities by tracking existing resource consumption levels through a detailed list of questions from a range of sources. Individual results are then compared to national and provincial averages. In community One Tonne Challenges across Canada, participants are encouraged to take the Challenge and then register their commitment as part of a community total. Public education and outreach from press releases, local advertising, special events and home visit programs include incentives such as prizes and discounts from local merchants. Resultant community efforts have included the implementation of renewable energy technologies, regional recycling plans and sustainable improvements to local transportation infrastructure.

Despite these benefits, the accuracy and effectiveness of the One Tonne Challenge tool are limited by several factors. Drop-down menu choices contained in some of the questions do not allow participants to record exact consumption quantities, while in other categories general assumptions are made; for example, the energy efficiency of a home's building envelope and resultant energy use are determined primarily from the size and age of house, regardless of construction type or whether subsequent upgrades have been made. Similar general assumptions are made regarding appliance

electricity consumption, while no questions are asked about water use. A generic list of recommendations displayed at the end of the survey has not been linked to previous survey answers, as in some cases these actions have already been taken by the homeowner. All participants are encouraged to reduce by the same one-tonne amount regardless of their different starting points and reduction potential.

Existing tools to assess and encourage sustainable community behaviour have often focused on a broad national scale. The Sustainable Communities Indicators Program database (CMHC, 2000) allows government officials and municipal planners to compare existing and potential environmental performance at the national, regional or various municipal levels across Canada. The smallest geographic level of data for comparison within this tool is made at the census tract level, which typically consists of 2,500 to 8,000 persons. In our research we sought to extend this type of sustainability assessment to a neighbourhood scale where individual households can identify with results visible in their physical context and among members of their immediate community.

Community Generated Reduction Strategies

Initiatives created by and for local communities often rely primarily on general recommendations to promote more sustainable behaviour. The Smart Living Journal, an energy-saving guide created by Toronto-based EnerACT (2005), suggests two to three environmentally-friendly actions per week over a twelve-week period and offers a helpline and local neighbourhood workshops to increase participant motivation. EcoPerth is an Ontario community example of a successful strategy to promote sustainable living by making available a wide range of local initiatives and fostering community pride (CMHC, 2001).

A series of energy and water-saving booklets developed to address specific deficiencies in Edmonton homes (City of Edmonton, 2004) employs prioritized cost and greenhouse gas reduction strategies for a specific community. Based on the results of a large sample of local EnerGuide home audits, retrofit recommendations contained in the booklets are grouped into four categories based on the year of house construction. The booklets and associated website link residents to information and discounts from local energy retrofit contractors and merchants. Following this approach, our monitoring technique also links recommendations and resultant cost and energy benefits to the individual requirements of households within a community.

2.1.3 Analyses of Environmentally Sustainable Projects

A significant portion of technical research on environmentally sustainable housing and communities has focused on design and construction techniques for newly constructed housing developments or retrofits for multi-unit residential buildings. A Calgary study (Perks and Wilton-Clark, 1996) assesses the level of interest among potential homeowners for a new residential suburb built with environmentally sustainable methods. At the municipal level, The Federation of Canadian Municipalities (2005) examines variations in the ecological footprints of various cities across Canada. A CMHC study of reduction methods for energy and water consumption in apartment buildings as tracked in the HiStar database (2001) demonstrates how building owners and managers can measure consumption levels and develop greenhouse gas reduction strategies by calculating past utility bills in combination with data on physical building and site characteristics. Decreased levels of consumption measured in case studies of household energy use (NRCan, OEE, 2000), home energy retrofits (CMHC, 2003; NRCan, OEE, 1997) and off-grid houses across Canada (CMHC, 2001) have allowed researchers to determine proven cost-effective and energy-saving retrofit measures.

2.1.4 Resource Conservation Techniques and Manuals

Over the past two decades, a multitude of sources of sustainable design methods for new construction have emerged, including general reference manuals (European Commission, 1999; Harland, 1999; Wilhide, 2002) and guides for energy-efficient residential retrofit projects (CMHC, 1985). Our study draws mainly from sources that focus on resource reduction methods that address the living patterns of

existing households, including heating and electrical energy conservation (Jones, 1998; Lechner, 2001; NRCan, OEE, 2003; NRCan, OEE, 1998; Wayne State University, 2004), water conservation (American WaterWorks Association, 2005; CMHC, 2004; Environment Canada, 2004; Griffin & Morgan, 2004), and waste reduction methods (City of Ottawa, 2004). A full description of the sources for results calculations and recommendations made in the Household Reports can be found in Appendix 1 of this report.

2.2 Selection of Study Group

The pilot community for this research is Lindenlea, a 150 household, 85 year old neighbourhood about 3 km from the downtown centre of Ottawa, Ontario. The main reason for the selection of this community is that it is the location of work, residence, and volunteer activities for the primary researchers, and community-based marketing approaches have been shown to be most successful when led by established community members. In addition, as one of Canada's earliest planned communities, Lindenlea possesses many of the attributes now considered critical to sustainable behaviour such as walkable streets and services within walking distance, ready access to public transportation and cycle paths, public green spaces and local communal facilities. It has a high level of community involvement and established communication channels to support participation in the study. The mix of dwelling type, size, age and occupants is fairly typical of many older communities across Canada.

A project introduction sheet describing the objectives and schedule for the study and an application form was circulated to the community via community newspaper, electronic mailing lists and community meetings (Appendix 2). Participant requirements (residence within a defined neighbourhood boundary, occupation of the home during the monitoring week in October 2004 and access by the study team to the previous year's household utility bills) and benefits (an assessment by the research team and EnerGuide home assessment) were outlined in the introduction literature. The application form included questions concerning housing type, age and size, number and age groups of occupants and extent of environmental knowledge of the household. Twenty eligible households expressed an interest in participating in the study. It is expected that this study sample would represent a somewhat higher than typical level of interest in environmental issues because it consists of those interested in volunteering their time in order to learn how to reduce their environmental impact. Figure 1 provides a summary of the characteristics of this study group.

Figure 1: Participating Household Information

Attributes	No. of Households	Percentage of Study Group
Number of Persons in Home		
1-2 persons	6	30%
3-4 persons	**13**	**65%**
5+ persons	1	5%
Year of House Construction		
1900-1939	**16**	**80%**
1940-1979	3	15%
after 1980	1	5%
Extent of Alterations Since Construction		
no changes	1	5%
minor changes	5	25%
major changes	**14**	**70%**
Knowledge of Options to Reduce Environmental Impact		
poor	1	5%
fair	**11**	**55%**
good	8	40%

2.3 Development of Monitoring Method and Forms

Based on the findings of our research into community marketing techniques and precedents for the analysis and recommendation of techniques for reducing environmental impact, it was decided to present results to participants in the form of a *Household Report*. This report would track and compare resource consumption levels among participants and provide recommendations for improvement. All results were presented so that individual households could compare their consumption with others in the study group without being able to identify the results of others.

In order to achieve reasonably accurate results in a format that would not be too onerous for participants, data collection consisted of EnerGuide home energy assessment results, household monitoring by the homeowners during a specified monitoring period of one week, a home visit by the research team to assess physical features most likely to influence household resource consumption, and utility records from the previous year. Analysis of resource consumption was divided into five categories: heating energy (home and water heating), electricity, water, transportation fuel and household waste. Physical and lifestyle factors to be measured were chosen based on their potential for improvement. To address seasonal variations, utility consumption was also calculated based on the previous yearly total divided by 52 weeks. The following documents, found in Appendix 2, were developed for use during the monitoring week period:

- A *Home Visit Checklist* was developed for use by the research team during a scheduled home visit to document the physical features of the home and site that have the greatest effect on resource consumption. Home heating energy factors such as house and window areas, and heating and hot water sources were measured. The number and type of indoor and outdoor lighting fixtures and appliances were noted to compare against electricity use. Plumbing fixtures and variations in landscaped area were evaluated to determine water use characteristics, and composters and recycling bins were counted to assess waste production.

- A *Household Log Book* was given to all households to track resource consumption for the same one-week period. All participating households recorded heating fuel, electricity and water meter readings, automobile odometer readings and weight of garbage, recycling and compost at the start and end of the week. Daily water use for lawn care, car washing, laundry, dishwashing, baths and showers was noted. Transportation use by modes of public transit, biking, walking or automobile was measured in trips taken during the week.

- A *Household Questionnaire* was distributed to each household to help to explain monitoring results by linking lifestyle patterns with resource consumption levels. Participants were asked to note such factors as seasonal furnace and air conditioner settings, weekly computer use and quantity and type of recycling and compost. Other inquiries included carpooling habits and most commonly used transportation methods. Participants were asked about their perceptions of sustainable options for their household, and what they saw as possible solutions, incentives or barriers to sustainable living.

