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# Investment in Technology & Voluntary Simplicity: Exploring Opportunities for Energy-Efficiency in the US Residential Sector

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Investment in Technology & Voluntary Simplicity:  
Exploring Opportunities for Energy-Efficiency in the US Residential Sector

Elaine Charlebois

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## Abstract:

This work examines alternative approaches for middle-class Americans to make lifestyle changes to promote energy efficiency. The US residential sector poses a significant opportunity for improvement in efficiency which will lead to electricity and carbon savings, further leading to long-term cost savings for each household.

A way to think about energy savings is by considering two radically different approaches: voluntary simplicity or investment in technology. Investments in technology include retrofits for existing homes and building new homes more efficiently, both focusing on aspects such as heating and cooling, insulation, water use and water heating, lighting, and appliances. Voluntary simplicity is rooted in choosing a simplistic lifestyle, and simplifiers make alternative consumption choices based on ethical and environmental considerations.

This paper will explore the advantages and disadvantages of both approaches, including potential barriers to implementation and solutions, and will analyze the potential economic impacts of a major shift towards either practice. While investing in technology or choosing to simplify are not mutually exclusive practices, by analyzing each method separately it becomes clear that embracing either approach or a combination of the two has great potential to positively impact both the US environment and the economy.

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## I – Introduction

### a. Why and how is the residential sector important in energy savings?

Direct energy use by households accounts for approximately 38% of overall United States CO<sub>2</sub> emissions, or 626 million metric tons of carbon (MtC) per year and is growing (Dietz et al. 2005, 18452). This is approximately 8% of global emissions and larger than the emissions of any entire country except China. US greenhouse gas emissions associated with household consumption (including indirect emissions) have been estimated to account for over 80% of total US emissions (Jones and Kammen 2011, 4088). Yet national policy initiatives thus far have addressed households only indirectly, mainly through setting motor vehicle, lighting, and appliance efficiency standards (Dietz et al 18452, 2005). US energy policy has recently focused increasingly on enhancing the efficiency with which the economy uses energy to deliver services such as transportation, refrigeration, cooking, space heating and cooling (Gillingham and Palmer 2014, 18). However, due to lack of federal policy to cap or tax CO<sub>2</sub> emissions, promoting low or zero energy emissions through a mix of standards and incentives has become the main policy approach (Gillingham and Palmer 2014, 18).

The United States residential sector is critical to overall energy savings and greenhouse gas (GHG) emissions reduction. According to McKinsey & Company (hereafter referred to as Choi et al.), the US residential sector is predicted to consume 29% of baseline energy nationwide in 2020 (Choi et al. 2009, 29). Relative to the ‘business-as-usual’ forecast, deploying all NPV-positive energy-efficiency improvements in the US residential sector would reduce its energy consumption in 2020 by 28%, saving the US economy an estimated \$41 billion in annual energy costs and avoiding about 360 million tons of CO<sub>2</sub> emissions that year alone (Choi et al. 2009, 29). Choi and coauthors (2009, 29-30) estimate that about 71% of the end-use potential (53% of primary energy potential) resides in improving the building shell and heating and cooling equipment mostly in existing homes and the remaining 29% of end use potential (47% of primary energy potential) is split between electrical devices, small appliances, and lighting.

While it is evident that the US residential sector has great potential for improvement in efficiency and overall reduction in energy use, debate arises over how significant change is possible. A major initial barrier to widespread change that many economists have studied is known as the energy-efficiency gap; this describes the behavioral anomalies that arise in consumer behavior when considering investment of time, capital, or both into improving energy efficiency. Although many studies have suggested that the present discounted value of future energy savings greatly exceeds the upfront costs of energy efficient

products, many consumers undervalue future cost savings causing the behavioral gap and leading to less investment than would be expected (Gillingham and Palmer 2014, 18-19).

Dietz and coauthors (2009, 18452) address the importance of the residential sector in energy savings as it relates to public policy decisions, arguing that “the potential of household action deserves increased policy attention. Further analyses of this potential should incorporate behavioral as well as economic and engineering elements”. Studies estimate that national implementation of household behavioral changes could cut US national emissions by nearly 10% with little or no reduction in household well-being (Dietz et al. 2009, 18452). While household action is by no means a complete solution to global energy and GHG emission issues, the residential space is an area with significant untapped potential that can utilize many technologies that are already available and cost-effective, as well as generate a more positive culture of environmentally-conscientious consumers. Such a shift towards environmentally conscious attitudes and behavior would generate further positive externalities and potentially lead to a complete paradigm shift in consumer behavior towards environmentally-friendly and efficient consumerism and lifestyles.

This study discusses how consumers can overcome the initial barriers to improving energy efficiency, and, assuming that they are able to overcome them, questions what approach middle-class Americans could take to becoming more environmentally conscious. The focus will be on two major schools of thought: voluntary simplicity and investment in technology at the household level, investigating the micro and macroeconomic implications of each alternative if practiced on a large scale, as well as examining potential cost and carbon savings.

For the purpose of this paper, we will focus on behavioral choices and investments made by the “average” middle-class American family, because this demographic group makes up the majority of the residential sector in the US. According to the United States Census Bureau, median annual household income between 2007 and 2011 was \$52,762. The average number of individuals per household from 2007-2011 was 2.60 people. Although this group is our focus, we will also address unique challenges to the low-income residential space, as these issues are tied closely with the more general issues of household investment barriers overall.

#### b. Addressing the energy efficiency gap

For the past several decades, environmental scientists, economists, suppliers, and retailers alike have been studying the behavioral and cultural drivers that affect consumer choices regarding energy efficiency. “Market failures including environmental externalities, inefficient pricing of energy, lack of

information, and agency issues can lead to inefficiently low levels of investment in energy efficiency....more recently, some economists have proposed systematic behavioral biases” to account for this gap (Gillingham and Palmer 2014, 19). It is critical to consider the energy efficiency gap and behavioral economics in the study of consumer energy choices. As Gillingham and Palmer (2014, 22) point out, “engineering estimates alone cannot fully estimate the net benefits – they may overstate them failing to consider hidden costs, heterogeneity in consumers, and failure to account for risk/uncertainty in the decision process”. Further costs to investing in more efficient products and technologies include the administrative costs of an energy efficient program, the time costs to research and install an efficient product that is equally as reliable as the known product, and the opportunity costs of alternative services or investments foregone to make the investment in energy efficiency (Gillingham and Palmer 2014, 22).

Further contributions to the energy efficiency gap come from principal-agent issues; when one party makes a decision related to energy use and another party pays or benefits from the decision. This applies primarily in landlord and tenant situations (Gillingham and Palmer 2014, 24). According to the US National Multi-Housing Council 2012 data, about 35% of the US population rents their home or apartment. This suggests that, depending on the education and awareness level of the population of renters, the principal-agent problem could potentially significantly contribute to the energy-efficiency gap. Empirical evidence supports this hypothesis, suggesting that landlord-tenant situations may lead to increased energy use (on the tenant side) and/or decreased investment in efficiency (on the part of the landlord) in the residential space due to several factors including imperfect information and distorted incentives of both landlord and tenant (Gillingham and Palmer 2014, 24).

A barrier that is perhaps more pertinent specifically to the residential sector than other sectors such as commercial or industrial is the issue of credit constraints. Many environmentally conscious technologies come with a high upfront cost for the buyer. Although many studies have suggested that the present discounted value of future energy savings greatly exceeds the upfront costs of energy efficient products, evidence suggests that many consumers “undervalue” future cost savings causing the behavioral gap (Gillingham and Palmer 2014, 19). Further exacerbating the problem, lack of information on the part of lenders about the payoff from energy investments may contribute to credit rationing (Gillingham and Palmer 2014, 25).

There is much economic and political debate surrounding the role of regulatory failures in the environmental space. More specifically, Gillingham and Palmer (2014, 25) note that regulation of the electricity markets results in prices that differ from marginal costs, and that this difference can distort

incentives away from efficient behavior. If regulated prices fall below marginal cost, regulation contributes to the gap, but net, “it is unlikely that regulatory failures are an important explanation for the energy efficiency gap” (Gillingham and Palmer 2014, 25).

While all of the aforementioned factors play a role in contributing to the gap in energy efficiency, arguably the largest portion comes from a cluster of consumer behavioral anomalies. Behavioral anomalies do not arise from irrational or random choices but rather must assume that consumers vary from the standard utility maximization with systematic biases (Gillingham and Palmer 2014, 26). Such systematic biases create a difference between decision utility, the utility consumers maximize at the time of choice, and experienced utility, the hedonic utility that the consumers later experience as a result of the prior decision. In the most general sense, behavioral economists have classified behavioral anomalies into three major categories, all of which can tie back to the energy-efficiency gap: nonstandard preferences, nonstandard beliefs, and nonstandard decision making (Gillingham and Palmer 2014, 26).

Nonstandard preferences can be classified as self-control problems, reference dependence, and social preferences (Gillingham and Palmer 2014, 26). Reference-dependent preferences refer to decision making under uncertainty in which the utility from any positive or negative payoff depends what it is in reference to. Empirical evidence suggests that consumers consistently exhibit tendencies towards loss aversion (Gillingham and Palmer 2014, 27). This type of behavioral anomaly can be extended to energy related decision making in several ways. For example, a consumer with imperfect information may be unwilling to make a large initial investment in an energy-saving appliance due to loss aversion and concerns about whether the appliance will “pay for itself” in cost savings and over what timescale. Social preferences have the potential to relate to the energy efficiency gap in a positive manner; for if the “nonstandard” social preference towards environmental concern becomes more widespread, a paradigm shift could occur, making a consumer who is less environmentally and energy conscious the anomaly.

Nonstandard beliefs, or systematically incorrect beliefs about the future, affect energy savings and investment in a large way (Gillingham and Palmer 2014, 27). For example, Allcott et al. (2010, 3) propose that consumers surveyed cannot estimate the true cost of fuel cost savings in a fuel-efficient vehicle holding driving behavior constant. Survey respondents most often used calculations that did not represent a simple net-present value calculation (Allcott et al. 2010, 3). Further behavioral economic studies are needed to address this anomaly, perhaps the most perplexing and widespread issue affecting consumer behavior as it relates to the energy-efficiency gap.



Finally, nonstandard decision-making is a large factor in the energy efficiency gap. There are many forms of nonstandard decision making, but Gillingham and Palmer (2014, 28) argue that the three forms of nonstandard decision-making relevant to energy efficiency are limited attention, framing, and suboptimal heuristics used for choices out of menu sets. The idea of limited attention is closely tied to models of bounded rationality, in which consumers simplify complex decisions by processing only a subset of information (Gillingham and Palmer 2014, 28). These effects combined with limited attention and misestimates lead to inefficient consumer choices. For example, Turrentine and Kurani (2007, 1217-1219) perform structured interviews with recent car buyers and conclude that nearly all consider future fuel savings in a very simple way that does not resemble calculating the present discounted value of future fuel costs. Evidently, when faced with a wide array of choices for simplifying or investing in technology to save energy, the average consumer will not process the entirety of the available information and will instead make a decision based on limited research, leading to inefficient choices.

The systematic biases that play a role in the energy efficiency gap are by no means the only barriers to efficiency in the residential space, but serve as an important basis for understanding the underlying consumer behavior that impacts all consumer choices in both voluntary simplicity and investment in efficient or alternative technology.

## II – Investment in technology

Although the two are in no way mutually exclusive means to save energy and benefit financially, there is debate over whether it is generally better to invest in new technologies to become more environmentally conscious, or to take the route of voluntarily simplifying one's life. Which method leads to more cost-savings in the short and long term? Which method leads to more carbon savings? Is one method behaviorally preferable or more likely to be practiced on a large scale than the other? What are the economic impacts of each method? These crucial questions will be explored throughout this piece.

### a. Introduction

According to The Economist (2008), major factors that have contributed to a 'green housing boom' over the past few decades are rising energy prices, new efficiency standards, and improved technology. Although these technologies have existed for some time, they have recently been developed for the mainstream market. In 2007, McGraw Hill Construction estimated that 40% of all residential renovation in the US that year included some green features, largely windows or heating and

cooling systems designed for efficiency and savings. This percentage is expected to rise, as The Economist (2008) predicts that it will become “typical of a new generation of green building homes to have a dramatically reduced environmental impact but not require big changes to their inhabitants’ lives”.

Depending heavily on their beliefs, preferences, and financial situations, consumers may decide to make large or small investments in efficient technology at the household level. As awareness about environmental issues has risen sharply since roughly the 1960s, technology has been able to advance in order to make new energy-saving technologies available to the average middle-class US consumer. Programs have been put in place to both quantify costs, energy savings, and carbon savings, and to raise awareness towards methods of attaining a “green” home. For example, for over a decade the EPA has offered Energy Star Certification for homes, and in 2007 the US Green Building Council released versions of LEED certification standards that apply at the residential level (The Economist 2008). Case studies yield some insight into the costs and benefits of such a certification. For example, according to estimates reported in The Economist (2008), a 2100ft<sup>2</sup> house costs an additional 23% (estimated \$75,000 additional cost) to build LEED Platinum Certified (the highest LEED certification) than the estimated cost to build conventionally. The homeowner was able to recoup about \$35,000 in rebates and incentives from state and federal governments. It would be helpful if the example provided an estimated payback period for the total energy savings of this home.

Despite the long-term cost and efficiency benefits of entire-home projects, a large percentage of middle-class households are unable or unwilling to invest the time, research, and capital into such a large scale project. Thus it is important to break down the potential investment into the several pieces of technology in which one could invest in a newer, more efficient model at the individual level. The optimal consumption bundle for each consumer would be slightly different depending on household size, electricity and appliance use, and several other factors. However, it is clear that larger up-front investments, such as a heating and cooling system or improved insulation, will ultimately yield larger payoffs and greater electricity and carbon savings. The two major sectors for improvement in existing homes are the building shell and household appliances.

#### b. Building Shell

The major pieces of a residential structure that can be improved using technology are the heating and cooling system, insulation, and the water-use and water-heating system. These shell improvements can be either low or high capital (Choi et al. 2009, 34). Low-capital maintenance includes

installing programmable thermostats, sealing home air leaks and ducts, and performing routine HVAC maintenance. In this space, older homes have significant potential for improvement (Choi et al. 2009, 34). Higher capital improvements include investments such as installing solar panels, geothermal heat, or any costly investment requiring more access to credit and having a longer-term payback period.

Choi et al. (2009, 32) discuss the use of efficient home-building design for new homes, focusing on the sector's large potential for growth as well as significant barriers to implementation. The intrinsic value of whole-building design is in viewing a building as a system that can be optimized within a specific site rather than focusing on a set of independent end-uses; Choi and coauthors argue that this type of design is able to achieve additional energy savings in a cost-effective manner relative to investments in one particular technology. The approach requires a fundamental change in how end-users interact with energy and offers many opportunities. Whole-building design has the potential to optimize the structure for the local environment, as design decisions such as building orientation, landscaping, and exterior design can organically reduce the demand for heating and cooling. Optimal designs vary by climate and latitude but typically save 10% of energy use, and can save up to 40% in some cases (Choi et al. 2009, 32-33).

However, significant burdens remain in developing and implementing whole-building design projects. Choi et al. (2009, 33) point out that "due to specialization in education and building trades, contractors tend to design each mechanism system in isolation". A shift towards contractor training in holistic design rather than one specialization such as insulation, plumbing, or electricity alone would be necessary to meet demand. If this industry became more widespread, this could also lead to job creation in this area. Closely related to the need for increased training is the need to improve design and installation processes. Improper design and installation of HVAC equipment and building insulation can reduce their efficiency by as much as 30% (Choi et al. 2009, 33). In order to achieve the full potential of energy savings, the consumer as well as the installer must be well-informed. By integrating various systems in the home, holistic design would reduce energy consumption and encourage savings (Choi et al. 2009, 33).

Closely tied to holistic building design is the option of whole-home retrofitting for existing homes. This could involve a variety of measures including replacing insulation, windows, installing a passive heating and cooling system, and upgrading appliances (Choi et al. 2009, 35). Barriers to retrofitting existing homes are arguably higher than those surrounding holistic building for new residences. Although a home retrofit has the potential to save energy and carbon emissions, a long payback period and lack of consumer awareness have thus far prevented full-home retrofitting from

being a very popular efficiency investment. According to Choi et al. (2009, 35), “homeowners don’t understand their home’s energy consumption and are unaware of energy saving measures. Half of homeowners consider recycling and energy efficient appliances as ways to reduce GHG emissions, although only 15% indicated that improving insulation would be a preferred means [of saving energy]”. This sentiment reveals a lack of consumer awareness, as improving insulation is typically significantly more effective at saving energy in the form of fuel savings compared with other measures.

Consumers also tend to underestimate retrofit savings. A survey asked consumers how much they would expect to save from a home insulation improvement project involving replacing insulation, caulking, and sealing the home. “These measures provide utility bill savings of 10-25%, but nearly 75% of respondents estimated the utility bill savings at less than 10%” (Choi et al. 2009, 35). Similarly, fewer than 2% of US homes have had an energy efficiency rating or assessment to identify savings opportunities in the home (Choi et al. 2009, 35). The opportunity to increase the number of home efficiency ratings and assessments is important in raising consumer awareness and helping consumers make more informed decisions customized to their home.

The final largest burden to both holistic home design and whole-home retrofitting is the decision to pursue savings. This is a burden to virtually every technological investment; however, it is likely to most affect an entire-home project because it is initially the most costly option. In an average middle-class home, competing uses for capital in the homeowner budget inhibits allocation of money to energy-saving investments in many cases (Choi et al. 2009, 35). “Core-spending accounts for about 90% of a typical household’s budget, leaving only 10% for retrofitting and other home improvements. A typical residential energy efficiency retrofit costs about \$1500, based on a median annual US household income of \$50,740” (Choi et al. 2009, 35). This reveals that the cost of retrofit would be an affordable option for the family if they paid the “average” price and were planning to live in the home long enough that the investment would be worthwhile. However, a typical family would need to plan and save in advance in anticipation of this investment.

Finally, high transaction costs are a barrier in several types of home investments. “Such barriers arise as consumers incur significant costs in researching, identifying, and procuring efficiency updates, as well as preparing for and enduring lifestyle disruption during the improvement process” (Choi et al. 2009, 36). Uncertainty of savings capture adds to the consumer risk and increases the transaction barrier.

Even after committing to pursue the efficient investment, challenges remain. Poor quality of insulation or improper use of equipment after installation can reduce or eliminate the potential savings

(Choi et al. 2009, 36). Overall, it would be most beneficial for companies offering whole-home retrofits and efficient new home building design to implement training for specialists and employ a consultant or advisor to serve as a liaison between the contractor and customer for the duration of the project. The consultant could assist the customer with the financial questions they may have and assist in the process of obtaining a loan and in calculating an estimated payback period for the energy savings of the project. This would promote greater transparency and encourage residences to pursue whole-home improvement projects.

### c. Home Heating & Cooling

Investment in efficiency for home heating and cooling is closely tied to a whole home retrofit because improving the building envelope to be thermally-well insulated is the most critical aspect to achieving energy savings (Cansino et al. 2011, 3809). Dovjek et al. (2010) illustrate that insulation of buildings has a much greater effect on reducing energy requirements than do improvements in boiler efficiency, and Cansino and coauthors (2011, 3809) extend the analysis to show that holistic approaches that combine improving insulation with an upgrade to the heating system will result in the greatest energy savings. Although many consumers may be unaware of the relative quality of insulation in their homes, Cansino et al. (2011, 3809) note that since 1990, new properties in the EU require about 60% less energy for heating compared with properties built before. This shows the significant opportunity for savings in this sector if homes built before 1990 focused on upgrading insulation. Additionally, with the rising costs of home heating oil averaging over \$4 per gallon in the US, the potential for savings in home heating costs is high with a short payback period.

Cansino and coauthors (2011, 3809) study policy measures implemented in the EU-27 which the US could potentially model. “Two facts explain why government-implemented measures should be specifically related to residential heating and cooling features: the fact that the heat generated from residences has to be used locally because it is not possible to feed it back into a distribution grid, and the fact that there are no major operators given that most producers are households. Therefore, the diversity of measures taken by countries is in line with that expected”. In a comparative analysis, Cansino and coauthors (2011, 3810) note “Denmark has only used fiscal incentives and showed an improvement in efficiency of 7.6%, while Cyprus has only used subsidies and shown a 7.1% growth. Government financial support is seen therefore as a necessary and appropriate instrument to ensure the development and uptake of technology based on residential heating and cooling”.

Subsidies have been the most widely used instrument employed to encourage improvement in residential heating and cooling efficiency (Cansino et al. 2011, 3810). The main reason for subsidies is that they encourage adopting specific technologies that are capital intensive by reducing the up-front costs of investment in a straightforward manner. Cansino et al. (2011, 3810) note that “subsidies are an easy way to promote residential heating and cooling efficiency because their application is based on a simple scheme. First of all, the size of the subsidy is easily fixed as a percentage of the total cost of investment. Second, subsidies allow authorities to discriminate between not only the technologies promoted but also the type (public or private) of beneficiaries”.

The major disadvantage of a subsidy is the close link to budgetary resources and therefore to budgetary constraints, making the number of projects limited. Further, a subsidy could lead to a higher cost of the good because manufacturers will tend to raise prices in anticipation of the discount granted to the consumer (Cansino et al. 2011, 3810). Additionally, subsidies carry the disadvantage of being an ex-ante incentive. Investors are required to apply for funding and preapproval before installing the good. The bureaucratic process slows the rate of investment and could even deter some consumers from proceeding (Cansino et al. 2011, 3810). Consumer misinformation could also play a role at the residential level in particular, where consumers may not be aware of the potential to access a subsidy or how much the subsidy would help fund their investment. Another disadvantage is that the government must fund the subsidy through distortionary taxes. Based on these disadvantages the World Energy Council in 2008 said it would be desirable to actually reduce the number of subsidies in favor of looking for other ways to reduce cost to consumers or development of alternative financing methods (Cansino et al. 2011, 3810). Of course from a pure economic efficiency perspective it would also be advantageous to limit the total use of subsidies as well.

Tax credits are another form of subsidy that may aid in financing a home heating and cooling retrofit. An advantage to tax credits is that the investor is able to receive compensation after they have carried out the installation, which Cansino et al. (2011, 3810) argue is a faster and simpler procedure than applying for a subsidy. Weighing against this advantage is the notion that a tax credit is an ex-post incentive which does not lower the initial cost. Therefore they would not be as helpful to low income households or middle-income households subject to credit constraints (Cansino et al. 2011, 3810).

Although low-interest loan options have been used sparingly in the residential energy efficiency sector, they have the advantage that they can bring down the average cost per unit and can easily be implemented by banks rather than government programs. The 2008 World Energy Council report suggested that measures promoting low interest loans in efficient investments should be increased, but

notes that this measured does not guarantee investments will be made in specific targeted technologies and would therefore need to be accompanied by regulations (Cansino et al. 2011, 3810-3811).

Although difficult policy decisions will need to be made in order to encourage larger investments such as a whole home retrofit to improve insulation and heating and cooling efficiency, it is clear that the significant barriers to investment for the average middle class consumer stand in the way of investments at this time. Better consumer information combined with tax credits and low-interest loans would be beneficial ways to incentivize consumers and encourage whole-home improvements towards greater efficiency.

#### d. Water Use & Water Heating

Investment in reduced water use and more efficient water-heating at the residential level is an important step towards efficiency with not only great savings potential but also with large-scale ecological benefits. According to a water-use and infrastructure study by Novotny (2013, 590), the United States average total energy consumption for treating, delivering, and disposing of used water is about 7% of total energy consumption, while the global average is only about 3% energy use for this purpose. This suggests that many other nations have infrastructure designed to better support efficient water use and distribution. Part of this problem is geographic, with water shortages in the southwest United States becoming more problematic each year. Because water to these states must be mostly imported, “water-related energy use is especially high in some areas in the western US states with water shortages, reaching 19% in California” (Novotny 2013, 590).

Estimates of total per-capita US water use are exacerbated by extensive outdoor irrigation, water leaks, and swimming pools, averaging about 650 liters per capita per day (about 171 gallons); the highest in the world and a factor of 2 or 3 compared to Europe (Novotny 2013, 591). Virtual water footprint, a measure of water-use that accounts for indirect uses and inputs, is about 3 times higher in urban areas than average household use due to water-demanding production activities including agriculture, production of electricity, and fuel/oil use (Novotny 2013, 592). Thus while the individual may have minimal control over the indirect contributors to daily water use, they do have control over direct total household water consumption and should take measures to reduce excessive water use. However, irrigation is the largest water use in a typical US household, which is problematic because this is an indirect water use accounting for consumption of food from irrigated agriculture. Thus a large-scale agricultural shift would be needed to realize the greatest potential water savings at the household level (Novotny 2013, 593).

A large problem with controlling household water use is lack of awareness combined with the lack of incentive to save due to the artificially low costs of municipal water. Renwick and Archibald (1998, 357) find that demand side management through water pricing policies has the potential to increase conservation. Although household water demand is overall responsive to price changes, lower income households were found to be five times more price-responsive compared to wealthy households. “These results suggest that price policy will achieve a larger reduction in residential demand in a lower income community than a higher income community, all other factors held constant...[and] lower income households would bear a larger share of the conservation burden” (Renwick and Archibald 1998, 357). These results suggest that increasing the price of municipal water would not necessary be a favorable policy for social equality reasons.

Use of greywater systems can lead to water savings of up to 70% with accompanying reduction of energy use and GHG emissions (Novotny 2013, 592). ‘Greywater’ is wastewater generated from household uses such as bathing and laundry. Unlike ‘blackwater’ containing food waste or sewage, grey water has the potential for reuse if separated in the waste stream (Allen et al. 2010, 5). “When greywater is reused....it has the potential to reduce the demand for new water supply, reduce the energy and carbon footprint of water services, and meet a wide range of social and economic needs” (Allen et al. 2010, 5). “By appropriately matching water quality to water need, the reuse of greywater can replace the use of potable water in non-potable applications like toilet flushing and landscaping. For instance, many homes have one set of pipes that bring drinking water in for multiple uses and another that takes water away. In this system, all devices that use water and all applications of water use a single quality of water: highly treated potable drinking water. This water is used once and then it enters a sewer system to be transported and treated again, in places where wastewater treatment occurs. In most modern wastewater systems treated wastewater is then disposed of into the ocean or other water bodies, voiding the reuse potential of this treated wastewater. In other places, once used wastewater may be disposed of directly in the environment. This system wastes water, energy, and money by not matching the quality of water to its use. A greywater system, on the other hand, captures water that has been used for some purpose, but has not come into contact with high levels of contamination, e.g., sewage or food waste. This water can be reused in a variety of ways. For instance, water that has been used once in a shower, clothes washing machine, or bathroom sink can be diverted outdoors for irrigation. In this case, the demand for potable water for outdoor irrigation is reduced and the streams of wastewater produced both by the shower, washing machine, and sink are reduced” (Allen et al. 2010, 6).



A problem with greywater systems is difficulty of implementation into existing infrastructure. “Reuse of greywater requires separating greywater from sewage water, which is not standard plumbing practice in many countries, and therefore requires plumbing retrofits. The difficulty and expense of this retrofit varies widely, depending on the building and complexity of the system” (Allen et al. 2010, 20). Although this makes community-wide greywater systems difficult to implement, smaller technologies operating similarly are available today. For example the OrbSys shower recycles water in a closed loop system, saving 90% of water and 80% of energy compared to an average shower (Blendis and Rivalland 2013). Widespread use of this technology would bring ecological benefits and the purification technology developed could be implemented in taps and drinking fountains in developing countries (Blendis and Rivalland 2013).

In total, significant water and energy savings at the household level can be achieved by installing appliances such as efficient showerheads, low-flush toilets, low energy clothes washers and dish washers, and efficient water heaters (Novotny 2013, 593). However, “it is difficult to use traditional economic methods for enumerating the benefits for projects which involve pollution abatement, carbon and other footprints, watershed management, value and enjoyment from living within a green community”. Many of these benefits are intangible, thus community residents must have a willingness to pay for these benefits (Novotny 2013, 602).

#### e. Appliances

If a consumer is unable or unwilling to invest in a whole-home project aimed at energy savings, many smaller and less expensive alternative investments are available for this “quasi-green” consumer. Bansal et al. (2013, 3748) reviewed the household appliance industry with a focus on reducing electricity consumption through design and innovation. This study “presents an overview of the options and potential barriers and risks for reducing the energy consumption...and emissions of seven key energy consuming residential products”, with a primary focus on the potential energy savings from use of advanced technologies in appliances in the US market.

Bansal et al. begin by addressing the major barrier of high initial cost, noting that although significant energy savings may be achieved, the cost barrier negatively affects both the supplier and the consumer. Suppliers must direct capital toward research and design of new products, and consumers must be willing to pay a premium for a more efficient appliance. Bansal et al. (2013, 3748) argue that an important way of addressing this issue is “to ‘level’ the playing field for all manufacturers by establishing Minimum Energy Performance Standards (MEPS), which are not cost prohibitive and are effective at

promoting energy efficient products through incentives to both manufacturers and consumers”. While there is some intrinsic value to establishing minimum efficiency standards and such standards generate positive externalities for society, Bansal and coauthors’ argument that the standards can help overcome the cost barrier on the supply side is weak. The household appliance industry is not one of undercutting prices because most household appliances are durable goods; rather consumers look for quality and a lasting product that will be of good value. It is doubtful that most appliances sold in the US would not meet some hypothetical “minimum efficiency standard”. The least efficient products are older ones that are still operating in existing homes. Perhaps a subsidized trade-in program to recycle an old appliance and receive credit towards purchasing a new one could foster change on the consumer side, although such a program should be implemented with caution as programs in the past like “Cash for Clunkers” have been shown to have mixed effects (Li et al. 2011, 27).

Methods developed over the past two decades that have led to improvement in household appliance efficiency include the following: energy labeling, increased availability of efficient appliances at the residential level, voluntary agreements, demand side management, and the enforcement of minimum energy standards. Demand for major appliances is growing worldwide, especially in developing countries; hence the improved energy efficiency in household appliances is of priority for many governments (Bansal et al. 2013, 3748).

#### i. Large Appliances

Refrigerator-freezers are among the most common household appliances in the world, contributing approximately 7.2% of the average US household energy consumption (Bansal et al. 2013, 3749). Insulation and air leakage are typically the major factors affecting thermal performance. Cabinet improvements, making structural changes to the appliance to increase cabinet internal load and thermal performance, utilize technology that is currently available. However, cabinet improvements have been largely ignored in energy measurement standards to date (Bansal et al. 2013, 3749). Advanced insulation, aimed at reducing cabin heat gain rather than altering the structural build of the appliance, has the potential to lower electrical power input by up to 25% (Bansal et al. 2013, 3749). Advanced insulation has not yet significantly impacted the retail market due to high costs of research, design, and testing, and difficulty procuring dependable and safe insulation materials.

Another means of improving refrigerator-freezer efficiency is the use of vacuum insulation panels (VIPs), which consist of powder and fiber filled panels, [and] compact vacuum insulation with stainless steel walls or aerogels (Bansal et al. 2013, 3749). “Although VIPs have been used intermittently

in the refrigeration industry for several decades, there is a view in the industry that they sometimes fail to achieve expected improvements. The challenge facing VIPs and similar advanced insulation panels is that they cannot be used in corners or edges and have to be integrated with the blown foam to maintain structural integrity. This would require a novel manufacturing process with retooling and additional labor costs....thus there is a need for breakthrough cost reduction technology to enable wide-scale use in domestic refrigerators” (Bansal et al. 2013, 3749). Based on Bansal’s summary it seems that use of vacuum insulation panels, once further developed, could be beneficial in the commercial refrigerator-freezer space. However, due to the structural restrictions of inability to install in corners and edges, it could be argued that use for this technology in the residential sector is unlikely.

The final major structural revision that could be made to refrigerator-freezers is improved gaskets. Current refrigerator door seals utilize magnetic strips that are encased in flexible polyvinyl chloride (PVC) gaskets. The magnetic material attaches to the steel outer wrapper of cabinet to form a seal. The metal in contact with the gaskets provides a heat transfer path resulting in heat leakage into the refrigerator (Bansal et al. 2013, 3749). Research efforts applied to gasket improvements have been limited, possibly due to variations in cabinet and door designs. As other improvements are made in the cabinet and vapor compression system, heat losses around the gasket will become more significant. This will render gasket improvements more significant as potential contributors to improving refrigerator energy efficiency. Finally, consumer safety laws that prohibit the use of excessive door sealing forces contribute to the inherent problem of reducing energy loss in the gasket area (Bansal et al. 2013, 3749-3750).