2.4 Household Monitoring

In October 2004, twenty households participated in the one-week monitoring period to track their use of heating fuel, electricity, water and transportation fuel, as well as their levels of waste production. The *Household Questionnaire* and *Household Log Book* were distributed to all participants, who were asked to review material and inquire about any aspects of the questions or monitoring that required clarification.

The home visit by the research team and the EnerGuide home energy assessment were also conducted during this week. Each household was visited by the research team to examine the physical factors that could potentially influence monitoring results, and to evaluate the household potential for passive and active solar features, natural ventilation, daylighting, water collection and landscaping. During this visit researchers reviewed the log book and questionnaire with occupants to resolve any

questions or concerns. The home energy assessment was conducted to assess the energy efficiency of the home by examining levels of air leakage, insulation and solar heat gain, and measuring furnace and hot water heater efficiencies. Completed home energy assessment reports were later provided by the City of Ottawa EnviroCentre to researchers for inclusion in each *Household Report*.

2.5 Household Assessment and Report

Data contained in the household reports was compiled from the results of the *EnerGuide Home Energy Assessment*, *Home Visit Checklist*, *Household Questionnaire*, *Household Log Book* and previous utility bills. A Microsoft Excel-based database was created to calculate and sort results for comparison between households and to link to recommended improvements (Appendix 3). Values for household heating energy use, electrical energy use, water use, transportation fuel use and waste generation were plotted to assess the environmental performance of each household in relation to average, highest and lowest levels within the community study group. Results were compared with questionnaire data and personal observations in order to better understand reasons behind the results. Results were also examined for possible linkages between factors such as dwelling size, age, number of occupants and number of vehicles. Potential areas for improvement were considered for each household and compared for similarities across the twenty participant households.

Individual *Household Reports* were then generated for each household (Appendix 4). Each report included monitored values for heating energy, electricity, water, waste, and transportation fuel charted against community norm, high and low values, with weekly monetary costs associated with each component. An evaluation of factors affecting the results was included with suggestions for the most productive actions to achieve increased sustainability. Estimated implementation costs and potential cost and resource savings were provided for these recommendations.

2.6 Community Forum and Questionnaire

Once participants had received and reviewed their copies of the household reports, they were asked to complete a *Post-Monitoring Questionnaire* (Appendix 5) that assessed their opinion of the value of the process, potential improvements, their interest level in proceeding with individual recommendations, and alternative ideas for achieving reduced environmental impact. Participants were invited to discuss these issues at a community forum.

In May 2005 the community forum was held at a local community centre to discuss the results of *The Household Environmental Monitoring Project* and future community initiatives. The forum consisted of a brief presentation of common themes encountered in the individual reports, an assessment of significant environmental issues for the community as a whole, and suggested directions or initiatives for future reductions. Participants were encouraged to comment on the process and what they had learned, and suggest changes they would like to see implemented at the community level. Sixteen of the twenty households were represented at the forum. A summary of forum comments is included in Appendix 5.

2.7 Community Initiatives

In response to a suggestion made by participants at the community forum, a bulk purchase of environmental products was organized with the City of Ottawa EnviroCentre and Arbour Environmental Shoppe. Seven households participated, purchasing rain barrels, hot water tank blankets and faucet aerators at reduced prices with delivery to the community included.

Another suggestion made at the community forum which materialized in the following year was the introduction of smart meters to allow residents to become more aware of their consumption. Fifteen of the twenty households in the study group along with 35 other houses in the neighbourhood had smart meters installed in the summer of 2005 as part of a pilot project by Hydro Ottawa to test this new technology and its effect on electricity consumption.

2.8 Assessment of Following Year Results

One year after the monitoring week, participants were requested to provide their revised vehicle mileage and return the final page of their Household Report with a listing of each recommendation that was implemented over the year and the approximate date of implementation. Utility readings for gas, oil, electricity and water utilities were obtained for the year in order to allow comparison with results from the previous year.

Eighteen of the twenty households responded to this request for further information. One of the remaining households had moved out of their home during the year, and the other expressed their intention of providing the information but did not follow through. One of the households who responded, indicated that they did not appreciate the comparisons that were made and that they did not intend to implement any of the recommendations. A chart of the measures implemented by the households is provided in Appendix 6.

3. Analysis of Results

3.1 Viability of Technique

Participant Satisfaction

The research project was successful in finding 20 households willing to participate in the research project, and in maintaining their participation throughout the study. The quite extensive requirements of participants were clearly stated in the introductory material in order to ensure volunteers were prepared to complete several questionnaires, a monitoring week log, EnerGuide and research team visits, and attend a community forum before signing on to the study. The research team was nevertheless surprised at the high level of enthusiasm, honesty, and thoroughness with which the participants completed the assigned tasks. All responded positively to a survey question asking if they were satisfied with the information they received in comparison with the level of effort required to participate.

One of the main objectives of the study was to make homeowners very aware of their consumption and the resulting environmental impact, in order to motivate them to take action. Recording daily activities in a log during the monitoring week was evaluated by participants as an important part of making them think about the environmental impact of each of their daily actions. Participants commented that they were very interested to see their consumption rates, and the dollar and environmental cost associated with that consumption. Many participants expressed surprise at how high their consumption was, including some whose levels were well below average.

Comparisons were made between the consumption rates of the study households in order to allow participants to see their environmental impact in context with those immediately around them. Although this information was presented anonymously, the research team had some concern that these comparisons would upset participants whose environmental impact was above the average and discourage them from further participation. Several households with higher than average results noted extenuating circumstances like high vehicle use for business purposes included in their total or single or double occupancy of a house that led to perhaps unfairly higher per occupant results. The household that expressed dissatisfaction with the comparisons and recommendations made to them did not participate in the community forum or provide end of year vehicle mileage. Surprisingly, the following year utility bills for this household showed some of the most significant reductions in heating, electricity and water use among the study group, suggesting that their participation in the study may have had more impact than they acknowledged. In general, participants accepted the detailed accounting of their environmental impact and the comparisons graciously, describing them as a necessary and highly motivating “guilt trip.”

Participants were asked to rate the usefulness of the EnerGuide Assessment, Monitoring Week, and Household Report as part of the monitoring technique. Each part was rated as being useful or very useful, with the Household Report judged as the most useful by about two thirds of the group because it

brought together all the information gathered, and the EnerGuide Assessment rated as the most useful by the remaining third. Further details on these evaluations are contained in Appendix 5.

The study group was also asked to rank a series of possible government initiatives to encourage reductions in household environmental impact including existing programs and new proposals. The results are presented in Figure 2 .

Figure 2 : Participant Evaluation of Potential Government Initiatives

Initiative	High Priority	Very Effective	Combined Total	Somewhat Effective	Not Effective
Improve transportation infrastructure to encourage public transit use, biking and/or walking.	47%	47%	93%	7%	0%
Legislate higher energy efficiency standards for appliances and vehicles.	67%	13%	80%	20%	0%
Provide significant tax rebates for purchase of energy-efficient appliances, vehicles, alternative energy sources.	47%	33%	80%	20%	0%
Provide additional grants for energy-efficient home improvements, similar to those currently provided through the EnerGuide program.	33%	40%	73%	27%	0%
Implement progressive utility billing where rates increase with household consumption.	40%	33%	73%	27%	0%
Increase utility charges (heating fuel, electricity, water) to reflect the full cost of production and environmental impact.	20%	53%	73%	20%	7%
Increase taxes on inefficient vehicles or appliances.	47%	20%	67%	27%	7%
Fund community-based alternative energy sources or other sustainable initiatives.	13%	47%	60%	40%	0%
Expand the EnerGuide program to include assessment of lifestyle factors, electricity, water, transportation and waste consumption (similar to the Household Report).	14%	36%	50%	36%	14%
Implement community programs to assist households in reduction of household impact.	13%	33%	47%	53%	0%
Promote resource conservation programs for individuals such as the One Tonne Challenge.	0%	27%	27%	73%	0%
Promote voluntary energy efficiency standards for appliances and vehicles.	7%	7%	13%	53%	33%

The most highly ranked initiatives involved measures like legislating higher energy efficiency standards, changing pricing standards to financially reward environmentally sound purchases and penalize high consumption, and creating infrastructure to support wiser transportation choices. Voluntary

standards and resource conservation programs like the One Tonne Challenge received little support because it was felt they were unlikely to be adopted and were more political gestures than practical techniques to promote change. Community based programs like this Household Environmental Monitoring Project were judged to be effective by most respondents, but less so than the introduction of mandatory standards and pricing described above.

Recorded Results of Environmental Reductions

In order to judge the success of the monitoring method in reducing environmental impact, the positive assessment by the participants was compared to the record of measures implemented and the utility consumption rates before and after the monitoring period.

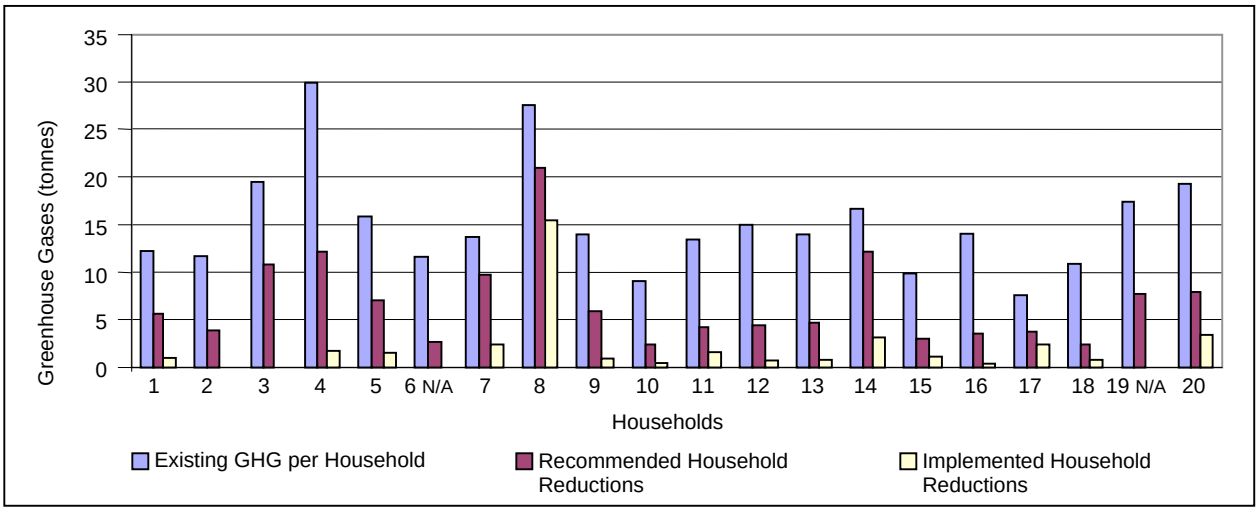
Across the participating households, 26% of the recommended environmental measures were implemented in the first year, resulting in an estimated average greenhouse gas reduction of about 12%, or 2 tonnes per household and .77 tonnes per occupant. These reductions were divided among the participating households as shown in Figures 3 and 4. Two households who did not return the recommendations sheet are excluded from these totals.

Figure 3: GHG Reductions Resulting from Household Report Recommendations

		GHG per Household (T)						GHG per Occupant (T)			
No.	**No. of Occup**	**Existing GHG**	**Recom Reduc**	**Implem Reduc**	**Revised GHG**	**% of Recom Implem**	**% Total Reduction in GHG**	**Existing GHG**	**Recom Reduc**	**Implem Reduc**	**Revised GHG**
1	4	12.20	5.68	0.99	11.21	17%	8%	3.05	1.42	0.25	2.80
2	2	11.70	3.80	0.00	11.70	0%	0%	5.85	1.90	0.00	5.85
3	3	19.50	10.75	0.00	19.50	0%	0%	9.75	5.38	0.00	9.75
4	4	29.90	12.10	1.72	28.18	14%	6%	7.48	3.03	0.43	7.05
5	4	15.90	7.06	1.47	14.43	21%	9%	3.98	1.77	0.37	3.61
6	n/a	See Note 1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7	2	13.70	9.77	2.35	11.35	24%	17%	6.85	4.89	1.18	5.68
8	4	27.50	21.01	15.36	12.14	73%	56%	6.88	5.25	3.84	3.04
9	4	13.90	5.88	0.95	12.95	16%	7%	3.48	1.47	0.24	3.24
10	3	9.10	2.38	0.42	8.68	18%	5%	3.03	0.79	0.14	2.89
11	5	13.50	4.18	1.57	11.93	38%	12%	2.70	0.84	0.31	2.39
12	4	14.90	4.43	0.63	14.27	14%	4%	3.73	1.11	0.16	3.57
13	3	13.90	4.60	0.84	13.06	18%	6%	4.63	1.53	0.28	4.35
14	1	16.70	12.10	3.12	13.58	26%	19%	16.70	12.10	3.12	13.58
15	4	9.80	3.00	1.18	8.62	39%	12%	2.45	0.75	0.30	2.16
16	4	14.00	3.49	0.37	13.63	11%	3%	3.50	0.87	0.09	3.41
17	2	7.60	3.72	2.38	5.22	64%	31%	3.80	1.86	1.19	2.61
18	4	10.90	2.40	0.75	10.15	31%	7%	2.73	0.60	0.19	2.54
19	n/a	See Note 2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
20	2	19.30	7.98	3.40	15.90	43%	18%	9.65	3.99	1.70	7.95
Avgs	**3.22**	**15.22**	**6.91**	**2.08**	**13.14**	**26%**	**12%**	**5.57**	**2.75**	**0.77**	**4.80**

Notes: 1. One year follow-up information was not available because owners had moved from their home.
2. One year follow-up information was not provided by participant household.

Figure 4: Household Greenhouse Gas Reductions Based on Household Report



As Figure 4 indicates, the existing greenhouse gas emissions per household vary dramatically as do the recommended and implemented household reductions. From an average greenhouse gas emission of about 15 tonnes per household, reductions of just under 7 tonnes per household were recommended, of which 2 tonnes was implemented. For two of the households no reduction is indicated, however, in the case of Household 2, some upgrades were made which could not be linked to a specific greenhouse gas reduction. In the case of Household 3, the homeowners replied that they did not intend to implement any recommendations, however the utility records indicate greatly reduced consumption for this household that suggests changes of some kind were made. The majority of households implemented reductions in the range of .5 to 3.5 tonnes, and these reductions were generally proportional to the extent of recommendations made. 5 of the 20 households made per occupant reductions equal to or greater than the One Tonne Challenge goal of a one tonne reduction per Canadian.

Household 8 stands out for the magnitude of its reduction of over 15 tonnes, which resulted from implementation of 12 of the 16 recommendations made to them plus one additional recommendation. The most significant reductions related to changes in automobile use, including replacement of 2 vehicles, one of which was very fuel inefficient, with one more efficient vehicle, reducing the amount driven by 25%, and switching to ethanol gasoline. Other measures included adding insulation, increasing air tightness, installing low flow fixtures, rain barrels, ceiling fans, and reducing air conditioning usage. Household 17 is also noteworthy because it began the study with the lowest household greenhouse gas emissions in the group at 7.5 tonnes, and still found ways to reduce this amount by 30% or 2.4 tonnes.

A comparison of utility bills and vehicle mileages for the year before and after the monitoring week also showed reductions in consumption in most areas. However the extent of reduction is difficult to quantify in this way because many of the environmental measures were implemented part way through the year and because weather conditions varied significantly between the two years. These results are illustrated in Figures 5 and 6 below. Appendix 6 contains a comparison of the Heating and Cooling Degree Days for the two years.

Heating energy use dropped an average of 9% across the study group, in a period where the number of heating degree days was 1% lower. Water use in the year after the monitoring week dropped by 14%. Electricity use was 9% higher, however this occurred in a year where hot summer weather resulted in 2.23 times the cooling degree days of the previous year and therefore much higher than usual air conditioning demand. Vehicle emissions were 3% lower, although very difficult to compare accurately since the previous year results depended on only a one week mileage record.

Figure 7 lists all the household that reduced heating energy, electricity, and water usage by 10% or more with the Household Report Recommendations that were implemented.