Although these ideas show that there are significant opportunities to improve electrical efficiency of residential refrigerator-freezers, perhaps a more pressing need and greater opportunity lies in changing the chemical refrigerant. Following the phase out of chlorofluorocarbons (CFCs) in the late 1970s, residential refrigerators sold in the US have been using hydrofluorocarbon (HFC) refrigerant HFC-134a, which has a global warming potential (GWP) 1430x that of carbon dioxide, based on estimated impact over a one-hundred year period. It seems that the urgency with which CFCs were removed from production due to the damage they cause to stratospheric ozone led to a situation where the replacement fluid was only slightly better for the environment. Thus, there is now an urgency to replace hydrofluorocarbons with a lower GWP alternative, and HFCs are currently scheduled for phase-out in Europe and Japan (Bansal et al. 2013, 3750). Recently DuPont and Honeywell have identified new single component, sustainable alternative refrigerants with low GWPs of 4-6 and low toxicity levels – testing is currently ongoing to determine the energy saving and ecological implications of these alternative

refrigerants. The energy savings potential is estimated at 5%. Barriers to this method include a more complex and more costly manufacturing process, and a need for product redesign to achieve optimal performance (Bansal et al. 2013, 3750).

Dishwashers are another large household appliance with potential for energy savings. About 65% of US households use dishwashers, which accounted for 3.2% of the 2005 residential primary energy use in the US (Bansal et al. 2013, 3753-3754). The majority of energy use in dishwashers occurs during the washing cycle due to hot-water use. This is because of a serious design flaw in most US dishwashers, which is that they typically have a cold water connection. Water is brought into the dishwasher through the connection, and then heated in the dishwasher by a resistance heating element; generally one of the least efficient ways of heating water. Technology for improved dishwasher performance exists today and is already affordable and has large market presence, for example Energy Star dishwashers, which use about 39% less energy than a standard model (Bansal et al. 2013, 3753). The Super Efficient Home Appliances Initiative, adopted on August 11, 2009, is currently promoting energy efficient dishwashers, which use 17% less electricity and 35% less water than the federal minimum standards. For any dishwasher built to be more efficient in electricity and/or water use, the energy savings potential averages about 17% by the estimates of Bansal and coauthors (Bansal et al. 2013, 3753-3754). Although the review sites high production and design cost and higher initial cost for the buyer as barriers to the efficient dishwashers, it is evident that the sale of improved technology at the residential level is currently available and the true barrier is consumer awareness or willingness to invest. Educating consumers about the cost, water, and energy-savings benefits is necessary to push efficient dishwashers further into the market.

Clothes washers and dryers are the final large household appliances present in most residences and with great potential for improvement in efficiency. Over 80% of all US households have clothes washers, consuming 3.7% of total residential primary energy based on the 2009 Building Energy Handbook. Similar to the discussion of dishwasher efficiency, in clothes washers most energy is required for hot water use rather than motor use. Advancements have led to about a 20% reduction in motor electricity and water use of the past decade; examples include automatic or improved fill-control, high efficiency motors, low-standby-power designs, increased thermal insulation, and water-reducing rinse technology (Bansal et al. 2013, 3754). These improvements are very promising; Bansal and coauthors (2013, 3754) estimate that the energy savings potential for the most efficient models using existing technology is about 43% improvement.

Over 80% of US households also own clothes dryers, consuming 4.2% of total residential primary energy based on the 2009 Building Energy Handbook. Some dryers on the market now include a moisture sensor that saves up to 15% of total energy. Additionally, cabinet insulation can provide nearly 7% additional energy savings (Bansal et al. 2013, 3754-3755). It is evident that significant improvement in efficiency has been made in home washers and dryers and that more efficient machines are affordable and readily available for purchase.

An important caveat that Bansal and coauthors fail to discuss is consumer discretion in use of large appliances. Use of refrigerators is excluded from this discussion because refrigerators are an essential appliance and cannot be unplugged when not in use. Aside from trying to buy an efficient model and reduce the number of times and duration of time that the refrigerator-freezer is opened per day to avoid heat-gain, there is little that the consumer can do to reduce energy use of this appliance. It is important to note, however, that consumer discretion plays a large role in dishwasher, clothes washer, and clothes dryer use. Buying an efficient model is important, but great further savings can be achieved by making a conscious decision to limit use. For example, washing clothes in large loads rather than small and using cold water rather than hot can save significant energy over the course of time. Additionally, although considered a modern convenience, use of a dryer is technically not necessary. Air-drying clothes is a viable option for the conscious consumer who is willing to invest a bit more time in allowing the clothes to dry for the environmental benefit. Some consumers also argue that air drying clothes can preserve their quality.

## ii. Small Appliances & Lighting

Common small household appliances include cooking equipment and electronic devices. The cluster consists of hundreds of smaller electricity-consuming appliances and represents an area of sustained consumption growth in the United States (Choi et al. 2009, 46). In 2008 the average household spent \$330 on energy for these devices, with the expenditure growing at an estimated rate of 2% annually (Choi et al. 2009, 46). According to Electronic Industries Association (EIA) forecasts, “increased penetration of these devices in the market will drive consumption from 500 TWh of electricity in 2008 to 630 TWh in 2020, rising from 35% of end-use residential electricity consumption in 2008 to 40% in 2020” (Choi et al. 2009, 46). “This cluster provides 590 trillion end-use BTUs of NPV-positive potential, accounting for 19% of residential energy efficiency potential and 44% of residential electricity potential in 2020”. Incremental capital required to capture this potential in 2020 would be approximately \$3.4 billion and provide present-value savings of \$65 billion, resulting in an estimated

cost savings of \$1.00 per-MMBTU. This potential is highly cost effective, as 90% of this potential would have a payback period of less than 2 years (Choi et al. 2009, 46-47).

According to 2006 data, US residential cooking, including microwaves, ovens, and stove-tops, consumes slightly below 3.5% of residential annual primary energy. Electric ovens are so inefficient that it could be reasonably argued they should be used only when preparing meals for a large group of people and otherwise substituted with a toaster oven. Electric ovens have a reported thermal efficiency of only 12.7% because most of the heat is absorbed by the structure (walls, doors, insulation) or dissipated into the surroundings (Bansal et al. 2013, 3755). In a test case of a more efficient oven, the heating element was encased within a reflective compartment so that heat losses were considerably reduced. The energy saving potential for this technology, based on pilot tests, is about 45% (Bansal et al. 3756, 2013). However, parts of this technology need further research and testing before implementation; considerable barriers exist to this technology becoming available in the near future (Bansal et al. 2013, 3755-3757).

Microwaves use some energy but are efficient relative to other cooking appliances. Advances in technology have recently further improved the efficiency of this appliance over the past several decades (Bansal et al 2013, 3757). Microwaves are compact and efficient compared to ovens, stoves, and grills. Gas cooking appliances such as cookers and heaters, barbecues or grills, stovetops, and burners dominate the market because they tend to be more economical, easy to maintain, and have a longer life compared to other appliances. Efficiency and improvements vary on a case-by-case basis for these appliances, but in most situations an efficient model is available for a relatively low premium (Bansal et al 2013, 3757).

Contrary to increasing consumption in the rest of the sector, consumption of electricity for lighting is expected to decline .3% over the next decade, which reflects provisions in EISA 2007 affecting lighting consumption, gradually phasing out incandescent bulbs in favor of more efficient lighting (Choi et al. 2009, 50). Lighting constitutes 9% (80 TWh) of total residential potential for savings (Choi et al. 2009, 51). Relative to replacing other large or small appliances, replacing home lighting is simple and inexpensive. The lighting space as a whole (residential and commercial) represents an area of great improvement and even greater potential. Contributing largely to this has been the deployment of general-use LED technology, the lowest cost lighting technology widely available. Estimates from implementation of LED lighting from 2014 through 2017 expect that each household will save over \$180 on electricity per year (Choi et al. 2009, 51).

### iii. Barriers to Efficiency – Total Residential Appliance Sector

Choi and coauthors (2009, 50) estimate that total incremental capital required to purchase higher-efficiency appliances and lighting in the residential sector between 2009 and 2020 would be about \$11 billion and would provide present value savings of \$42 billion at an average per-MMBTU cost savings of \$4.50. This illustrates the great financial and energy saving benefits that could result from changes and innovation in the residential appliance sector.

The major barriers to efficiency in this cluster are similar to barriers of entire-home efficiency projects. Choi et al. (2009, 52) categorize the barriers to improvement in the large appliance sector into three major categories. An ongoing issue is the uncertainty of savings; while most consumers are aware that energy saving technology exists, they are unsure of the monetary savings and length of payback period for various investments. Because there are so many choices to the consumer, they could exhibit systematic nonstandard behavior when choosing from a menu set, and opt to ignore efficiency in favor of other factors in their purchase decision such as price. Without conducting research before the point of sale, the average consumer would also likely be confused as to which appliances have great energy and cost savings potential and which appliances have less potential.

Quality trade-offs, perceived or accurate, are also a barrier (Choi et al. 2009, 52). Perhaps the most popular example of this is consumer resistance to front-loading design washer and dryers. Bansal and coauthors discuss consumer response to this product, which is popular in many parts of Europe as an energy saving measure. However, American consumers reported that they find it inconvenient to load and unload items from the front, inconvenient that the system locks and the consumer is unable to load additional clothes once the cycle is underway, and found that the cycle times were too long compared to top-loading machines (Bansal et al. 2013, 3754). Although one could argue this is a convenience trade-off or a time trade off due to longer wash times, it is a misperception that there is a difference in the quality of wash between the top and front loading machines.

Supply chain-availability is a major issue in increased large appliance efficiency and is often overlooked in research. Consumers avoid replacing large appliances before they break down because of high up-front costs (Choi et al. 2009, 52-53). For example, over 50% of water heater replacements in the US are “emergency” replacements, replacements that result from the previous heater breaking down. This limits the choice of the consumer for a new water heater to whatever the contractor has in stock, and does not give them time to research efficiency and other features of the new heater (Choi et al. 2009, 52). This problem can extend to any other large household appliance such a refrigerator,

dishwasher, or clothes washer and dryer. However, this problem does not extend to whole-home projects, which are more carefully researched and planned in advanced, and is unlikely to extend to small appliances, which consumers can generally live without for a short period while they research and purchase a replacement.

#### iv. Strategies for Improvement – Total Residential Appliance Sector

Several strategies for improvement in the appliance sector can be extended to the residential energy sector as a whole. “Public awareness and voluntary standards and labeling systems as the efficient option, combined with broad public awareness campaigns, can increase transparency of home energy use and catalyze action to capture efficiency opportunities” (Choi et al. 2009, 37). Choi (2009, 38) and coauthors categorize rebates and incentives for efficient appliances as a proven method to increase ownership at the residential level. However, other analyses such as Li (2011) argue that consumer information is both simpler and more effective than pricing policies. Li (2011, 1) uses empirical analysis to argue “that [the] information-based Energy Star program and energy efficiency standards influence the adaptation of energy-efficient appliances. Surprisingly, financial incentives aimed to lower the initial costs of energy-efficient appliances, such as the popular rebate programs, are far less effective”.

Although consumer education and awareness is important in every sector, it is arguably most important in the appliance sector because the homeowner and inhabitants have very direct control of energy use of all types of appliances. With the exception of a refrigerator-freezer, most household appliances can and should be unplugged when not in use. This will save energy as well as eliminate unnecessary expenses on a home’s electricity bill. Similarly, consumers need to consider what appliances use a large amount of water, energy, or both, and make the conscious decision to reduce use of these appliances. For example, using a clothes washer and dryer only when necessary and doing large, cold loads instead of small loads and using hot water can generate savings without inconveniencing the consumer.

#### f. Tax Credits

Tax credits are a highly debated means of encouraging residential conservation investments. Although theoretical approaches predict that greater amounts of tax incentives should lead to higher probabilities of investment, empirical work has often not shown this (Hassett & Metcalf 1995, 202). Several empirical studies have shown that tax incentives either appear to decrease investment (Walsh



1989), or that coefficient estimates are insignificant (Dublin & Henson 1988). Hassett and Metcalf (1995, 202) note that this perception of ineffectiveness in tax policy has contributed to the overall belief in the “energy paradox” or energy efficiency gap, the seeming anomaly that very attractive investment opportunities in energy efficient capital with high ex-ante rates of return are routinely passed up by potential investors.

Hassett and Metcalf (1995, 202) hypothesize that “a major reason why studies of tax incentive programs for energy conservation have been unable to find a statistically and economically significant relationship between tax incentive programs and investment is because individual specific effects are likely to be correlated with explanatory variables”. The authors propose conservation “taste” factors as a driving effect. “If a state contains a large fraction of citizens with a higher than average propensity to invest because of a taste for conservation, then there is less reason for the state to introduce a tax incentive program to encourage conservation. Failing to control for this factor imparts a positive bias to the tax price variable in a regression of the decision to invest on various factors”. Controlling for this in the empirical study, the results show that “tax incentives are statistically significant and increase the probability of investing in energy-efficient capital” (Hassett & Metcalf 1995, 202-203).

The study uses data pertaining to the federal Energy Tax Act of 1978 (ETA78), “which provided homeowners with tax credits to encourage conservation investment activities such as insulating walls and ceilings, replacing furnace burners and ignition systems, storm or thermal windows and doors, installing clock thermostats, and weather-stripping. These investments received a credit of 15 percent, with a credit ceiling set at \$300 and could only be taken on houses that were constructed prior to 1977” (Hassett & Metcalf 1995, 204). From a random sample of tax returns from the Ernst and Young/University of Michigan Tax Research Database, Hassett and Metcalf (1995, 211) generate a set of sample statistics following a three year panel of 37,658 individuals. Roughly six percent of the sample returns filed for a credit for energy conservation at least once in the three year period. Conservation expenditures ranged from \$0 to \$16,970 and the credits ranged from \$0 to \$301.

For Hassett and Metcalf’s summary statistics, see Figure 1 in the appendix. For regression analysis results, see Figure 2 in the appendix. These results reveal that the probability of investment in a conservation project increases with income. Homeowners are more likely than renters to claim a conservation investment tax credit. Residents of states with colder climates are more likely to claim a credit, which the authors hypothesize is due to a greater number of home heating days per year and the costs associated with home heating. Each of these variables is statistically significant, with *p*-values of less than 0.01. The authors note that as the unemployment rate increases, there is a lower probability

of making an investment (Hassett & Metcalf 1995, 212-213). Although the sample used for this study may be small to draw such a broad conclusion, it is logical that investments in conservation home projects and any major home project would decline during periods of high unemployment, reflecting macroeconomic conditions.

In the sample, there is a trend towards less conservation investment overtime (Hassett & Metcalf 1995, 213). The authors provide no support for this claim but merely offer it is an observation. I would argue that a three year period is too short to define an “overtime” trend. Additionally, the authors cannot be sure if investment actually decreased in the sample, or if only the number of returns decreased (e.g. investment stayed constant or increased but households neglected to file a tax credit reflecting the eligible investment).

Hassett and Metcalf’s (1995, 214) regression analysis (Figure 2, Appendix) suggests the importance of correlated fixed effects. The authors “formally test the null hypothesis of no correlated fixed effects by constructing a Hausman specification test comparing the vector of coefficient estimates from the first and second regressions. For this model, the specification test statistic has 8 degrees of freedom and equals 77.7. The p-value under the null hypothesis of no correlated fixed effects is essentially zero and we reject this hypothesis in favor of correlated fixed effects” (Hassett & Metcalf 1995, 214). Controlling for this effect changes the outcome of the analysis to reflect a positive correlation between tax credit options and household efficiency investments. “Based on our preferred estimate of the tax price coefficient, a 10 percentage point change in the tax price for energy investment would lead to a 24 percent increase in the probability of energy conservation investment” (Hassett & Metcalf 1995, 214).

Although Hassett and Metcalf’s analysis to account for the individual fixed effect of consumer taste or preference for conservation investment is promising, the overall literature regarding residential tax credits remains in disagreement regarding the potential for such credits to increase investment in the residential sector. Hassett and Metcalf show that such a policy has the potential to encourage investment; but in practice the policy choices would need to be handled carefully at a state-by-state level to operate effectively. Hassett and Metcalf acknowledge several uncertainties surrounding tax policy, concluding that “whether it is a good idea for the government to be in the business of providing tax incentives for conservation investments is another matter and cannot be resolved in this paper. For one, any subsidy to conservation investment that is earned by households that were planning to make conservation investments in the absence of the credit.....is a windfall. Moreover, one must ask whether energy consumption falls after investment (assuming reduced energy consumption is the policy goal)

and why it is in the public interest to promote energy conservation. However the policy debate unfolds, an important piece of information will be whether tax incentives can increase the probability at the margin of making conservation investments. The evidence reported here suggests they can” (Hassett and Metcalf 1995, 216). In future analysis, it would be beneficial for authors to conduct a similarly structured analysis on a pricing policy that is structured similarly such as a manufacturer’s rebate for buying an efficient household appliance. Additionally, an expanded study of tax credits following a period of longer than three years would be a valuable contribution to the literature and could provide insight for future policy decisions.

g. Barriers to Efficiency in Low-income Households

Although the general focus of this analysis is on how the American middle class can promote efficiency and energy savings, it is important to examine opportunities and barriers unique to low-income households as well. Capital constraints and a history of government and policy intervention distinguish this cluster, which will represent 19% of total residential energy savings potential in 2020 (Choi et al. 2009, 39). The low-income housing cluster consists of 24 million single-family homes, 16 million multifamily homes, and 5 million manufactured homes (e.g. mobile home or trailer). Choi and coauthors (2009, 39) estimate that 68% of potential for energy savings is in single family homes, 23% in multifamily, 9% in manufactured.

This sector is important to consider because lower income homes have a higher energy consumption and higher potential for savings per square foot than middle class homes. However, they are also smaller on average, 1480 ft<sup>2</sup> compared to the middle-class average size of 2462 ft<sup>2</sup>, driving lower per-capita energy consumption overall. About 92% of the opportunity for energy savings in this cluster is in shell upgrades, with the remaining 8% in HVAC system upgrades. Capital required to achieve this potential would require an estimated \$46 billion and provide present value savings of \$80 billion (Choi et al. 2009, 39).

Barriers to achieving greater energy efficiency are similar to those discussed in non-low-income homes, but with capital concerns far more pronounced. Allocating capital to a typical shell retrofit would cost \$910 for the average low-income family, and \$1820 for the average low-income single family home (Choi et al. 2009, 40). This would require spending roughly half of the household’s non-core budget on the retrofit, making funding through cash savings very challenging. Additionally, this cost compares poorly relative to the value of many older homes in need of other types of maintenance. When debt financing is available, it is often at higher interest rates for individuals in lower-income

households, reducing or eliminating some of the savings that would come from saving energy from the retrofit (Choi et al. 2009, 40).

Unlocking the potential in the low-income sector can use strategies similar to those presented for the non-low-income sector, including raising consumer awareness and education, and promoting investment in smaller purchases such as appliances which have a short payback period. Due to credit constraints it is reasonable for a low-income household to invest only in technologies which would have a payback period of less than two years. Additionally, government assistance programs are also an option for this cluster, although this idea has yet to be piloted (Choi et al. 2009, 40).

#### h. Opportunities in the New Home Sector

New homes are another unique sector to look at relating to investment in green technology. Although they represent a much smaller segment of the market than existing homes, upgrades installed while a home is being built save energy at an average cost of \$4.30 MMBTU, less than half of the average price of the \$8.80 per MMBTU for retrofit upgrades (Choi et al. 2009, 41). However, “new residential buildings represent a modest portion of the 2020 potential because the 21.6 million new homes added to the national stock through 2020 are forecast to account for a relatively small share of all homes in 2020 at 17%. Additionally, these new homes will consume about 25% less energy per house than existing homes” (Choi et al. 2009, 41). These estimates reveal that improvements are already being made to residential energy efficiency and are expected to continue. However, there is still room to expand upon these improvements and build homes focused on minimizing ecological impact.

There are two major barriers to targeting maximum efficiency in the new home sector. First, ownership transfer between builders and future owners is a problem, because builders will not benefit from future energy savings they must cover their incremental costs through a price premium on the efficient home (Choi et al. 2009, 41). This brings into question whether consumers are willing to pay more for such a home. Empirical evidence suggests that home-buyers often value other home attributes more heavily in their purchasing decision, such as location and school district. Due to lack of extensive research in this field and the changing macroeconomic conditions after the 2008 housing crisis, it remains unclear what percentage of homebuyers are willing to pay a premium for more efficient homes (Choi et al. 2009, 42).

Choi and coauthors site mandatory building codes and making current codes more stringent as a proven part of the solution to increasing efficiency in the new home cluster (2009, 43-46). Improving code compliance and increasing monitoring for compliance is important but poses a large administrative

burden. Nevertheless, the most recent improvements in the International Energy Conservation Code (IECC), which is updated every 3 years, have resulted in 1 to 3 percent improvements (Choi et al. 2009, 44), an example of success for building codes.

An area with even greater opportunity for growth is voluntary building standards and home labeling, with the two major certifications being an LEED home certification and an Energy Star home certification. Energy star homes are 20-30% more efficient than the average new home. In 2008, Energy Star homes made up a 17% share of the new home market and together save 2 TWh of electricity and 15 trillion BTUs of natural gas per year (Choi et al. 2009, 46). LEED Certified homes must be at least 15% more efficient than the latest IECC code, allowing for tradeoffs between the following goals: energy savings, water efficiency, GHG reduction, and improved indoor air quality (Choi et al. 46, 2009).

One example of the success of voluntary home improvement programs can be seen in Portland, OR and Seattle, WA, where new homes that were certified to be energy efficient were selling at a 3-5% premium and 10% faster rate compared with homes that were not (Choi et al. 2009, 45). It should be noted that this data was from 2007/2008 sales, before the US housing market collapse. More recent studies should be conducted to gauge whether consumers are willing to pay a premium for certified homes.

#### i. Macroeconomic Implications

Although there is little debate that increased investment in efficiency technology would be beneficial to the economy by creating more jobs and increasing spending, and bring numerous positive externalities to the environment and public health, the public policy decisions that lie ahead will be difficult and debated. Cicea et al. (2014, 555) conducted a comprehensive analysis of investments in renewable energy. In terms of more limited resources and of needs constantly multiplying and diversifying, the concept of efficiency has a permanent viability in actual economic and social life, which prompted the study. "The efficiency of an investment is strongly connected with economic efficiency. One of the many ways of convincing humanity of green energy's importance for our future is to study the efficiency of investments allocated to this type of energy" (Cicea et al. 2014, 555). The effects of investing in renewable energy are complex, but can be broken down into three distinctive concepts: economic efficiency of the investment, environmental or ecological efficiency of the investment, social efficiency of the investment (Cicea et al. 2014, 555-556).

The investigation is conducted by analyzing the effects on society as a whole using energy and economic indicators for several states from Europe: CO2 emissions from electricity and heat production,

total million metric tons; GDP per capita (constant 2000 dollars); electricity production (kWh); electricity production from renewable sources (kWh), gross inland consumption of energy (all products, 1000 tons oil equivalent) (Cicea et al. 2014, 556). The difficulty in any type of economic analysis of efficiency lies in unifying operational performance with desirable outputs with environmental performance with potentially undesirable outputs (Cicea et al. 2014, 556). The study is an extension of the work of Knight and Rosa, who conducted a measure for environmental efficiency or well-being (EWEB) using the ecological footprint per capita and average life satisfaction. Knight and Rosa's (2011, 931) findings reveal that the effect of economic development on EWEB is negative, and the effect of income inequality is also negative.

Commonly used efficiency indicators in general (non-economic) case studies include carbon intensity, energy intensity, CO<sub>2</sub> emissions, energy consumption, and energy production (Cicea et al. 2014, 557). The energy intensity is "a measure of the amount of energy it takes to produce a dollar's worth of economic output; or conversely the amount of economic output that can be generated by one standardized unit of efficiency". The carbon intensity is "the amount of carbon (in terms of weight) emitted per unit of energy consumed", and is commonly measured is the weight of carbon per British thermal unit (BTU) (Cicea et al. 2014, 557). The Kaia Identity is the most commonly used equation which links together emissions, wealth, energy intensity, and population as a decomposition that expresses the level of energy related to CO<sub>2</sub> emissions as the product of the following four indicators: carbon intensity (CO<sub>2</sub> emissions per unity of total primary energy supply TPES), energy intensity (TPES per unit of GDP), gross domestic product per capita (GDP/capita), and population (Cicea et al. 2014, 557).

The classic form of the Kaia Identity is as follows (Cicea et al. 2014, 557):

$$C = [P (GDP/P)] (TE/GDP) (C/TE)$$

C = carbon emissions                      (TE/GDP) = energy intensity

P = population                              (C/TE) = carbon intensity

TE = energy consumption              [P (GDP/P)] = GDP

Based on analysis of this equation the authors realize that there are four ways to decrease emissions: by reducing the population, thereby reducing the population factor as fewer people generate fewer emissions; by reducing GDP per capita, as a smaller economy and limitation of wealth could also mitigate emissions; decreasing energy intensity; and decreasing carbon intensity by combining or replacing energy sources to generate the same amount of energy with fewer emissions. Only energy

intensity and carbon intensity changes are socially and economically feasible transformations (Cicea et al. 2014, 557).

An application of the extended Kaia Identity reveals the importance of renewable energy in carbon emissions mitigations. The work of Zhang and Ang (2001, 182-183) defines the following relation:

$$C = \sum C_i = \sum (E_i/E) (C_i/E_i) (E/Y) (Y/P) P = \sum S_i F_i I G P$$

i = fuel type

$C_i$  = total CO<sub>2</sub> emissions from fuel type i

E = total energy consumption of all fuel types

Y = GDP

$E_i$  = energy consumption of fuel type i

P = population

C = total CO<sub>2</sub> emissions from all fuel types

$S_i$  = consumption share of fuel type i

$F_i$  = CO<sub>2</sub> emission coefficient for fuel type i

I = aggregate energy intensity

G = GDP per capita

(Reprinted in Cicea et al. 2014, 557)

Analysis of this application reveals that regardless of region, the average per capita income, GDP per capita, and total population are generally dominant forces leading to different emission levels (Cicea et al. 2014, 557). Further developing Zhang and Ang's (2001) analysis, O'Mahony (2013) transformed the relation by adding terms for the fossil fuel substitution effect and renewable energy penetration effect, as well as a term to index annual change in CO<sub>2</sub> emissions (Cicea et al. 2014, 558). Upon extended analysis, an important contribution to a drop in carbon emissions is brought by two factors – fossil fuel substitution effect and renewable energy penetration effect. O'Mahony (2013) concludes that in order to reach targets, policies should pursue the increase of total investment in renewables and the increase of general efficiency (Cicea et al. 2014, 558). Other studies, such as Duro and Padilla, Pani and Mukhodaphyay, among many others, come to the general conclusion that international inequalities in per capita CO<sub>2</sub> emissions are mainly explained by inequalities in affluence, measured by per capita income, across countries (Cicea et al. 2014, 558). Focusing on China and the United States, Wang concludes that "output growth is a major source for increases in carbon dioxide emissions while decline in energy intensity is the main contributor to the reduction of emissions" (Cicea et al. 2014, 558; Wang 2013, 235).

The authors create a regression model based on the Kaia Identity to index environmental efficiency, energy intensity, CO<sub>2</sub> intensity, and GDP per capita per unit of renewable investment (Cicea et

al. 2014, 558). The final index is calculated as a ratio between effects (the CO<sub>2</sub> emissions) and efforts (the investments) and therefore we can consider that this index to be an efficiency indicator. The model looks for small values of the indicator, which indicate a high level of the environmental efficiency of renewable energy investments (Cicea et al. 2014, 561). In displaying the final results based on the EU nations, the authors note that for the leading countries, the small index values are mostly due to reduced emissions rather than a high level of investment (Cicea et al. 2014, 561). Although this does not argue against direct efficient investments, it shows that a multifaceted approach must be taken.

In discussion of their findings, "Iceland ranks as the leader, having both high investments in green energy (almost all of its energy production and electricity generation is from renewable sources, especially geothermal systems) and reduced CO<sub>2</sub> emissions. Luxembourg is the second leading position, although they do not have investments in renewable energy they have very low CO<sub>2</sub> emissions (due to having very little or no presence of polluting industries)" (Cicea et al. 2014, 561). Further supporting Cicea and coauthor's findings are the parallels between the regression model developed in their paper and the Environmental Performance Index (EPI) rankings. "The top three countries in this study's index (Latvia, Luxembourg, Norway) are in the top five EPI (a ranking developed by Yale and Columbia U in collaboration with the World Economic Forum and the Joint Research Center of the European Commission) ranking for 2012, supporting the accuracy of the authors' model. Iceland was number 13 in the EPI 2012 but was the leader in 2010 (Cicea et al. 2014, 561). "The EPI provides a powerful tool for steering environmental investments, refining policy choices, optimizing the impact of limited financial resources, and understanding the determinants of policy results. It focuses on two overarching environmental objectives: reducing environmental stresses to human health and promoting ecosystem vitality and sound natural resource management" (Cicea et al. 2014, 561).

Although Cicea and coauthors depend heavily upon the EPI as a basis for their analysis, other authors have criticized this index due to unequal weights assigned to different variables. For example, in a 2013 Financial Post article by Peter Foster and David Boyd, "Foster argues that the Climate Change and Energy category of the index is weighted too heavily....while the Environmental Health objective is not weighted as heavily in the final EPI score as its counterpart objective of Ecosystem Vitality" (Lloyd 2013). Foster "brushes off the significance of the Environmental Performance Index because of its 'murky metrics'" (Lloyd 2013). Lloyd (2013), a research associate at the Yale Center for Environmental Law and Policy, published an open letter in response to these criticisms. Lloyd argues that a departure from the equal weights within the EPI framework is the result of consultations with environmental science and policy experts, noting that the weights are revisited with the development of each edition of the EPI to



maintain the most fine-tuned methodology possible (Lloyd 2013). Lloyd (2013) entirely dismisses Foster's accusation of "murky metrics", as the entire EPI process "from data to methods to the final ranking, is available online and is free and open to the public". Although no index will offer a perfect ranking due to the complex nature of the relationship between environmental welfare, wealth, governance, trade, public health, and several other variables, the EPI is a powerful tool partially due to the transparency of the methods, frequency of revisions, and openness to modifying and improving. Perhaps Cicea and coauthors could have directly addressed some critiques of the EPI to increase transparency; nevertheless, it seems that the EPI was overall an appropriate tool for use in Cicea and coauthors' analysis.

j. Rebound effect

A pronounced concern with regards to energy saving technology is the rebound effect, the potential problem of increasing use of an efficient technology because of its efficient properties, thus partially or completely offsetting the energy saving potential. Furthermore, lower energy costs increase real income, which leads to an increase in consumption of other goods. This can also offset emission reductions from the initial energy-savings potential (Brännlund et al. 2007, 2). "A third effect may be denoted general equilibrium effects, since changes in aggregate consumption patterns may lead to structural change and changes in relative prices. Taken together, these effects can be denoted the rebound effect" (Brännlund et al. 2007, 2). Depending on the definition used for the rebound, the effect can be insignificant or can result in a total offset to increase of fuel consumption (Greening et al. 2000, 389). Brännlund et al. (2007, 15) suggest, based on their own macroeconomic model, that the rebound effect is greater than 100%. Yet Greening et al. (2000, 389), based on a review of over seventy-five estimates of the rebound effect in the literature, find the overall rebound effect to be very low to moderate.

Brännlund et al. (2007, 2) create a three period econometric model based on Swedish macroeconomic data to investigate the presence and scale of the rebound effect. Although the model is not based on US data, it has implications for the US as both are developed nations with similar demographic features. Further literature could potentially apply the model to US macroeconomic data and draw comparisons between the two results.

The piece defines economic efficiency improvements to include "both new technology that replaces the old capital stock, and new technology that makes the present capital stock more efficient" (Brännlund et al. 2007, 2). The three periods of the model are described as follows: In period 1, the

household determines how much to spend on durable goods, how much to spend on non-durables, and how much to save. In period 2, the household allocates the total expenditure for non-durable goods on different groups (food, transportation, heating, and/or other non-durables). Given this allocation, in period three the households allocate their group expenditures on various items within the group. The resulting model is then used to simulate various changes in energy efficiency (Brännlund et al. 2007, 3). Please see the appendix (figures 3-6) for the complete model and results.

Brännlund and coauthors (2007, 15) conclude that “initially an improvement in energy efficiency implies lower consumption of energy goods, and thus lower emissions. However, this also means that the real relative prices between goods are altered, and that real income increases, the latter due to the initial reduction in energy costs. Thus it may very well be the case that the initial energy savings is counteracted by these changes in real relative prices and income. In the literature, these latter effects are denoted as ‘rebound effects’. The magnitude of this rebound effect is, however, an empirical issue, which will depend on consumer’s preferences for various goods. “In this particular empirical application, we have shown that the rebound effect can be considerable. That is, the initial emission reduction due to an increase in energy efficiency is more than counteracted by changes in consumption. The main conclusion, then, is that an exogenous increase in energy efficiency may not lead to lower energy consumption and thus lower emissions. On the contrary, it is very likely that this “growth effect” will result in higher emissions. Furthermore, the results show that the CO<sub>2</sub> tax change necessary to counteract and hold CO<sub>2</sub> emissions constant is quite large, 135% ”(Brännlund et al. 2007, 15). Although these results would be more valuable if the model were to analyze several nations and draw comparisons, the existing results suggest that the rebound effect is significant and efforts should be taken to reduce it. This suggests that investing in technology alone is not enough to reduce overall emissions, but that mindful consumption and choosing to use less is a necessary behavioral component as well to truly lead to reduced energy use and emissions.