Figure 5: Comparison of Household Utility Consumption Between 2004 and 2005

	Heating Energy				Electricity				Water			
	2004	2005			2004	2005			2004	2005		
No.	Weekly Energy Used (MJ)	Weekly Energy Used (MJ)	Diff 2005 to 2004 (MJ)	% Change	Weekly Energy Used (kWh)	Weekly Energy Used (kWh)	Diff 2005 to 2004 (kWh)	% Change	Daily Volume Used (L)	Daily Volume Used (L)	Diff 2005 to 2004 (L)	% Change
1	2728.3	2408.1	-320.2	12% lower	134.5	125.1	-9.4	7% lower	511.0	466.0	-45.0	9% lower
2	1968.3	1866.9	-101.4	5% lower	218.6	220.3	1.7	1% higher	231.4	310.0	78.6	34% higher
3	3824.1	3551.4	-272.7	7% lower	234.9	204.2	-30.7	13% lower	1184.6	663.0	-521.6	44% lower
4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	428.6	452.0	23.4	5% higher
5	n/a	n/a	n/a	n/a	198.7	203.2	4.5	2% higher	535.9	507.0	-28.9	5% lower
6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7	n/a	n/a	n/a	n/a	81.6	146.1	64.5	79% higher	584.9	510.0	-74.9	13% lower
8	n/a	n/a	n/a	n/a	93.3	120.6	27.3	29% higher	322.3	238.0	-84.3	26% lower
9	2410.4	2439.9	29.5	1% higher	167.1	190.0	22.9	14% higher	842.6	696.0	-146.6	17% lower
10	1612.2	1510.8	-101.4	6% lower	119.8	133.8	14.0	12% higher	613.3	569.0	-44.3	7% lower
11	2612.0	2689.2	77.2	3% higher	200.8	223.6	22.8	11% higher	1188.0	1029.0	-159.0	13% lower
12	3170.0	2998.7	-171.3	5% lower	143.0	172.2	29.2	20% higher	600.6	660.0	59.4	10% higher
13	2290.3	2062.4	-227.9	10% lower	236.3	228.9	-7.3	3% lower	663.9	573.0	-90.9	14% lower
14	2221.5	1966.7	-254.8	11% lower	143.2	142.4	-0.8	1% lower	388.4	257.0	-131.4	34% lower
15	2210.4	2165.6	-44.8	2% lower	91.3	102.0	10.7	12% higher	551.0	542.0	-9.0	2% lower
16	1905.9	1894.8	-11.1	1% lower	162.2	191.3	29.1	18% higher	597.9	609.0	11.1	2% higher
17	1616.0	1650.4	34.4	2% higher	138.7	114.9	-23.8	17% lower	344.3	348.0	3.7	1% higher
18	2081.5	1838.2	-243.3	12% lower	111.2	122.5	11.3	10% higher	355.4	281.0	-74.4	21% lower
19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	592.3	386.0	-206.3	35% lower
20	3219.4	1692.5	-1526.9	47% lower	174.6	237.5	62.9	36% higher	591.1	520.0	-71.1	12% lower
Avg	**2419.3**	**2195.4**	**-223.9**	**9% lower**	**155.9**	**169.3**	**13.5**	**9% higher**	**585.7**	**506.1**	**-79.6**	**14% lower**

Figure 6: Comparison of Vehicle Fuel Consumption Between 2004 and 2005

No.	2004 Monitoring Week (L)			2005 Weekly Average (L)				Weekly Difference 2005 to 2004 (L)	% Change 2005 to 2004 Monitoring Week		Yearly GHG Estimation (T)			
	Car 1	Car 2	Total	Car 1	Car 2	Car 3	Total				based on Monit Week	based on 2005 Wkly Average	Difference 2005 to 2004	
1	9.55		9.55	28.69			28.69	19.14	200%	higher	1.2	3.5	2.3	higher
2	11.65		11.65	24.40			24.40	12.75	109%	higher	1.4	3.0	1.6	higher
3	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a		n/a	n/a	n/a	
4	23.71	110.57	134.28	47.30	70.99		118.29	-15.99	12%	lower	16.5	14.5	2.0	lower
5	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a		n/a	n/a	n/a	
6	n/a		n/a	n/a			n/a	n/a	n/a		n/a	n/a	n/a	
7	43.06		43.06	38.18			38.18	-4.88	11%	lower	5.3	4.7	0.6	lower
8	146.24	15.92	162.16	20.80	28.28	8.68	57.76	-104.40	64%	lower	19.9	7.1	12.8	lower
9	26.59		26.59	33.09			33.09	6.50	24%	higher	3.3	4.1	0.8	higher
10	14.59		14.59	41.99			41.99	27.40	188%	higher	1.8	5.2	3.4	higher
11	13.05		13.05	15.73			15.73	2.68	21%	higher	1.6	1.9	0.3	higher
12	18.95		18.95	10.15			10.15	-8.80	46%	lower	2.3	1.3	1.0	lower
13	18.82		18.82	27.11			27.11	8.29	44%	higher	2.3	3.3	1.0	higher
14	58.31		58.31	53.67			53.67	-4.64	8%	lower	7.2	6.6	0.6	lower
15	10.06		10.06	25.18			25.18	15.12	150%	higher	1.2	3.1	1.9	higher
16	11.94	29.30	41.24	40.74	22.07		62.81	21.57	52%	higher	5.1	7.7	2.6	higher
17	0		0.00	15.86			15.86	15.86	n/a		0.0	2.0	2.0	higher
18	19.08		19.08	36.45			36.45	17.37	91%	higher	2.3	4.5	2.2	higher
19	43.04		43.04	26.63			26.63	-16.41	38%	lower	5.3	3.3	2.0	lower
20	36.27	12.86	49.13	29.57	9.55		39.12	-10.01	20%	lower	6.0	4.8	1.2	lower
Averages			**39.62**				**38.54**	**-1.08**	**3%**	**lower**	**4.8**	**4.7**	**0.1**	**lower**

Figure 7: Initiatives Taken by Households who Reduced Utility Use Between 2004 and 2005 by 10% or More

Heating Energy

House hold	% reduction	Recommendations Undertaken in 2005		
		Recommendations	**Potential Annual Savings (MJ)**	**Other Potential Reasons**
1	12%	increased house air tightness	10400	
13	10%	insulated hot water tank (just purchased in October 2005)	1340	
14	11%	insulated foundation	22700	
		insulated main walls	25200	
18	12%	washed clothes in warm water and rinsed in cold water	n/a	
20	47%	insulated main walls	39000	
		increased house air tightness	4200	

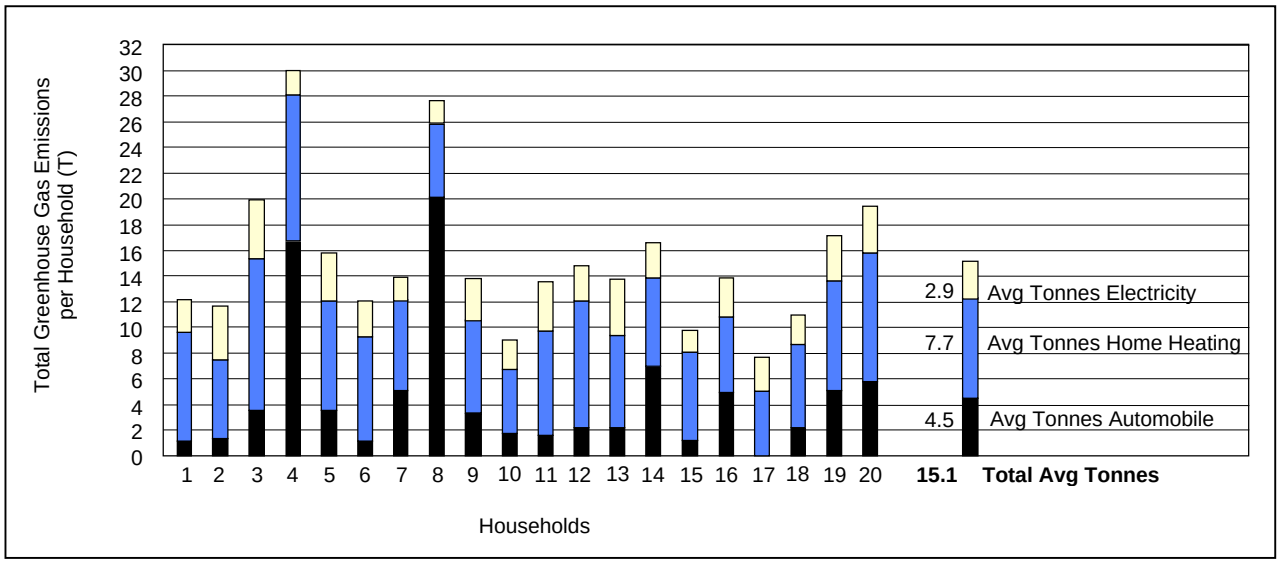
Electricity

House hold	% reduction	Recommendations Undertaken in 2005		
		Recommendations	**Potential Annual Savings (kWh)**	**Other Potential Reasons**
3	13%	unknown (no update provided)	n/a	
17	17%	replaced bulbs	430	stopped using air conditioner (not originally one of HEMP recommendations); started adjusting time-of-day usage of dishwasher, etc., since house began use of smart meter
		used energy-saving features on computer	n/a	