However, not all findings in the literature suggest the rebound effect to be as significant as Brännlund and coauthors claim. More typical estimates of the rebound effect in the residential sector range from about 10-50% (Greening et al. 2000, 398). Greening and coauthors (2000, 392,398) compare results from over seventy-five pieces of literature on the rebound effect, derived from both econometric studies and direct measurements. The study finds that “definitions of the effect vary in the literature and among researchers. Depending on the boundaries used to describe the effect, the measured size of this behavioral response will vary. Therefore, one of the primary tasks for further research will be to reach a common view of the definition” (Greening et al. 2000, 399). These observations prove true

when comparing the results of Greening et al.'s (2000) analysis to Brännlund et al.'s (2007) findings; Greening and coauthors suggest that the rebound effect in the residential sector is about 16.5%. Adding in consideration of the rebound effect in the commercial sector, they cautiously estimate the economy-wide rebound effect at less than 1%, but note that this figure should be seen as an estimate with a high degree of uncertainty because of current data and forecasting tools. Although Greening and coauthors (2000, 399) find the rebound effect to be very low to moderate, they nevertheless suggest that “policies that rely only on energy efficiency technologies may need reinforcement by market instruments such as fuel taxes and other incentive mechanisms”.

Given the shocking contrast between Greening et al.'s (2000) and Brännlund et al.'s (2007) estimates of the rebound effect in the residential sector, of 16.5% and 135% respectively, it is clear that this effect is of concern but is an area in need of further research. As Greening and coauthors (2000, 399) suggest, it is necessary for researchers to reach a common definition for this effect in order to conduct more meaningful analysis. Despite these wide differences in estimating the size of the rebound effect, it is clear that the effect is of concern. More meaningful analysis extending to possible policy tools to reduce the rebound effect will be reached only after researchers have agreed on a common definition of the effect.

#### k. Discussion

It is evident that regardless of the particular approach to econometric analysis, investment decisions in the residential efficient and alternative space will need to be accompanied by some policy measures to encourage further investments. Most importantly, the focus of individual decisions and broad policy decisions must be on decreasing energy intensity and decreasing carbon intensity of applicable technologies.

In a detailed analysis of solutions to unlock potential in residential efficiency investments, Choi et al. (2009, 37) call for increased public awareness, home labeling, and voluntary standards. The authors note that “rating systems and labeling programs (e.g. LEED, Energy Star), combined with broad public awareness campaigns can increase transparency of home energy use and catalyze action to capture efficiency opportunities”. It is no question that increased awareness is an important starting basis to increase investments in efficient and alternative technology, but awareness alone will not be a sufficient catalyst for large-scale change. Choi et al. (2009, 38) suggest combining increased awareness with innovative financing, which can reduce capital constraints and agency issues by tying loan payments to the property or utility meter instead of the homeowner, and assuring cash flows from the

investment is always positive to the home owner (monthly energy savings are greater than the loan payment). This echoes Cicea's (2014, 557) analysis calling for an increase in low interest loans and financing options directly through private banks rather than government measures.

Another approach involves programs offered by utilities or other organizations to provide low or no cost energy assessments – these programs have tended to be on a small scale so far and thus have provided only gradual impact due to low funding levels and low participation rates (Choi et al. 2009, 38). As previously discussed, the major potential exists for home energy savings through better insulation to assist in heating and cooling efficiency, including investment in a whole-home retrofit. This approach could yield many benefits by both raising awareness and providing a resource (the assessor) to encourage change and investment. Further piloting and analysis of this method is necessary but it seems to have great potential.

Choi and coauthors (2009, 38) discuss building mandates as an emerging solution, concluding that “mandates can capture a large percentage of the potential, effectively removing all barriers, however would be a more significant intervention to the market”. Authorities could require perspective or performance-based improvements at point of sale, during a major renovation, or over a specified interval of time. A similar but milder mandate would require home assessments rather than improvements (Choi et al. 2009, 38). The City of Austin, TX is planning to pilot a program of this nature, which will recommend upgrades and provide referrals to approved contractors to address the service availability barrier but it would not guarantee savings. The results of this test once completed will yield valuable insight into the costs, benefits, and overall effectiveness of this type of home-assessment program (Choi et al. 2009, 38-39).

A final but critical step that Choi et al. (2009, 39) recommend is a larger market of home performance contractors. “At the current pace of 200,000 retrofits annually, capturing the full efficiency potential of 70 million homes within ten years would require a 30-40 fold increase in certified contractors, from approximately 40,000 to 1.5 million” (Choi et al. 2009, 39). As mentioned previously in discussion of retrofitting, contractors would need training and certification in holistic building science rather than one concentrate discipline.

Considering these measures it is evident that a multifaceted approach to investing in efficiency is the only possible way for large-scale change to happen in the residential space. The cost of investments would need to decrease on average, consumers would need more and better information and means of government intervention might be necessary or helpful to encourage investments. A major but complex addition to estimating carbon savings from technology investments is the question of

the carbon and pollution intensive processes that go into producing some of this technology. Although this analysis will not be conducted in this work, it is an important point to consider as an offset to the value of investment in technology.

### III – Voluntary Simplicity

An alternative approach to a household pursuing an ecologically friendly lifestyle is voluntary simplicity. There is not one set definition of voluntary simplicity, and there are also varying degrees of the lifestyle that can be practiced. Walther and Sandlin (2013, 37) state that “individuals who are seeking a way to consume less can be roughly clustered under the umbrella of voluntary simplicity”. Elaborating, they state that “many studies suggest that simplifiers are concerned about ecological and environmental issues as they strive to consume locally, buy organically, reduce their dependence on cars, and recycle” (Walther and Sandlin 2013, 37). The roots of a voluntarily simplistic lifestyle can be traced back to a counterculture ideal in the 1970s. However, many consumer behavior theorists and behavioral economists now recognize voluntary simplicity as “a reality and significant trend of the new millennium” (Craig-Lees and Hill 2002, 189-190).

#### a. Introduction to Voluntary Simplicity

The driving force behind voluntary simplicity differs on an individual basis, making the group as a whole difficult to classify and study as one category. Over the past several decades, voluntary simplicity has emerged as a growing sector of consumer behavior theory. The major debate is whether voluntary simplifiers generally practice less market participation than the average consumer, or if they simply participate in the market in different ways than the average consumer, with a focus on ethical consumption. Walther and Sandlin (2013, 37) argue the former, generalizing that voluntary simplifiers “focus on limiting material consumption in order to free up one’s time and money to seek satisfaction through other non-commercial, non-material means”. However, Burch’s (2012) “Simplicity and Economy” takes a slightly different perspective, namely that simplifiers are marked by a focus on local consumption, sense of heritage and connection to local place.

Etzioni (2004) explores the roots of voluntary simplifiers. Etzioni notes that social science has generally shown that amount of income correlates strongly with happiness at low incomes, but the correlation levels off as soon as a comfortable level of income is attained. Based on this notion, “voluntary simplicity ‘works’ precisely because consuming less, once one’s basic creature-comfort needs are taken care of, is not a source of deprivation, so long as one is freed from the culture of

consumerism. Voluntary simplicity represents a new culture, one that respects work....and appreciates modest rather than conspicuous or lavish consumption, but does not advocate a life of service and sacrifice” (Etzioni 2004). In this argument, consumer culture is tied closely to environmental degradation.

Empirical evidence in the US suggests that voluntary simplifiers are well-educated and have above average incomes (Shaw and Moraes 2009, 217). Shaw and Moraes say there is empirical evidence to suggest that products have already been developed to capitalize on this group of consumers, which raises questions about an individual’s ability or want to opt out of the market, and reinforces the view that voluntary simplicity is a lifestyle that still involves market participation. Similarly, Craig-Lees and Hill (2002, 188) argue that “since the 1970’s, marketers have been aware that there are clusters of consumers who restrict their consumption and who make market decisions for lifestyle, ethical, and/or ecological reasons”. Etzioni (2004) points out an interesting cultural barrier to voluntary simplicity, that in a society where status is defined by showing off luxury items to indicate success, if people choose a job or career path “that is not income maximizing and is voluntary simplistic, they have no established means of signaling that they have chosen such a course rather than being forced into it, and that they have not failed by the mores of capitalist society”. This implies that strong personal, spiritual, ethical, or ecological values must drive the voluntary simplifier enough that they will remain unconcerned about how their lifestyle choice reflects on their perceived social status.

#### i. Types of Voluntary Simplifiers

Etzioni is cited in several later works focused on voluntary simplicity for pioneering three major variations or levels of intensity of simplification. There is no way to readily profile the various kinds of simplifiers or to establish the total number of simplifiers; however Etzioni estimates that 1 in 4 Americans rank voluntary simplicity high among their values. An important question in estimating the scope and sustainability of voluntary simplicity is whether the lifestyle requires sacrifices that the individual must constantly be willing to make, or whether simplifying in itself is a major source of satisfaction and hence is self-motivating (Etzioni 2004). It is becoming more widely accepted that voluntary simplifiers should not be viewed solely in an anti-consumption framework but rather as an approach of modified consumption (Etzioni 2004; Shaw and Moraes 2009, 217; Burch 2012).

Etzioni’s (2004) first group of simplifiers is classified as “downshiftners”. This is the least intense level of simplification, “economically well-off or secured people who voluntarily give up some consumer

goods, often luxuries, which they could afford, but basically maintain a consumption oriented lifestyle". Etzioni argues that this type of simplifier is not truly free from consumer culture, and that most downshifters are held back by the desire to be seen as successful by others within their community. Although this is the most moderate group of people practicing a voluntary simplistic lifestyle, it is likely that further research would find this is also the largest group of simplifiers, as downshifting does not require major lifestyle changes.

Strong-simplifiers are the middle-level of simplification, a more extreme group "who have given up a higher paying job to live on less income and consume less". The major way in which individuals in this group differ from downshifters is that they show a strong preference for leisure time. Those who retire early to enjoy leisure time, choose to stay home to spend time with family or children, and who quit their jobs to switch to a field they find more meaningful but less lucrative would also fall into this category (Etzioni 2004).

The third type of voluntary simplifiers Etzioni calls the "Simple Living Movement"; comprised of the most dedicated, holistic simplifiers who adjust their whole life patterns according to the ethos of voluntary simplicity. The major difference between this group and the other two groups is both the scope of change and also that it is motivated by a clearly articulated philosophy, drawing on the traditions of the Quakers, Puritans, transcendentalists such as Emerson and Thoreau, and various world religions, to provide a set of philosophical underpinnings to living a simple life (Etzioni 2004). This philosophy may be more explicitly anti-consumerist than the other two groups. Empirical evidence has not supported that many people self-identify as part of the Simple Living Movement (Craig Lees and Hill 2002, 191-192, 207).

Craig-Lees and Hill (2002) discuss several historical views of voluntary simplicity, going into more intricate details than Etzioni's three categories. Several common themes are evident in both Etzioni's (2004) and Craig-Lees and Hill's (2002) description of simplifiers: (1) the element of free choice to lead a simple life, reduction of material consumption (but a life of poverty is not required); (2) simplifiers are driven by values such as humanism, self-determination, environmentalism, spirituality, and self-development; (3) voluntary simplifiers have access to resources such as wealth, education, and unique skills that could be traded for higher income; and (4) simplifiers focus on control and personal fulfillment. Going forward this piece will use this set of values as a loose classification of voluntary simplicity rather than attempting to assign individuals into a more stringent set of values or categories.

## ii. Ethical Consumption

Rather than focusing on an anti-consumption oriented simplifier, this piece will focus on various motives such as using fewer resources in order to be more ecologically conscious and making ethical consumption choices in order to teach values to the family (Shaw and Moraes 2009, 216). Consumption may, in turn, be reduced by some practices: for example engaging in communal laundry, a change in transportation practices to cycling or car sharing, or vegetarianism motivated by concerns about resource usage (Shaw and Moraes 2009, 216). Consumption can also be reduced by simplifiers repairing items to lengthen the item's lifespan. One way to look at the rise of voluntary simplicity is as a response to some negative effects of industrialization such as pollution, work-focus, and most importantly a loss of control and focus over the home – none of these are necessarily a direct opposition to the market system (Shaw and Moraes 2009, 216-217).

Shaw and Moraes (2009, 218) conducted a focus group study of people who self-identify as practicing varying degrees of voluntary simplicity, and a major finding was that simplifiers hold on to a strong sense of community through both local links and communion with nature. Participants in the study sought to re-establish some of the symbiotic links between their communities and the markets. Several specific examples of this are documented, as simplifiers “attempt to reclaim some of the lost communal norms and morals through purposeful market interactions” – for example several participants critiqued current agricultural methods involving use of chemicals and pesticides and thus supported local produce by shopping at the farmers market and eating only produce that is in season (Shaw and Moraes 2009, 218-219). Participants were focused on community, ethical, and environmental issues – price was not seen as a barrier although other studies have found this to be untrue. In one example a participant stated she was willing to forego her desire to exclusively purchase organic if it meant supporting local farmers rather than supermarkets. Additionally, several participants reported boycotting multinational products such as Nestle as well as genetically modified products (Shaw and Moraes 2009, 219).

Some participants also felt a spiritual connection to nature that created an individualized approach to making their consumptive decisions. Some participants' desires to reconnect with nature stemmed from concerns over global health risks emanating from environmental degradation, as well as concerns over climate change and unsustainable production (Shaw and Moraes 2009, 219). The link between consumption and ethical problems such as environmental degradation and fairness in world trade has led to the emergence of a group of consumers commonly referred to as ethical consumers (Shaw and Newholm 2002, 168)



Shaw and Newholm (2002, 169-170) identify general differences between moderate to strong-simplifiers and ethical consumers. The two are nonexclusive variations of voluntary simplicity; however ethical simplifiers are distinguished from downshifters by their concerns about environmental, social, and animal welfare issues. Downshifters are less driven by ethical issues and focused more on gaining quality time in their lives for themselves and families. Because of this fundamental difference, patterns of consumer behavior between the two are likely to be very different (Shaw and Newholm 2002, 170).

Ethical consumers consider the environmental and social impact of their consumption choices; such practices may include seeking technological solutions, recycling, refilling, and buying from preferred goods and companies; as well as other behavioral solutions including reduced levels of consumption, using shared goods, secondhand purchasing, and domestic production. Consumers looking to technological solutions would include buying green products such as catalytic converters on fuel-economic cars, superefficient refrigerators, and green alternatives to laundry detergents (Shaw and Newholm 2002, 171). Solutions employing technology and meaningful consumption choices such as buying fair trade or locally, according to these authors, involve maintained levels of consumption rather than reduced market participation (Shaw and Newholm 2002, 171). This alludes to the notion that voluntary simplicity and investing in technology can be combined for optimal household energy efficiency and financial savings.

#### b. Case Studies and Microanalysis

Shaw and Moraes's (2009, 215) case study attempts to explore how voluntary simplifiers in a rural context have negotiated the relationship between voluntary simplicity and market-based consumption by focusing on multiple different manifestations of voluntary simplicity and their effects. Regardless of the degree of simplification, participants in the study focused on "careful and wise use of resources....aimed at achieving long-term sustainable consumption goals" (Shaw and Moraes 2009, 221). This reflects a difference between the simplified lifestyle as opposed to investing in household technology to reduce energy use and carbon emissions; voluntary simplifiers are more likely to accept inconveniences as part of their lifestyle and make sacrifices for a greater ecological good, whereas investors in technology want their lifestyle to remain more-or-less the same while purchasing more efficient devices to reduce the ecological footprint. Many are quick to see this difference and judge that, if adopted on a large-scale, voluntary simplicity would be devastating to the economy. However Shaw and Moraes place great focus on emphasizing that these ethical consumption decisions do not represent an exit from the market or an anti-consumption attitude.