Water

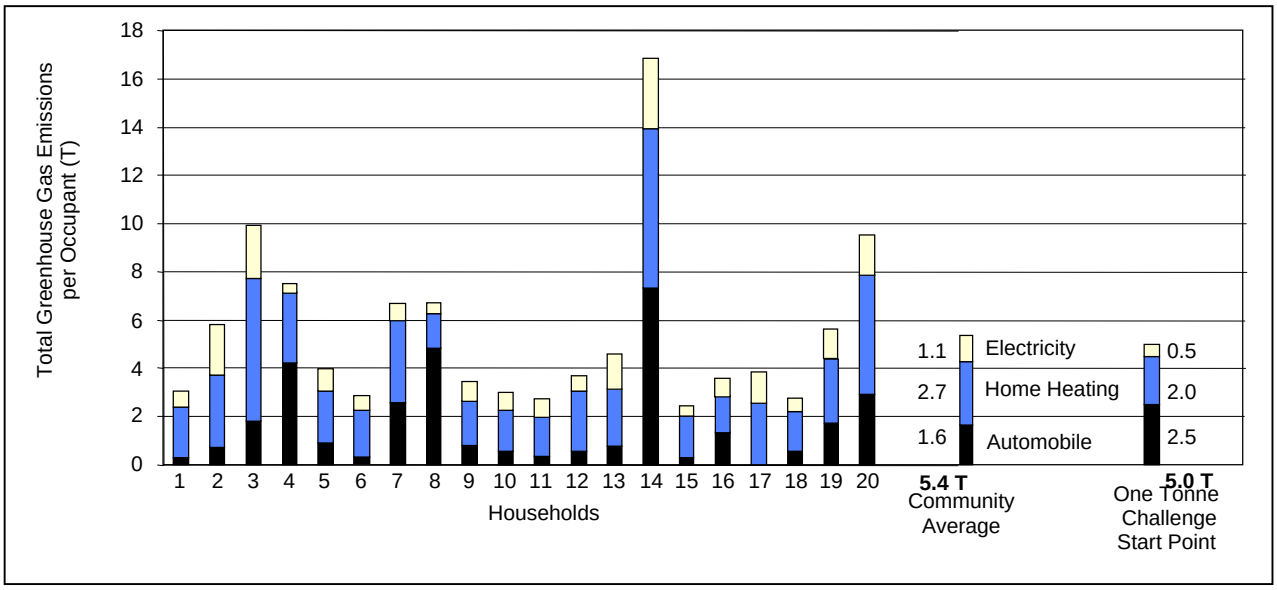
House hold	% reduction	Recommendations Undertaken in 2005		
		Recommendations	**Potential Annual Savings (L)**	**Other Potential Reasons**
3	44%	unknown (no update provided)	n/a	
7	13%	installed kitchen faucet aerator	3300	
8	26%	installed water-saving showerhead	10300	
		installed kitchen faucet aerator (just installed in September 2005)	550	
9	17%	none	n/a	
11	13%	repaired leaking faucets	20000	effective Sept 05: only 4 people living in household; 2005 avg. calculated between months Feb-Sept only
		installed water-saving showerhead	51500	
		installed kitchen faucet aerator	2200	
13	14%	reduced sprinkler use	8400	
14	34%	reduced sprinkler use	8400	
18	21%	installed rain barrel	n/a	
19	35%	unknown (no update provided)	n/a	
20	12%	reduced sprinkler use	8400	

Figure 8: Per Household Comparison of Annual GHG Emissions at the Beginning of the Study



Note : Greenhouse gas emissions calculated from October 2003 – October 2004 household utility records and 2004 monitoring week waste and vehicle fuel values.

Figure 9: Per Occupant Comparison of Annual GHG Emissions at the Beginning of the Study



3.2 Variability of Results

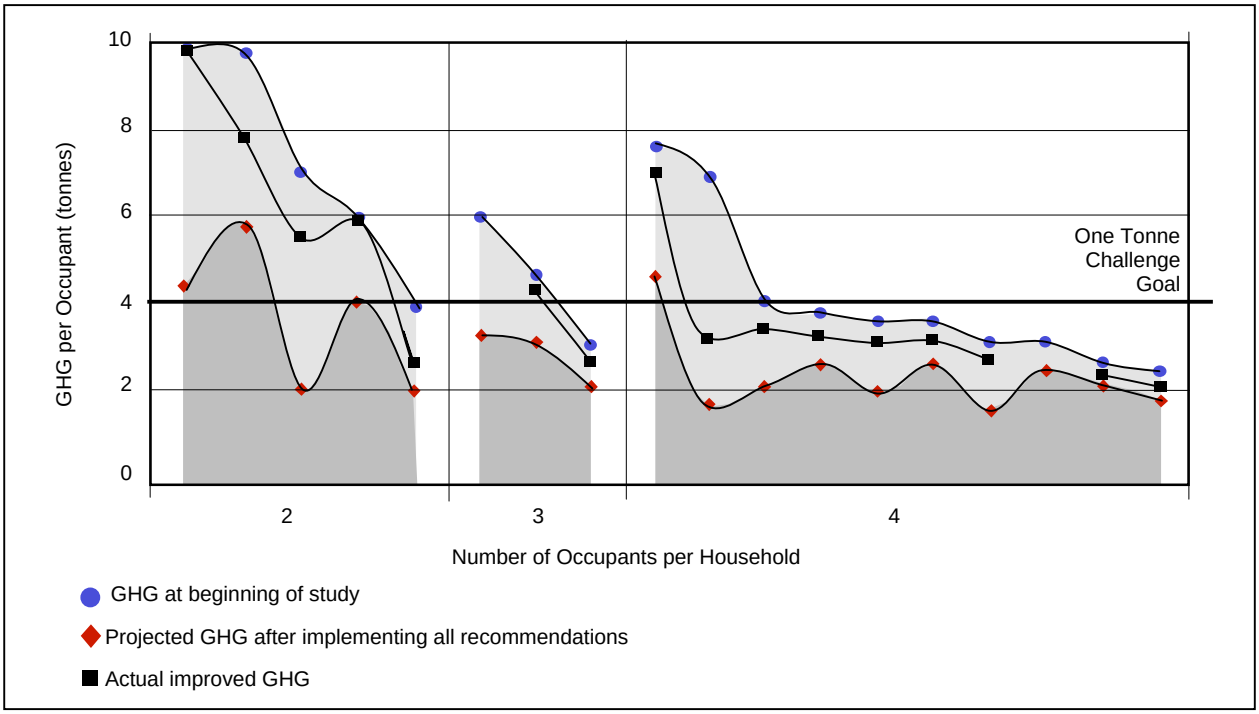
The environmental impact of the twenty households was assessed in the categories of home heating, electricity, water, personal transportation, and waste. The greenhouse gas emissions produced from home heating, electricity, and personal transportation were also presented as a combined total in order to allow comparisons with the One Tonne Challenge objectives.

The average greenhouse gas emissions recorded among the study group was 5.4 tonnes per person, very close to the One Tonne Challenge estimate of over 5 tonnes per Canadian. However, the percentage of this total derived from automobile use, home heating and electricity among the study group differed from the Canadian averages set out in the One Tonne Challenge. While the Canadian average is stated as 50% emissions from transportation, 40% from home heating, and 10% from electricity use, the study group breakdown was 30% transportation, 50% home heating, and 20% electricity. This is

reasonable for a community of older homes where low levels of insulation and air tightness result in increased heating costs, and where convenient access to downtown, shops and public transportation encourages lower than average automobile use. These results suggest that the kinds of environmental initiatives that will make the most difference could vary significantly between communities.

Each of these categories was calculated as both a household total and on a per occupant basis using the total household impact divided by the number of occupants. Figures 8 and 9 show the greenhouse gas results calculated on a household and per occupant basis at the beginning of the study. In doing this, we discovered that the variation was less on a household than per occupant basis, as the environmental impact of operating a household depended more on the size of the home and amount of vehicle use than the number of occupants. As a result, households containing one or two occupants tended to have higher environmental impact per person. These differences in results between two, three, and four person households are shown in Figure 10. Two person households in the study group averaged about 7 tonnes of greenhouse gases per occupant versus the 4 tonne per average of the four person households. The only two person household which operated at the average level of the four person houses was a very small house with no automobile use during the monitoring week.

Figure 10: Greenhouse Gases per Occupant vs. Number of Occupants



Results were presented for the monitoring week for all five categories, and as a weekly average for the previous year based on previous year utility bills for home heating, electricity and water. While these yearly averages based on utility bills were more accurate than the one week snapshot, in several cases the utility records could not be obtained or contained insufficient data, making the monitoring week records a useful tool for comparing all households. Data on vehicle use and waste generated was not available for more than the one week monitoring period for the purposes of the household report comparisons, however mileage was tracked for the year following the monitoring week in order to determine what a more typical yearly average was for each household. Participants commented that the one week period for tracking waste generated was too short to be very accurate, but also that they may not have been willing to continue their monitoring for a longer period, so this level of accuracy was accepted as a reasonable compromise.