Shaw and Moraes's (2009, 219) study details several participants' lifestyles, many of which were clearly "alternative" ways of living that resulted in reduced environmental impact and carbon savings. For example, several participants reported growing their own food, ranging from nearly self-sufficient to growing a very small portion of produce. Shaw and Moraes (2009, 215) note that in every case it only represented a "partial exit from the restraints within the market.....this [homegrown food] had to be managed alongside consumption choices within the market". Indeed, participants used a combination approach to purchasing grocery items, accessing two or more of the following: supermarkets, local stores, farmers markets, home production, and wholefood suppliers (Shaw and Moraes 2009, 220).

Additionally, "Concerns about the risks associated with modern farming methods regarding animal welfare and health scares such as foot and mouth disease resulted in a higher number of participants reducing their meat consumption and sourcing meat locally from farmers, neighbors or friends, where the link between consumer and producer is direct. Others participants reported practicing a vegetarian diet, with a small number bordering on veganism" (Shaw and Moraes 2009, 219). Many participants who reduced meat intake would eat fish from the wild which they accessed themselves. Organic farming was strongly associated with a more responsible answer to food production (Shaw and Moraes 2009, 219). Purchasing fair-trade products that could not be grown locally such as tea, coffee, and sugar, were also a priority for participants (Shaw and Moraes 2009, 219-220). These results reflect two phenomena; concern for personal control of food intake and concerns for animal welfare.

Shaw and Moraes's (2009, 221) detailed example about grocery-shopping and dietary choices reveals a larger theme within voluntary simplicity; the objective of "bringing about more personalized and caring exchanges because of the consumer choices involved, and by extension reinstating socially and environmentally orientated norms in local markets". Ultimately, voluntary simplicity helps us view communities and markets as embedded in symbiotic relationships (Shaw and Moraes 2009, 221) as opposed to traditional attitudes with disregard for sheer environmental exploitation.

The authors conclude with the argument that "the practice of voluntary simplicity is one of living within capitalism, not in complete opposition to it.....Voluntary simplifiers are really making use of market systems to find desired local and ethical alternatives". They found that participants' consumption bundles were a mix of: positive choice (e.g. fair-trade/organic), non-consumption, reduction, re-usage and modification of consumption, and that participants choose to create a healthier, more environmentally friendly, and more balanced lifestyle for themselves, [rather] than seeking to escape the marketplace (Shaw and Moraes 2009, 221-222).

Another case-study by Craig-Lees and Hill (2002, 194) conducted a similar analysis of attitudes and practices of people self-identifying as “practicing minimal consumption/living with less, focused on people, community oriented, focused on harmony, self-well-being, and growth, environmentally and/or spiritually focused”. Differing from the Shaw and Moraes (2009) study, which focused only on rural simplifiers, Craig-Lees and Hill’s (2002, 191) participants were both urban and rural simplifiers, presenting a broader presentation of different types of simplifiers in various living situations. The study also asked a group of non-voluntary simplifiers in the area with similar demographic characteristics to respond to the same questions as the simplifiers to draw comparisons.

Differences in responses were close to hypothesized differences between simplifiers and non-simplifiers. Craig-Lees and Hill refer to the voluntary simplifiers as VS group and non-simplifiers as the NVS group. Craig-Lees and Hill (2002, 200) summarize some consistencies in their findings, noting that simplifiers had a more symbiotic relationship with their homes, and many did their own renovations. Furniture was important to the simplifying respondents only if it was previously owned or made by someone important to them which added sentimental value to the piece. The VS group discussed their cars in terms of reliability, necessity, and functionality. Many of them expressed feelings of guilt for owning a car, while the NVS group was interested in comfort, quality, and brand name (Craig-Lees and Hill 2002, 201).

Substantial differences were noted in the way that VS versus NVS focus groups discussed activities and leisure time. Reading was by far the most popular activity for the VS group; whereas theater, travel, and restaurants were important to the NVS group and they reported high expenditures in these areas (Craig-Lees and Hill 2002, 202). Many VS respondents were concerned about environmental issues in terms of damage to the earth and their consumption patterns were based on making minimal use of the earth’s resources (Craig-Lees and Hill 2002, 204). Closely related to this, VS respondents were concerned with packaging such as buying organic produce in bulk and using secondhand furniture and clothes. The VS group reported owning standard household appliances but using everything as long as possible without frequent replacement. None of the simplifiers mentioned the anti-consumption movement or direct opposition to market participation (Craig-Lees and Hill 2002, 204-205, 207).

Craig-Lees and Hill (2002, 207) ultimately group the simplifiers into three categories based on motivation: environmentally, spiritually, or self-oriented. The self-oriented group was more interested in spending less, for example buying distributor brands over brand name grocery items. The environmentally focused group was more concerned with product quality, packaging, and advertising.

This group was more likely to buy organic and earth-friendly products even if they cost more – this especially applied to food products (Craig-Lees and Hill 2002, 207). It is noteworthy that regardless of the motivation, positive environmental externalities will result from voluntarily simplistic lifestyles. For example, a simplifier categorized as “self-oriented” may choose to take the bus or carpool to work to save the added expense of fuel costs for commuting by car alone; although they are motivated by the financial incentive, they will in turn be burning less fuel and generating fewer CO<sub>2</sub> emissions by pursuing an alternative means of commuting.

A study by Shaw and Newholm (2002) discusses similar topics explored in the Shaw and Moraes (2009) and Craig-Lees and Hill (2002) studies, and notes an important discussion point regarding inconsistencies in the green practices of voluntary simplifiers. “Many respondents lived with various inconsistencies, such as the occupation of houses with limited insulation potential, operating cars, washing machines, and other appliances that were secondhand and generally less efficient than new items. These practices seem to be opposite of the technological solutions that some advocate in this respect” (Shaw and Newholm 2002, 178). This is an important point; however, similar inconsistencies could likely be cited for consumers who invest in household technology solutions. For example, consider a consumer who buys a fuel-efficient vehicle but still drives to work every day alone; although they have invested in a more efficient technology, they have not adapted their behavior to truly reflect these intentions and result in energy and financial savings. When questioned about the inconsistencies in their simplified lifestyles, participants responded that they didn’t aim for “perfect” consumption patterns but did the best they could within the framework of their own ethical concerns (Shaw and Newholm 2002, 180).

#### i. Generation of Green Capital

An interesting idea proposed by Walther and Sandlin (2013, 42-43) in discussion of voluntary simplicity is “green capital” generated by families practicing this lifestyle. These authors argue that voluntary simplifiers are “creating a new kind of ‘green’ or ‘globally educated/aware’ middle class where eco-friendliness, community-mindedness, and other similar values and practices become a new kind of social or green capital that they pass on”. Walther and Sandlin define this “capital” as the inherent benefits and sense of well-being that voluntary simplifiers gain from their lifestyle choice.

Voluntary simplicity, in conjunction with generation of green capital, frees up actual (e.g. economic or monetary) capital for college and retirement funds; thus economic capital becomes intergenerational (Walther and Sandlin 2013, 43). Further research is needed on how families are creating and using this new green capital, as well as how children do or do not model similar consumption patterns in adulthood when raised in voluntary simplifying homes (Walther and Sandlin 2013, 43). The idea of green-capital would really be rooted in the hypothesis that voluntary simplifying is passed from one generation to the next; if not, the idea of green capital would just be equating voluntary simplifiers to a consumer who has a high propensity for savings.

Overall, it seems that regardless of the degree of simplification, voluntary simplifiers will have different spending patterns at the micro-level, and in some cases less spending overall. Although a simplifier is likely to spend less per year on services such as restaurants, many simplifiers are willing to pay a premium for local or organic foods to prepare at home. This is just one of many possible examples to reiterate that less spending in one area will not necessarily transfer to less spending overall. Perhaps the largest case for voluntary simplicity from an economic standpoint is that simplifiers will still invest in large life expenditures such as owning a home, a college education for themselves and their children, and a retirement or other savings account.

#### c. Macroanalysis

Burch's (2012) "Simplicity and Economy" analyzes the macroeconomic implications if voluntary simplicity were to be practiced on a large-scale in the United States. Presenting a strong argument against those who say widespread voluntary simplicity would depress the economy, Burch analyzes several sectors of the economy including effects on taxation, primary production, construction, transportation, manufacturing, and services. While accepting that there would be many shifts in types of activities at the macro-level, Burch finds that the widespread practice of simplicity would not add any risk factors that are not already a part of the business cycle.

Etzioni (2004) also discusses the potential for voluntary simplicity to be more widely embraced, stating "There can be little doubt that voluntary simplicity, if constituted on a large scale would significantly enhance society's ability to protect the environment", and further asserting that "Voluntary simplicity, if more widely embraced, might well be the best new source to help create the societal conditions under which the limited reallocation of wealth needed to ensure the basic needs of all could become politically possible" (Etzioni 2004). In this view, simplicity is critical for both economic and environmental sustainability.

In a more general analysis, Alexander and Ussher (2012, 69) suggest that developed nations should give up the pursuit of economic growth in favor of moving towards a steady-state economy, one that develops qualitatively but does not grow quantitatively, adding that this type of development is compatible with voluntary simplicity on a large-scale. This would allow economies to stop growing in a planned and deliberate way instead of the result of unplanned recession or economic collapse that could happen if the exploitation continues (Alexander and Ussher 2012, 69). Given the deeply rooted focus on growth oriented classical macroeconomics, any realization of macroeconomics beyond growth would need to be built from the grassroots up. The example uses peak oil as an illustration as to why economic growth cannot continue forever, because the economy is so dependent on fossil fuels which are only going to get more expensive; the authors see this as an opportunity for growth of widespread simplicity (Alexander and Ussher 2012, 69-70). Burch's analysis, the focus of the next several sections, does not specifically reference a transition to a steady-state economy so we will assume for further purposes that the economy remains "relatively" the same (e.g. continues to grow at some rate). However, the idea of a steady-state economy certainly has merit for further research and analysis, particularly in the context of sustainable development.

#### i. Effects on Primary Production

Primary production includes mining, fishing, forestry, and agriculture. In 2007 about 4.5% of the US workforce was engaged in these activities. Burch argues (2012, 12-13) that jobs in this sector would not be lost in aggregate, but rather redirected towards conservation efforts, reducing the health effects of mining and forestry activities, and increasing jobs in the recycling and remanufacturing sectors. The net result would be a reduction in negative environmental externalities associated with present-day extractive industries.

Agriculture would be the part of this sector most likely to undergo major changes, as agribusiness is mostly owned by corporations, and it has recently come into question whether this is the most sustainable, healthy, or overall desirable system to use for food production (Burch 2012, 13). Further, agribusiness depends heavily on fossil fuel inputs, such as fertilizers and large-scale planting and harvesting equipment powered by gasoline, and environmental extractions. "It is increasingly clear that the current organization of the agricultural foods sector is neither environmentally nor economically sustainable in the long-term" (Burch 2012, 13). Shaw and Newholm (2002, 174) note that voluntary simplifiers are more likely to participate in restricted diets than the average consumer;

mindfully choosing diets based on a framework concerned with personal health, food quality, animal welfare, environment and biodiversity, global equity, and power relationships.

“People adopting simpler living tend to prefer organic or locally produced foods, and bring a somewhat more mindful approach to their food choices which includes consideration of the social and environmental aspects of the system” (Burch 2012, 13). It follows that a shift towards voluntary simplicity would lead to an increase of jobs in sustainable, local, and community agriculture, but a serious decline in jobs in agribusiness. Burch (2012, 13) cites a study conducted by a philosopher-farmer that illustrates small-scale production is associated with higher rural population densities and more profitable operations per hectare than are large-scale corporate farming regimes.

Burch’s analysis that the overall effect would be “very significant” in this sector is logical. However, it is unlikely that there would be nearly the level of destruction of agribusiness as Burch discusses. Although more consumers would favor buying locally-sourced goods, there would still be a portion of simplifiers who focus on reducing costs; an amenity offered to them by major brands and large retailers. Smaller-scale production cannot compete with undercutting these costs. Additionally, empirical evidence discussed prior suggests that most simplifiers “use a combination approach to purchasing grocery items, accessing two or more of the following: supermarkets, local stores, farmers markets, home production, and wholefood suppliers” (Shaw and Moraes 2002, 220). It is likely that only the extreme simplifiers would shop only locally, and the rest would continue to use the combination approach. By this logic, agribusiness would likely downscale but would by no means cease to exist as a major part of the agricultural sector.

## ii. Effects on Taxation

If more people lived simply, Burch (2012, 8) argues that there would be more widespread income equality and thus less need for tax revenue to be directed towards public assistance programs. Thus, more spending would be available for rebuilding local communities and investing in environmental restoration. This is an area in which Burch’s argument could use further support. Burch essentially finds that any decline in tax revenue due to more simplistic living would be matched by a decline in need for tax revenue, which might be a serious oversimplification in his argument. According to Walther and Sandlin’s (2013) definition of voluntary simplicity it is a “new middle class”, and would not really be embraced by the lower class that is practicing a lifestyle more necessary for survival simplicity. Thus the lower class need for government assistance would not logically decline.

### iii. Effects on Construction

In 2007, about 5.6% of the United States workforce was employed in the construction sector. The impact that simpler living would have on this industry depends on how society in the future would envision a more sustainable approach to shelter and transportation needs (Burch 2012, 14). Although a rise in voluntary simplicity could potentially result in a downscale of residential construction, the need for public and commercial industrial activities would be more dependent on overall civic and economic activities. Burch (2012, 14) suggests that there could be a shift towards interest in constructing more within the local community, including more attractive or larger museums, libraries, and public parks, which aligns with the notion that voluntary simplifiers place emphasis on a sense of community. Overall, the effects on this sector are extremely difficult to predict because it depends on whether the overall approach would be on decreasing the built environment, on making buildings less-durable and able to biodegrade more efficiently, or designing buildings to last even longer than they do today (Burch 2012, 14-15).

Another approach could be restorative architecture, an industry in ‘infancy’ where architecture is approached as a “life-science aimed at constructing buildings that are integrated with the natural environment” while also meeting human needs for the built environment (Burch 2012, 15). Goals in this approach include buildings that generate their own energy rather than drawing from a power grid, buildings that recycle and process their own waste in a closed-loop system, and buildings constructed with plant-based building materials (Burch 2012, 15). Although a relatively undeveloped industry today, restorative-architecture is certainly an interesting prospect for growth in the future.

Overall, regardless of which future residential construction approach is taken, a rise of voluntary simplicity would lead to a decrease in “mega-projects” such as dams, highway construction, and massive commercial construction; accompanied by increased activity in construction of public buildings, small-scale and sustainable energy projects, organic food production facilities, landscape restoration, and similar programs (Burch 2012, 16). This suggests that the net effect on aggregate employment in the construction industry would be minimal, although new training programs to shift the focus of some aspects of work may be required.

### iv. Effects on Transportation

It is evident that changes to the transportation industry are already underway, as “many people are now recognizing that transportation systems depending entirely on fossil fuels are collapsing due to



both price increases and supply restrictions” (Burch 2012, 17). Society must engage in the process of transitioning to a less energy-intensive transportation system, which is a great challenge given the constant need to transport goods and materials. Burch (2012, 17) also notes that presently there is no “entirely sustainable” mode of transportation besides human-powered modes of transport (e.g. walking or bicycles).

In Shaw and Newholm’s (2002, 176) case study, there is evidence to support the idea that simplifiers do seek to limit car transportation and use alternative means. “Simplifiers who did own cars still showed resistance to car ownership and cited that they saw no alternative due to work commitments, advanced age, poor public transport, and/or or rural locations”. Additionally, of those who did practice moderated car use, some did so by using public transportation, walking, cycling, or owning more efficient/new vehicles, restricting their family to fewer cars than they might otherwise own, and/or by replacing vehicles less frequently (Shaw and Newholm 2002, 176).

Burch notes that problems with transportation are closely tied with infrastructure issues, and that it is unlikely a major shift in means of transportation would occur “without a corresponding redesign of settlements to make them more pedestrian friendly, compact, and easily serviced by mass transit”. A shift in transportation practices would potentially be accompanied by better urban transit such as trains and train stations, fewer highways and parking lots, and more bike stations and pedestrian walkways (Burch 2012, 17).

Both Shaw and Newholm and Burch’s discussions of transportation seem a bit bounded in scope, because automobile transportation so heavily dominates the market currently. For individuals and families to live without a car, particularly in suburban areas, is difficult and sometimes inconvenient to manage. The best solution currently available is to use and expand upon public transportation systems. The US ranks fifth worldwide in motor vehicle manufacturing, behind China, Japan, Germany, and South Korea, respectively (OICA 2012). It would be difficult to estimate the impact of a significant drop in US car ownership, but it could potentially be detrimental to domestic employment unless offset by an increase in US automobile exporting. Additionally, expansion of public transportation systems and the infrastructure changes mentioned by Burch would foster domestic employment creation.

Nearly 57% of New York City households don’t own a car, and overall vehicle ownership per capita across the US has been declining over the past five years (Madigan 2014). Many factors other than environmental reasons may influence a household’s decision to own a car. Wall Street Journal (2014) notes that “the five US cities with the highest proportions of households without a vehicle were all among the top five cities in a recent ranking of the quality of public transportation”, suggesting an

empirical link between access to public transportation and decreased car ownership. Although this looks promising, evidently a major shift in attitude combined with expansion of public transportation and other transportation innovations are the only ways to dramatically reduce vehicle ownership, a necessity for many middle-class Americans today.

#### v. Effects on Manufacturing

The manufacturing industry accounted for 10.2% of the US workforce in 2007, defined as “any industrial operation which transforms the products of primary production into usable goods for sale” (Burch 2012, 18). Burch suggests that with the rise of simple living, this sector may move away from mass manufacturing and towards more craft, artisanal, and custom-built products. This is less economically efficient, Burch (2012, 18) notes, depending on perception of economy, but would be generally considered less efficient according to classical economics (e.g. fewer economies of scale).

In the classic book *Small is Beautiful*, EF Schumacher (1973) proposed that to create a more sustainable and humane economy we should consider the perspective of “Buddhist economics” including the idea that the main purpose of work is the perfection of human character rather than generation of profit for its own sake (Burch 2012, 18). Thus the economy should employ people using tools designed to ease work and encourage the creative process rather than machines designed to alienate people from work (Burch 2012, 18). This is an interesting take on the matter of manufacturing; however from a classical economics perspective this shift would represent a massive regression.

Burch further suggests that manufacturing might increase in sectors such as tools (gardening and home construction) and other goods that assist people in practicing self-reliance. An already expanding sector, Burch (2012, 18) hypothesizes further growth in the practice of organic and domestic clothing production.

At the fundamental level, an increase of voluntary simplicity would lead to a decline in manufacturing of disposable or single use products combined with an increase in products designed for easy recycling or manufacturing out of recycled products (Burch 2012, 18). This approach attacks the root of many wastes generated in society as the product of our “disposable” or “one time use” culture for the sake of convenience. Any form of design obsolescence, when science or technology design a product to fail sooner than they might otherwise fail so people will buy more, is toxic to sustainable living; Burch (2012, 18) suggests this could be prohibited by law. Currently, designing products to “fail on time” is a widely used and effective method for increasing consumption, as well as manufacturing products which require trivial updates or purchased upgrades to continue use (Burch 2012, 18-19).

Although Burch's arguments here lack empirical support, "planned obsolescence" is a well-known and widely discussed issue with many consumer goods. Since as early as the 1960's, this practice has been harming consumers and the environment (Clark Howard 2014, 1). A common example of a good designed to fail is ink cartridges, which are often difficult to refill and programmed to disable printing when ink falls below a certain level, even if there is really enough ink to complete the job. Yet each standard laser printer cartridge requires about three quarts of oil and two and a half pounds of plastic as inputs to make (Clark Howard 2014, 2). Other examples include car parts, light bulbs, and clothing (Clark Howard 2014, 3-7). Common items that require frequent updates or upgrades include textbooks, video games, software, and portable consumer electronics (Clark Howard 2014, 5-9). In cases of planned obsolescence, it is up to the consumer to attempt to avoid these products or look for solutions. For example, consumers can use the grayscale setting to reduce ink use when printing is necessary. Consumers also have the option of renting a textbook, buying a used copy, or purchasing an online copy (Clark Howard 2014, 2-4).

Evidently, manufacturing is a sector in which it is quite difficult to extrapolate and estimate the effects if there were a rise of simple living. Overall, it seems there would be a lot of shifts in the focus of manufacturing and the types of products manufactured, but aggregate activity and employment would be unlikely to decline.

#### vi. Effects on Services

The service sector is by far the largest industry in the United States; it includes retail sales, business and financial services, real estate, communications, health services, tourism, and entertainment, making up 60.5% of US employment in 2007 (Burch 2012, 19). Due to the several different industries that overlap within the service sector, the effects of a major social shift towards simpler living would be diverse and challenging to predict (Burch 2012, 19).

Some percentage of simplifiers falling into Etzioni's category of strong-simplifiers would choose to work less. This would reduce the need for childcare services and perhaps increase the demand for recreational or leisure services (Burch 2012, 19). Further research is needed to better estimate what percentage would choose to work less and what the implications of this would be. If a large percentage fell into this category, it could be economically depressing; however, it is likely that most individuals will fall towards the more moderate end of the simplifying spectrum.

Burch (2012, 19) argues that "a more active lifestyle marked by a greater interest in holistic health practices and health maintenance products/services would hopefully reduce the need for medical

services”. However, it is more likely that a shift in medical services would be seen, with a downturn of the pharmaceuticals industry, and an increase of holistic and natural medical practices. Still, the changes to medicine would probably not be very drastic, as people would take a more natural approach to everyday healthcare and wellness but practices for more severe ailments would generally remain the same.

The changes to agriculture mentioned in the discussion of primary production would impact retail food sales in many ways, as market-share for international retailers who do not source locally would fall in the grocery space, and share for organic health-food stores that source locally would be expected to grow. The increased market share for grocery stores with a natural focus is already underway, but the increase would be expected to continue at even more drastic rates. For example, the Organic Trade Association estimates that “US sales of organic food and beverages have grown from \$1 billion in 1990 to \$26.7 billion in 2010” (Organic Trade Association Industry Survey, 2011). This increase would likely be bolstered by an increase in voluntary simplifiers of any degree. Burch (2012, 19) also states that simplifiers “may show an increased interest in growing and preparing food at home, which could cause a decrease in restaurant patrons but an increase in attendance at cooking classes and gardening seminars”; although it seems here that he is simplifying his argument quite a bit, Burch is further drawing on the connection between simplifiers and conscious consumption as it relates to diet choices.

#### d. Empirical Study of Simplifiers

While there is concrete trend data to suggest that residential investment is generally increasing in alternative and efficient technology (US Department of Energy 2008, 18), a more challenging element in the realm of voluntary simplicity is estimating the actual number of simplifiers in the US and around the world, as well as the degree to which participants tend to simplify. Some trends over the past two decades may point to the rise of voluntary simplicity, such as an increase in buying secondhand goods or the trend towards organic food production and consumption, but obviously these general trends alone are not direct indicators of a rise in voluntary simplicity. They can be looked at, however, as a promising shift towards ethical consumerism.

Alexander and Ussher (2012) conducted the largest empirical survey and study of voluntary simplifiers to date. The study is based on a multi-national online survey of 2268 respondents who self-identified as practicing some form of voluntary simplicity. Participants answered 50 questions each, and

it is “the most extensive sociological examination of the movement available” (Alexander & Ussher 2012, 67). The authors note that “the mainstream position on sustainability seems to be that economies around the world simply need to adopt ‘sustainable development’ which in theory means continuing to pursue economic growth (i.e. increases in GDP per capita) while employing science and technology to produce and consume more cleanly and efficiently”, which is the basis for the United Nations Development Program; but the authors question the feasibility of this theory, which prompts the interest in voluntary simplicity (Alexander & Ussher 2012, 67).

Alexander and Ussher (2012, 68) note that the sustainable development theory does not reflect empirical reality because “although many economies around the world are getting better at producing commodities more cleanly and efficiently (relative decoupling), overall ecological impact is still increasing because every year an increasing number of commodities are being produced, exchanged, and consumed as a result of growing economies”. They provide one example of this situation, “Jevons Paradox”, which describes having more fuel efficient cars but there is the rebound effect of still driving more and buying more cars – this paradox “permeates markets, societies, and beyond. A paradox because per unit reduction in the throughput of commodities may not actually lead to reduced ecological impacts, because those efficiency improvements are partially offset by the increasing amounts of commodities consumed” (Alexander & Ussher 2012, 68).

An important finding of Alexander and Ussher is the diversity of simplifiers. The following tables present the highlights from Alexander & Ussher’s findings.

#### Demographics/General Information:

Location	% of respondents (rounded)	% globally (rounded, 2011 data)
North America	43	4.9
Oceania (Australia & New Zealand only)	41.8	0.52
United Kingdom	6.4	0.88
Western Europe (Excluding UK)	4.7	2.7
Other	4.1	91

(Alexander & Ussher 2012, 73; US Census Bureau 2011)

Household income (USD annually)	% of respondents (rounded)	% total US (rounded, 2011 data)
Over \$100,000	14	21
\$60,000-\$100,000	23	21.2
\$35,000-\$60,000	27	21.8
\$20,000-\$35,000	17	16.8
Under \$20,000	19	19.2

(Alexander & Ussher 2012, 73; US Census Bureau 2011)

#### Highlights:

When asked how often the households attempted to reduce energy consumption:

- 46% responded “at every opportunity”
- 41% responded “often”
- 12% responded “sometimes”
- <1% responded “not often”

(Alexander & Ussher 2012, 74)

Responding about dietary preferences/habits:

- 11% eat a typical diet (“most foods”)
- 63% emphasized fresh and unprocessed foods
- 9% eat fish but are otherwise vegetarian
- 13% strict vegetarian
- 4% vegan

(Alexander & Ussher 2012, 74)

Recycling:

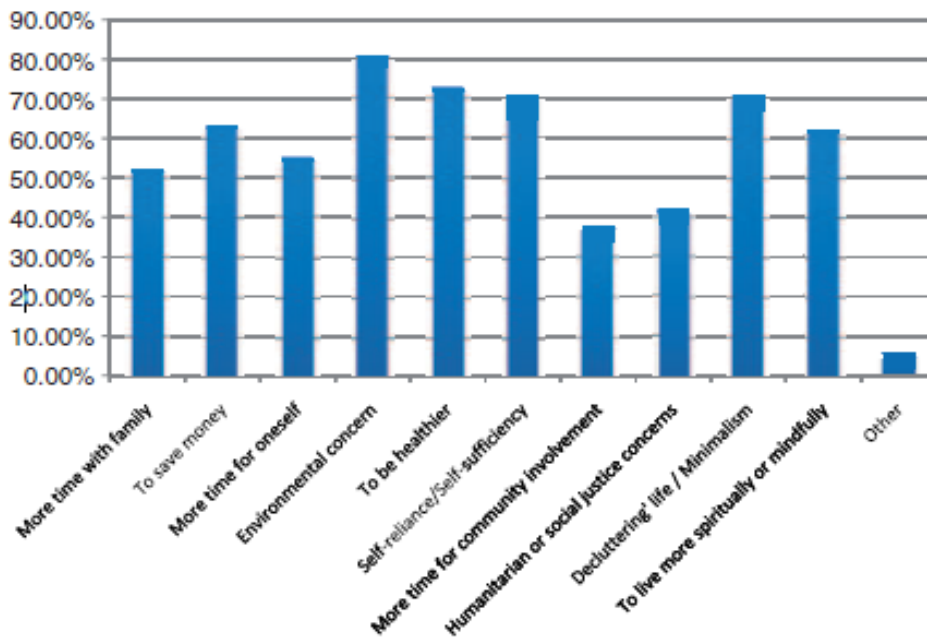
- 82% at every opportunity
- 12% usually
- 5% occasionally
- 1% rarely

(Alexander & Ussher 2012, 75)

Composting:

- 77% yes
- 23% no

Motivation:



(Alexander & Ussher 2012, 76)

The most important overall findings of this empirical study is the diversity of simplifiers and the finding that 90% of participants reported that they were happier after transitioning to a simpler life (Alexander & Ussher 2012, 76-77). Only 0.3% reported being less happy after making the lifestyle change (Alexander & Ussher 2012, 77). This brings us back to Etzioni's question of whether simplicity is a self-fulfilling happiness or is a way of life that requires constant effort and focus on simplification, suggesting the former. "The results suggest that arguments for simpler living based on environmental, humanitarian, population, limits to economic growth, etc. are also supported by an argument based on increased happiness" (Alexander & Ussher 2012, 77). Based on the graphics above we also see that simplifiers tend to embrace ecologically conscious lifestyles regardless of their own personal motivation for simplifying. The study roughly estimates that there are around 200 million people globally practicing voluntary simplicity and growing (Alexander & Ussher 2012, 82).

The authors favor looking at voluntary simplicity from a political perspective, emphasizing the need to "organize, radicalize, and expand" for the movement to have a large-scale impact. With this notion I strongly disagree, and would venture to hypothesize that many simplifiers would also disagree; a true lifestyle change must be self-motivated and while governments can promote specific environmental

programs and ideals, individuals must be internally motivated to make a total lifestyle change which is generally unrelated to political motives. However, Alexander and Ussher's illustration of the socioeconomic diversity of simplifiers and increased happiness and satisfaction of those who have embraced simplicity is evidence in itself that the movement has potential to take root and expand, bringing substantial ecological and social benefits.

#### e. Discussion

According to Alexander and Ussher (2012, 68) "the obvious implication is that technology and efficiency improvements are not going to solve the ecological crisis... [As] most optimistic advocates suggest they can". The authors "see the mainstreaming of voluntary simplicity ethos as being an absolutely necessary part of any effective response to the ecological crisis".

While it is almost certain that widespread investment in technology at the household level would stimulate the economy, or in the absolute worst case would cause differences in demand but no economic contraction, there is far more debate over the benefits if voluntary simplicity were practiced on a large scale as a means of becoming a more ecologically friendly society. Burch (2012, 22) notes that "any major transition towards a culture of mindful sufficiency would have momentous economic implications, but not necessarily catastrophic or destructive ones", adding that the transition would be gradual and preceded by a more general cultural change towards simpler living. Based on this notion, Burch believes the economy would evolve to fulfill the changing needs and desires rather than responding abruptly as in the case of a geopolitical crisis or a major market failure (Burch 2012, 22).

Burch (2012, 9) goes even farther with his analysis so as to consider the potential effects which a shift towards voluntary simplicity in the US would have on the global economy. Burch discredits the argument that if consumerism slows people in developing nations will starve or lose their jobs, such as manufacturing employees or plantation workers, on the basis that "our current hyper-consumption mostly supports corporate profits and shareholder dividends in developed countries".....the workers "are paid a criminally small fraction of the total price of most goods and services sourced from such companies". He argues that the current system of employing workers overseas who will work for little pay ignores the underlying problems that date back to colonization and exploitation; a self-serving cycle that the rise of voluntary simplicity could gradually slow or stop (Burch 2012, 10).

Further, Burch (2012, 7) argues that large-scale adaptation of voluntary simplicity would benefit emerging markets, which have previously been urged to focus on farming or manufacturing products for the western consumer economies. These nations would now be able to focus on using local resources



and locally adapted technologies to support their local economy and the needs of themselves and their families. Burch (2012, 7) says that the instability is worsened by the fact that “northern importing countries do not need what they import as much as the Southern exporting countries need to export it”, citing the 2009 collapse of Kenya’s exporting market of cut flowers to Europe, because this was a luxury good hit hard by the recession. Such import and export relationships, Burch argues, “are not a recipe for national security or social harmony”.

Burch’s analysis of importer-exporter relationships is seriously simplified. Although a focus shifted away from making products to export would likely benefit the environment due to less factory and agribusiness fossil fuel pollution and would free up local resources, Burch ignores the importance of geopolitical stability in the role of economic success and independence. Many of the less developed countries to which Burch refers would still be unable to thrive in the absence of exporting goods to the west, oppressed by their own governments or faced with serious instability. Losing manufacturing jobs in urban areas of these nations would likely depress the economies, as these workers would not have the land or resources to convert to local agricultural production, and may be unable to find other employment in the area.

Still, Burch’s analysis is considerably limited in that he focuses on only the shift towards voluntary simplicity in the United States – although the United States is one of the world’s top importers, in order for manufacturing jobs in less developed countries to slow or stop, there would need to be a rise of voluntary simplicity in most of Europe, and in the rapidly emerging markets such as Brazil, Russia, India, and China – a lifestyle shift that is extremely unlikely to occur in all of these places over a short period. Thus the net effect of an increase in simplistic lifestyles in the US to the global economy might be smaller than Burch anticipates.