The differences between per occupant environmental impact were substantial, as illustrated in Figure 11. Home heating fuel, electricity, and water consumption per occupant was 5.5 to 7.5 times greater in the highest consuming household compared to the lowest, with the average consumption being about 2.5 times the lowest recorded level. Vehicle emissions and waste production were even more variable, with highest levels at 11 to 21 times the lowest levels, and average levels at about 6 times the lowest levels. The total greenhouse gas emissions per occupant was 5.5 times greater in the household with the highest environmental impact compared to the lowest. These variations indicated that, for at least this population group, it is not accurate to assume individual Canadians are producing greenhouse gases at roughly similar rates, or realistic to ask them to cut emissions by the same amount.

Figure 11: Variability of Household Results

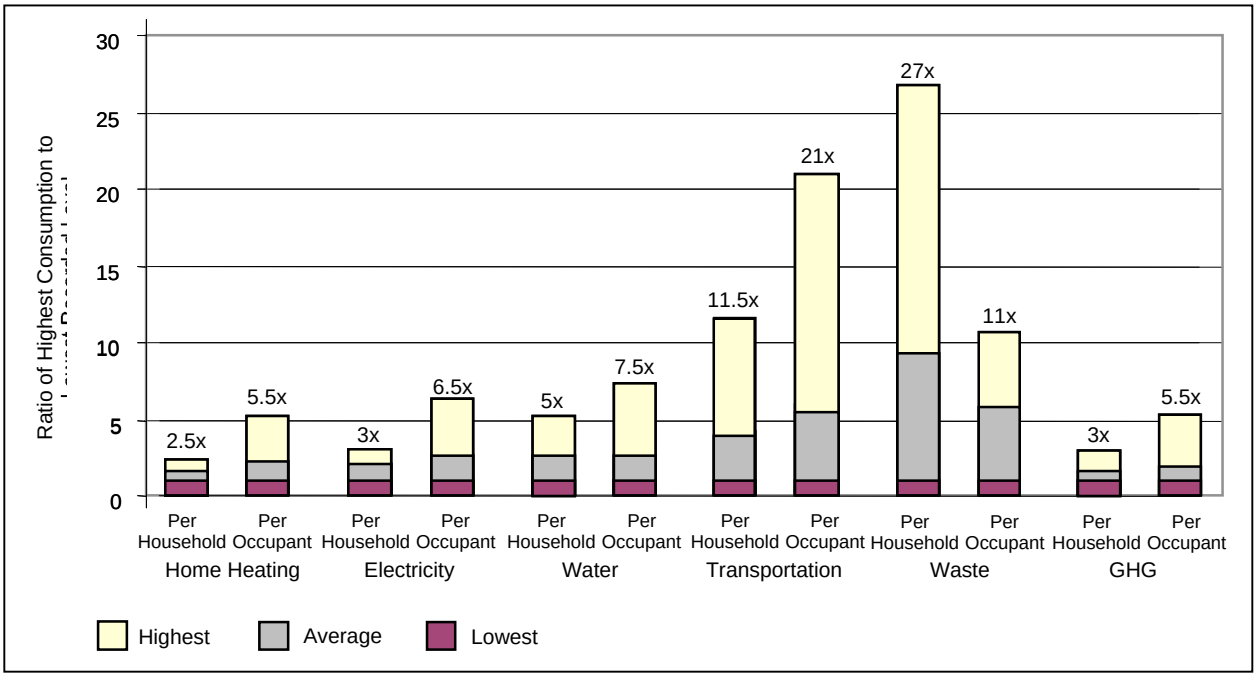


Figure12: Comparison of EnerGuide Estimation to Actual Energy Use

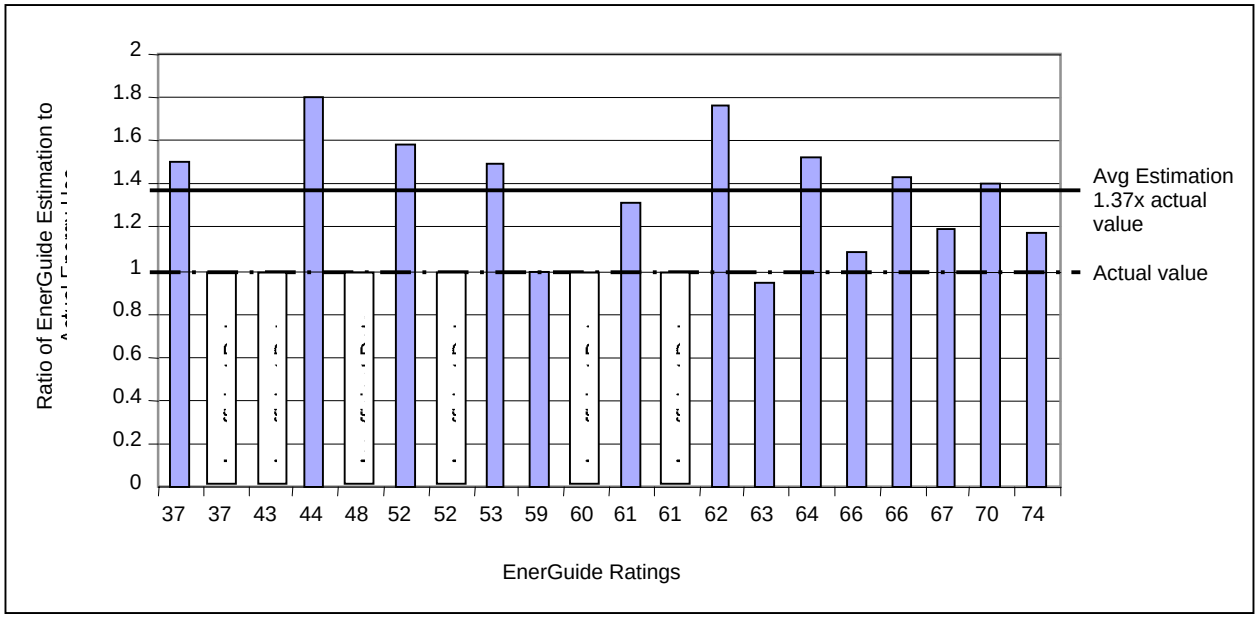


Figure 12 illustrates a characteristic of the EnerGuide program demonstrated while incorporating the energy assessment data into the *Household Reports.* The EnerGuide program uses standard assumptions to estimate existing heating energy and predict potential savings. In comparison with actual utility bills, these predictions were on average 1.37 times actual rates, with estimations up to 1.8 times actual values. While the use of standard assumptions simplifies the data collection process and treats all homes equally, the accuracy of the recommendations made to homeowners and expectation of savings are less accurate as a result. In comparing EnerGuide ratings of different ages of homes, it was interesting to note that a very carefully renovated 85 year old house could achieve the same energy efficiency rating as typical new home construction.

3.3 Factors Affecting Household Environmental Impact

The comparative consumption rates between households were analyzed against a series of factors to determine common causes of high and low environmental impact. In Figure 13, the participants' evaluation of their knowledge of techniques to reduce environmental impact and their perception of the extent of their efforts in comparison with other households was compared with their measured results. Seven households correctly identified themselves as doing more than others to reduce their environmental impact. Several of the households with above average emission levels believed they were doing as much or more than others. These were typically households where high automobile use or floor area outweighed other good environmental practices that had been adopted. Interestingly, none of the households judged themselves as doing less than others around them. These comparisons indicate that personal environmental evaluations are not a particularly reliable source of information, and that many households are unaware of their actual environmental impact.

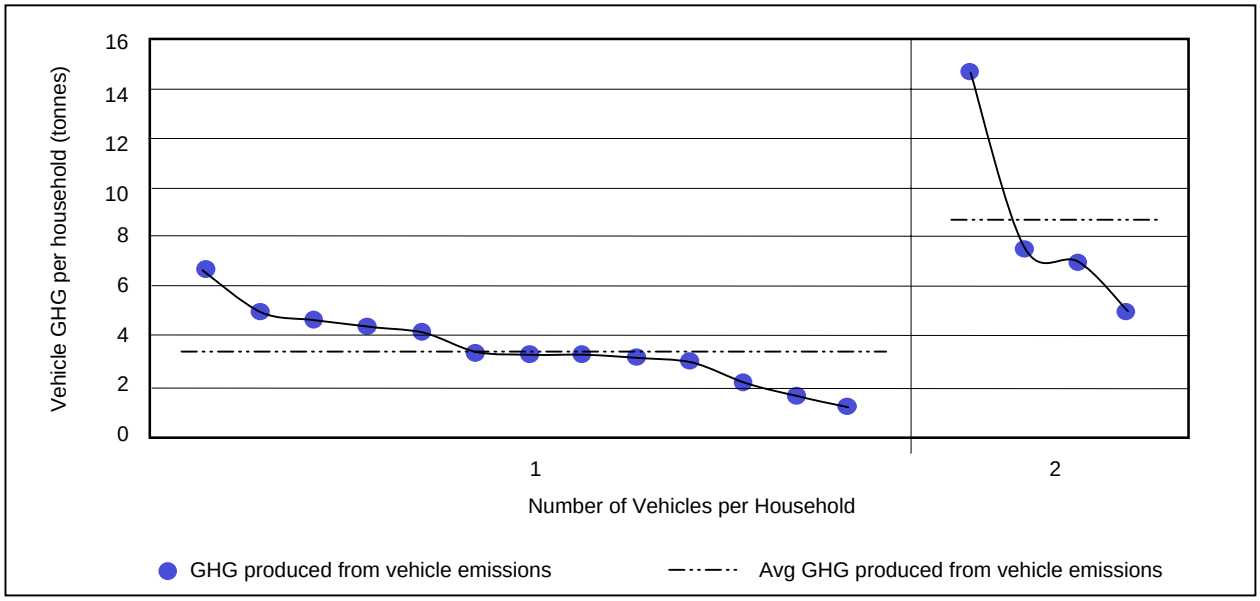
Figure 13: Level of Household Effort/Knowledge vs. Greenhouse Gas Emissions

		Self-Assessment				Measured Results	
No.	Number of Occupants	Knowledge of Environmental Options	Rate Personal Effort Compared to Neighbours	Total GHG (per Household)	Total GHG (per Occupant)	Above or Below Avg (Household)	Above or Below Avg (per Occupant)
1	4	fair	equal	12.2	3.1	3.0 below	2.4 below
2	2	good	more	11.7	5.9	3.5 below	0.4 above
3	2	poor	equal	19.5	9.8	4.3 above	4.4 above
4	4	good	more	29.9	7.5	14.7 above	2.1 above
5	4	fair	equal	15.9	4.0	0.7 above	1.4 below
6	4	fair	equal	11.9	3.0	3.3 below	2.4 below
7	2	fair	equal	13.7	6.9	1.5 below	1.5 above
8	4	fair	more	27.5	6.9	12.3 above	1.5 above
9	4	good	more	13.9	3.5	1.3 below	1.9 below
10	3	fair	more	9.1	3.0	6.1 below	2.4 below
11	5	good	more	13.5	2.7	1.7 below	2.7 below
12	4	fair	more	14.9	3.7	0.3 below	1.7 below
13	3	fair	more	13.9	4.6	1.3 below	0.8 below
14	1	fair	equal	16.7	16.7	1.5 above	11.3 above
15	4	good	more	9.8	2.5	5.4 below	3.0 below
16	4	fair	equal	14.0	3.5	1.2 below	1.9 below
17	2	fair	equal	7.6	3.8	7.6 below	1.6 below
18	4	good	more	10.9	2.7	4.3 below	2.7 below
19	3	good	more	17.3	5.8	2.1 above	0.4 above
20	2	good	equal	19.3	9.7	4.1 above	4.3 above
			Averages:	**15.2**	**5.4**		

Note 1: Shading indicates households that evaluated their environmental knowledge and/or efforts as above average, and those that achieved below average levels in the measured results. Shaded household numbers are those that correctly assessed their environmental impact as lower than peers.

Figure 14 illustrates a link between number of cars per household and greenhouse gas emissions. The four households that had more than one car averaged more than twice the greenhouse gas emissions of the one car households. Total driving distance was higher, and one of the two vehicles tended to be large and fuel inefficient.

Figure 14: Number of Vehicles per Household vs. Vehicle Greenhouse Gases



Heating energy, electricity and water consumption were plotted against household floor area per occupant with the results shown in Figures 15, 16 and 17. In each case, for households where the floor area per occupant ranged from 30 to 60 square metres, house area was not a determining factor with consumption fluctuating based on the extent to which environmental measures had been implemented. For households, however, where the floor area per person was well above average, consumption rose significantly.

The households with the highest environmental impact per occupant shared several common features. The floor area per occupant was generally higher than average, most owned two vehicles, at least one of which was a large fuel inefficient vehicle, they drove more than the average, and they tended to be homes with one or two occupants over 40 with no children living in the household. These lifestyle factors appeared to have more impact than the environmental features we think of most often like the quality of the building envelope or energy efficiency of appliances and fixtures. Strategies to encourage wise use of space, house downsizing as families age, and reduced vehicle size and use are an important part of efforts to reduce environmental impact. A few households with very high consumption had a disproportionate effect in raising the average environmental impact of the study group.

At the other end of the spectrum, 11 of the twenty households were already producing less than the One Tonne Challenge goal of 4 tonnes of greenhouse gas emissions per person. Four households were operating at less than 3 tonnes per person. These homes tended to be modestly sized for the number of occupants, they had been carefully renovated to increase insulation values, air tightness, and energy efficiency of appliances and fixtures, car use was low and/or they owned very efficient vehicles, and the owners were consciously adopting conservation practices. Although these four households were already performing well compared to typical levels, in each case the owners elected to implement 30% - 40% of the measures recommended to them to bring their greenhouse gas emissions down to between 2 and 2.5 tonnes per person. For many Canadian households it appears feasible to achieve targets well below the One Tonne Challenge goal.

Figure 15: Heating Fuel Consumption vs. Floor Area per Occupant

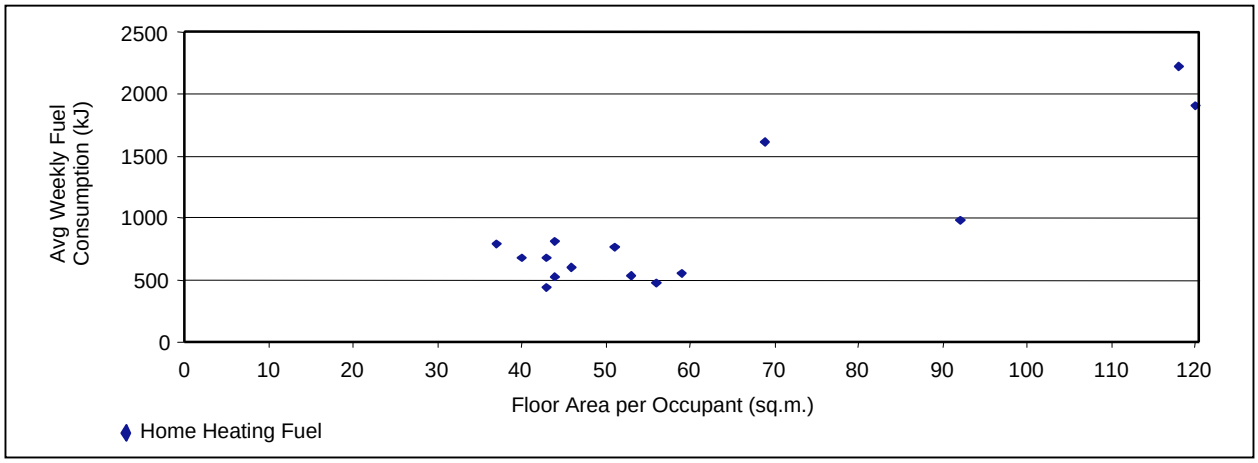


Figure 16: Electricity Consumption vs. Floor Area per Occupant

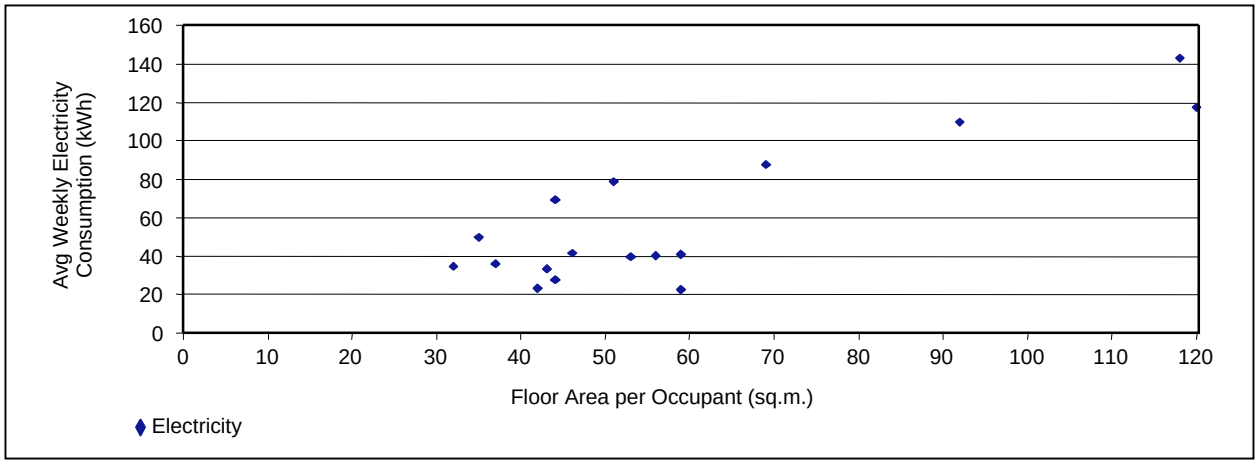
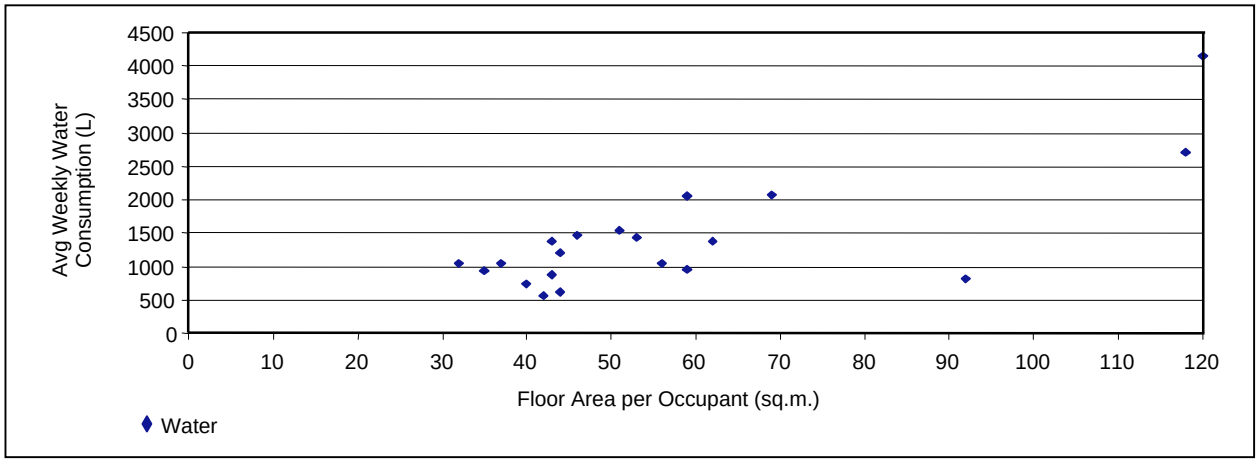


Figure 17: Water Consumption vs. Floor Area per Occupant



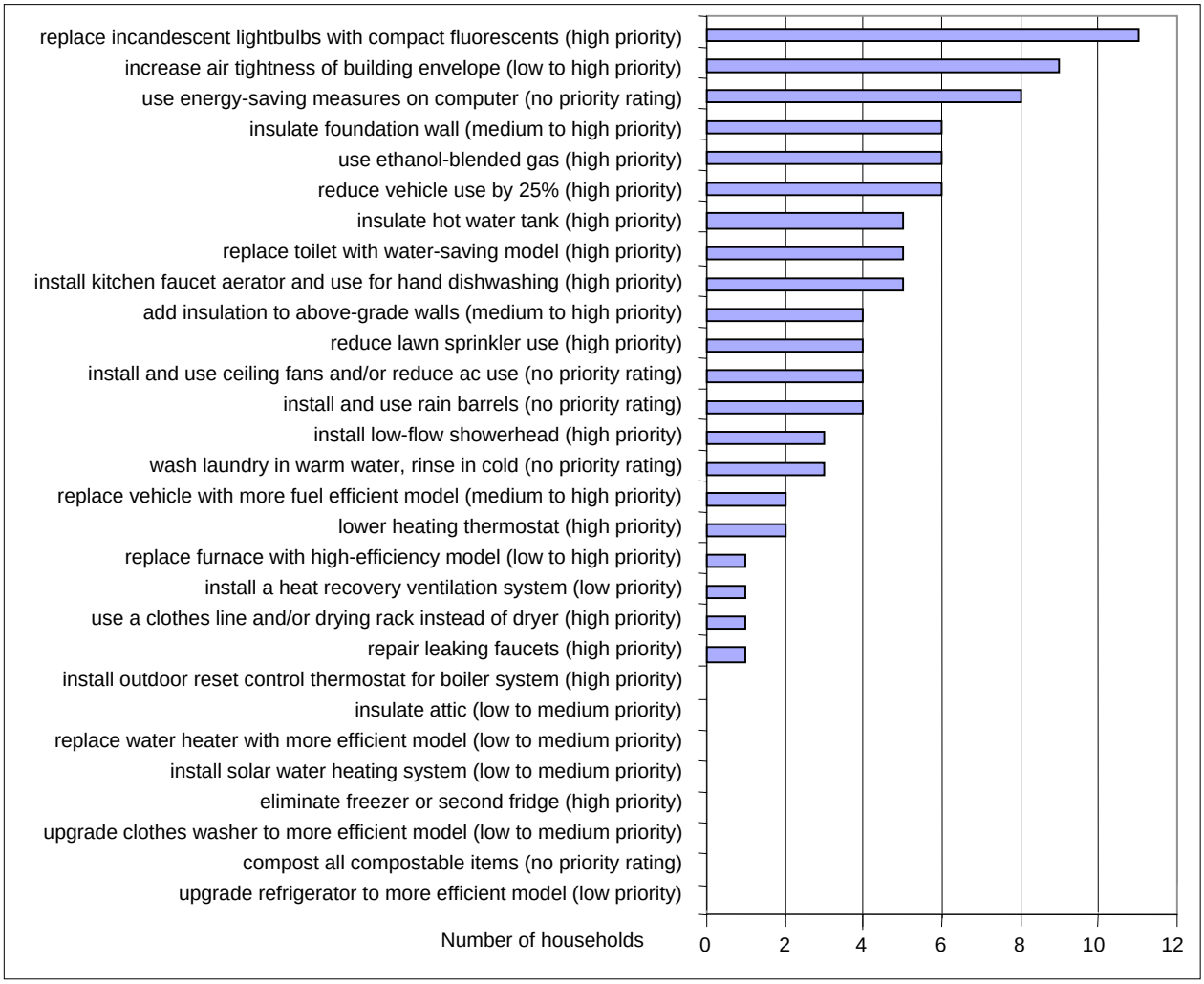
3.4 Most Viable Environmental Improvements

Of the approximately thirty environmental measures with a less than thirty year payback that were recommended to various households, thirteen were implemented by 20% or more of the households (Figure 18). These included the electricity saving measures of replacing incandescent light bulbs with compact fluorescent bulbs, activating energy savings settings on computers, installing ceiling fans, and reducing air conditioning use. Most popular heating energy reduction measures included increasing air tightness of the building envelope, and insulating foundation walls, above grade walls, and hot water tanks. Vehicle emissions reductions through lower vehicle use and ethanol blended gasoline were implemented by one third of households. The most frequently adopted water savings measures included replacing toilets with water saving models, installing kitchen faucet aerators, hand dish washing, reducing sprinkler use and installing rain barrels. All households were already recycling and 90% composting at the beginning of the study.

A survey of participants indicated that top priorities in making decisions about home upgrades were improving comfort and lowering operating costs, with reducing environmental impact and improving air quality ranked as lower priorities. The major obstacles to reducing environmental impact were seen as financial cost and lack of time and knowledge to evaluate and implement environmental measures. In keeping with this emphasis on practical, cost effective measures, the majority of the environmental measures that were implemented were those that the household report identified as high priority, with a less than 10 year payback period. Those with a payback period of more than 10 years tended not to be adopted in the first year, including more expensive items such as window replacement, solar hot water heating systems, or upgrade of appliances.

Appendix 6 includes a summary of the implemented recommendations that resulted in the most significant reductions to environmental impact.

Figure 18: Most Commonly Implemented Recommendations



4. Conclusions

These results indicated to the research team that the monitoring technique was of value in two ways. The technique succeeded in producing concrete reductions in environmental impact among the study group. In addition, detailed data was compiled on specific households that provided insights into factors affecting environmental impact and the types of initiatives that have the most potential to reduce that impact.

The following are potential avenues for further investigation in order to build upon and test the results obtained in this study:

- Continue to monitor the original study group to determine if the environmental reductions are lasting, and if the environmental momentum generated by this group can be used to influence the broader community.

- Simplify and standardize the monitoring technique so that it is a more economical and easy to use tool for a wider market.

- Repeat the monitoring process in order to test its effectiveness in different kinds of communities, and to gather information on how environmental impact varies between communities with different housing types and ages, income levels, urban design features and urban locations.

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