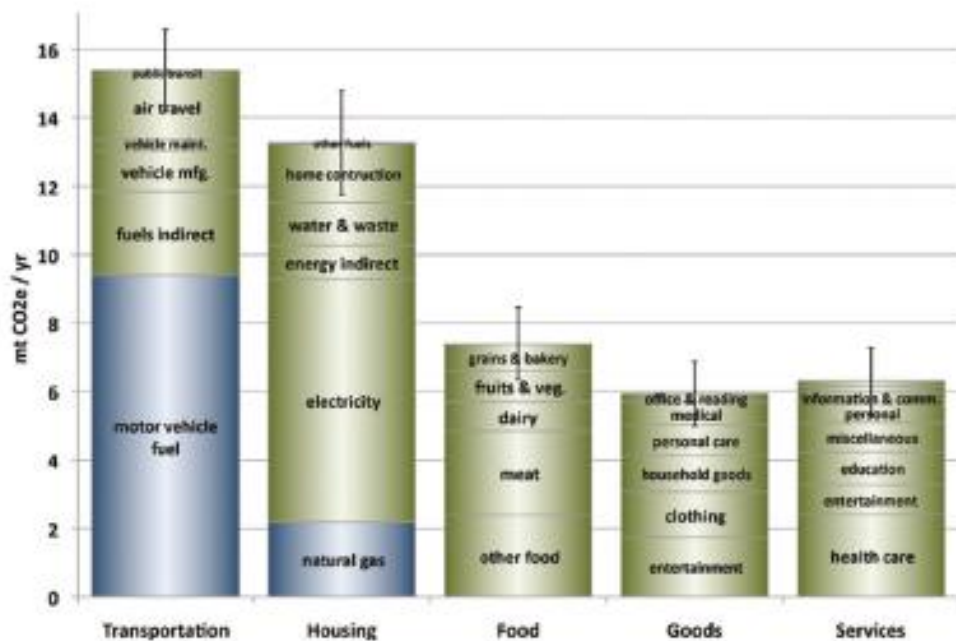
Globally and domestically, Burch admits that the economic effects of a gradual, large-scale growth of voluntary simplicity would be difficult to anticipate. If we generalize Burch’s analysis to think of voluntary simplicity as a different set of consumer preferences and the market as adapting to this change in preferences by some people, the results of an increase in voluntary simplifiers would be unlikely to be detrimental to the economy, because changing tastes and preferences in a large group of consumers is a normal function in the market. Burch (2012, 22) concludes by cautioning readers that “the effects we might imagine are benign compared to what lays in wait for us if we continue to pursue the path of exploitation that we are on”.

#### IV Comparative Analysis

Thus far this work has explored the different sides of how the US residential sector can make changes to improve the quality of the environment while also considering financial savings; through either investing in efficient technologies or through a lifestyle of voluntary simplicity. Of course these examples are two extremes on the spectrum of embracing an ecologically-friendly lifestyle, and are by no means mutually exclusive measures. Nevertheless it is important to construct a comparative discussion and analysis of the two extremes. Is one method better for the economy? Will one method foster more energy and carbon savings? Importantly, is either method more likely to be widely embraced by the population?

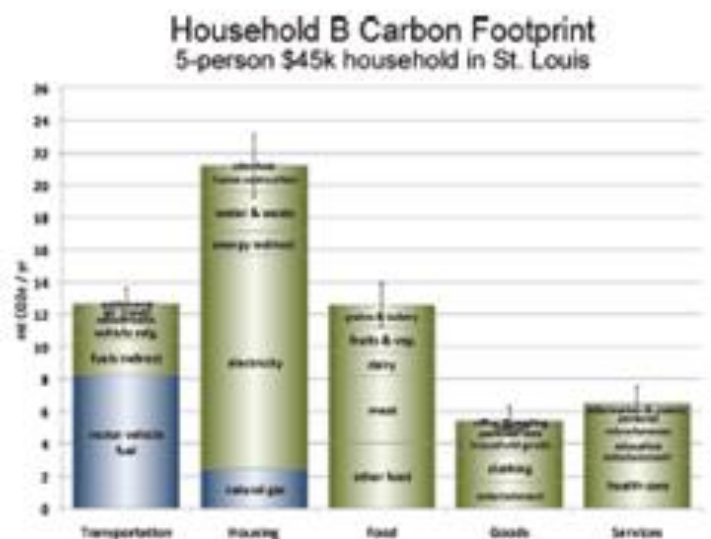
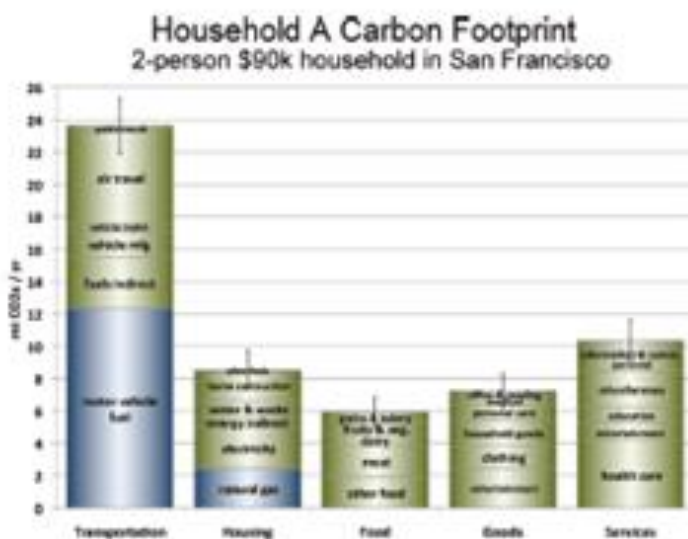
Jones and Kammen's (2011) "Quantifying Carbon Footprint Reduction Opportunities for US Households and Communities" provides a valuable basis for comparison of different actions and behavioral choices that can impact the carbon footprint of households and individuals. They create a model for "typical US households in 28 cities for 6 household sizes and 12 income brackets" which takes into account the emissions embodied in transportation, energy, water, waste, food, goods and service consumption (Jones and Kammen 2011, 4088). The goal of the publication is "to quantify greenhouse gas and financial savings from 13 potential mitigation actions across all household types" although they note that starting carbon footprints differ dramatically across geographic regions and within regions based on demographic characteristics. Perhaps the most valuable contribution of this literature is that the authors implemented their methods of calculation into an online carbon footprint calculation tool that is available for public use on the University of California Berkeley website (Jones and Kammen 2011, 4088).

The paper begins with a summary of the average carbon footprint of a typical US household. The breakdown of sources of direct and indirect emissions can be seen in the following graph (next page):

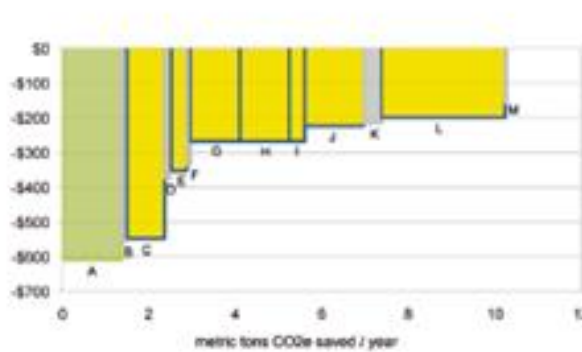


**Figure 1.** Total carbon footprint of the typical U.S. household: 48 t CO<sub>2</sub>e/yr. Blue indicates direct emissions; green indicates indirect emissions. (Jones and Kammen 2011, 4090).

The authors base their analysis on a basket of goods that involve both behavioral changes (voluntary-simplicity like actions) and investments in technology to illustrate the financial savings and greenhouse gas abatement for an idealized combination of efforts. Two such example cases are illustrated below:

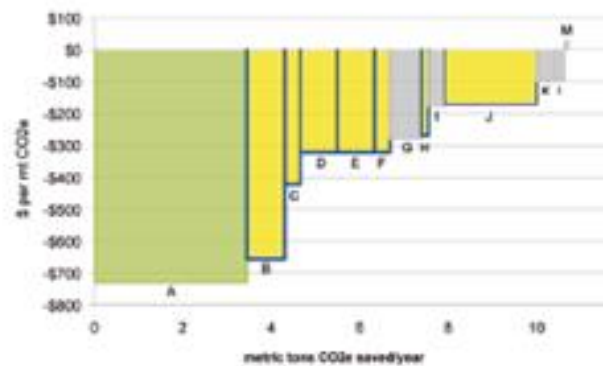


Household A GHG Abatement Cost Curve



A - Change diet  
B - Turn up thermostat  
C - Telecommute  
D - Buy CFLs  
E - Take transit  
F - Line-dry clothes  
G - Eco-driving  
H - Maintain vehicles  
I - Ride bike  
J - Reduce flying  
K - Turn down thermostat  
L - Trade in vehicles  
M - Energy Star fridge

Household B GHG Abatement Cost Curve



A - Change diet  
B - Telecommute  
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G - Turn down thermostat  
H - Reduce flying  
I - Turn up thermostat  
J - Trade in vehicles  
K - Buy CFLs  
L - Line-dry clothes  
M - Energy star fridge

(Jones and Kammen 2011, 4093)

Jones and Kammen's work is an example of an analysis to give a baseline for estimating carbon savings; it should be noted that it is extremely difficult to combine energy and carbon savings into 1 model but Jones and Kammen's model would indirectly imply energy savings based on their financial calculations reflecting costs saved in fuel and electricity based on various choices.

The model is skewed towards voluntary-simplicity like choices rather than investments. The investments in the menu of choices that they model make up only 4 of the 13 actions included in the model – buying CFLs, routine vehicle maintenance, trade in vehicles for more efficient models, and purchase an Energy Star refrigerator (Jones and Kammen 2011, 4093). In example A above, emissions reduction from these 4 investments makes up roughly 30% of the potential emissions reduction (about 3 out of 10 total metric tons of Co2 saved per year) and roughly \$1000 total savings per year of all investment efforts. Conversely, the voluntary simplistic actions include the following: diet changes, thermostat control (summer), telecommuting, use of public transit, line-dry clothes, eco-driving (driving more carefully to save fuel), riding a bike, reducing air travel, and thermostat control (winter). These actions make up about 70% of savings in Household A example and result in much greater cost savings than the investment actions of over \$3300 per year. Of course this is skewed by the number of simplicity actions being greater than the number of investments but it still provides an interesting basis for understanding, especially when compared to Household B whose costs and carbon savings are spread quite differently.

Conducting a similar analysis for example Household B above, the investment actions again make up about 30% of carbon savings and the simplicity actions about 70%, again as a result of the number each

type of choice goods differs just as in the previous example. Cost savings from investments is less than \$600 per year for this household. Total savings comes mostly from diet change, which accounts for over \$700 and 3 metric tons of CO<sub>2</sub> saved per year. Total cost savings for the voluntary simplicity bundle in this example is estimated around \$3200. Here we see that total cost savings and total carbon savings are similar for the different examples although the breakdown of actions resulting in the greatest savings are very different. We could hypothesize here that if the authors introduced a large investment such as solar panels or an insulation retrofit to the basket of actions modeled that the distribution of carbon savings would even out to about half of carbon savings from investment and half from voluntary simplistic actions. The figures for cost savings would also likely look more equal especially over a longer period where returns on investment from a more costly technology could be modeled.

Based on this analysis it remains ambiguous whether voluntary simplicity or investing in technology is strictly preferable for a typical US family. This is not surprising as we have explored many benefits and costs of each choice. The major takeaway from Jones and Kammen's work is that the authors "demonstrate the utility of tailoring different carbon reduction policies and programs to different audiences based on the size and composition of household carbon footprints" (Jones and Kammen 2011, 4093). For example, in Household A's example of a 2-person household in San Francisco with an income of \$90,000 per year, "transportation carbon footprints outstrip household energy (including electricity, natural gas, and other fuel) by more than five to one"(Jones and Kammen 2011, 4093). However for Household B in the example, a typical five-person household in St. Louis, "emissions from household energy are 1.5 times greater than emissions from transportation" (Jones and Kammen 2011, 4093). While Jones and Kammen admit that they have chosen rather extreme examples, they compellingly suggest that they "have demonstrated that carbon footprint compositions can vary quite dramatically between different population segments, suggesting that one-size-fits-all messages, policies, and programs may be shortsighted and less effective than more targeted messages and programs". In addition they suggest understanding barriers and solutions to potential barriers that prevent individuals from taking these actions (Jones and Kammen 2011, 4093-4094), issues we have already addressed in detail.

It is no surprise that a lifestyle of voluntary simplicity or investing in efficient and alternative technologies in the residential sector is complex and yields ambiguous solutions; one choice is not strictly better than the other because there are simply too many factors at play. Jones and Kammen harness one major variable, geography, that has often been ignored in the literature, to show one example of a way to tailor efficiency decisions as based on your geographic location. This is a powerful

method that has implications for the future. Going directly to Jones and Kammen's online tool (<http://coolclimate.berkeley.edu/carboncalculator>) and inputting your zip code, household size, and average gross annual income will yield a graph that gives an estimated breakdown of different carbon sources for your household. While this information is an estimate only, it can help households visualize the major areas for improvement and savings and serve as a 'starting point' to make the most meaningful changes customized for a particular household.

#### a. Labeling

Labeling is an interesting policy element that applies to both voluntary simplicity and investing in technology, as labels on various types of household products permeate the markets and impact all consumers. "Increasingly, consumer goods are differentiated by process attributes e.g. organically produced food, dolphin-safe tuna, free-range poultry, genetically modified organism (GMO) free food, low-emissions electricity, irradiated food, etc., as well as by use attributes e.g. taste, texture, performance" (Roe & Sheldon 2007, 1020). Important implications may arise for various sectors of agriculture, for the environment, and for international trade as consumers' decision making is shifted towards choosing among goods produced by different methods (Roe & Sheldon 2007, 1020).

Many of these process attributes are not correlated with end-use attributes, leading to an asymmetric information problem. Consumers cannot verify process attribute claims, even after extensive inspection or consumption of the good. Roe and Sheldon (2007, 1020) propose that goods that offer such ex post information asymmetries are a simplified version of a credence good – a good whose utility impact, gain, or loss is impossible or difficult to ascertain.

The major method of addressing the credence good problem with process attribute claims is through labeling. Roe and Sheldon (2007, 1020) summarize the process by which firms make labeling decisions. Firms have a choice between discrete and continuous labeling; "a label either communicates that a good meets a certain quality threshold (the tuna-fish is dolphin safe) or communicates the exact level of quality being produced (electricity costs for this appliance are \$55 annually under normal operating conditions)". Firms also choose between labeling under the authority of a government agency (US FDA, Energy Star) or through a private firm (Consumer Reports, private test results). If government labeling is mandated, a third choice must be made whether or not to include private certifiers to further communicate quality differences (Roe & Sheldon 2007, 1020-1021). For example, "electricity providers in 23 states must disclose information concerning the environmental profile of energy sources but they may also seek private certifications such as the Center for Resource Solution's Green-E renewable

electricity certification. In contrast, all organic certification in the US is overseen by federal and state government entities, and private firms may not establish alternative definitions of organic” (Roe & Sheldon 2007, 1021).

Roe and Sheldon (2007, 1028-1030) analyze how firms’ labeling decisions impact the size and distribution of surplus created in a market featuring goods differentiated along a single, vertically differentiated credence dimension. The piece details a model developed by the authors and analyzes several case studies for different types of labeling, including no labeling; mandatory, nonexclusive, continuous labeling; voluntary, nonexclusive, discrete labeling; mandatory, exclusive, discrete labeling; and finally mandatory, nonexclusive, discrete labeling. These studies are recommended for further reading although the cases are too detailed for the purpose of this paper.

Roe and Sheldon (2007, 1021) conclude “that as long as certification is not too expensive, firms will hire private certifiers to label goods that surpass a discrete quality threshold rather than participate in government certification programs, even when private certifiers have no cost advantage over government certifiers. This result is driven by the assumption that discrete labeling is less expensive than continuous labeling and by the assumption that private certifiers validate firm chosen levels of quality while public certifiers may validate quality levels that are sub-optimal for firms”. The work also shows that, “on average, consumers gain from private labeling, as the alternative in [the] game structure is a monopoly selling the lowest quality good”. Roe and Sheldon (2007, 1030) point out that their results are intuitive; “When firms enter the market, labeling options are present, and the costs of labeling are not too high, consumers are given greater choice and competition between firms pushes down price, improving consumer welfare”. Although the findings are subject to the restraints and assumptions of the model, Roe and Sheldon believe the results presented “retain relevance” under relaxed assumptions (shown on 1025-1029) and in application.

Roe and Sheldon’s findings that labeling improves consumer welfare combined with the general idea that making consumer information more readily available is an important aspect to encouraging investments in efficient technology and a simplistic, ecofriendly lifestyle, would suggest that increasing labeling programs would be a beneficial policy choice. Although several types of labels will surely persist in the market, Roe and Sheldon (2007, 1031) propose that “when the government mandates continuous labeling, or when government labeling is voluntary, the labeling regime delivers the same prices and quantities as would be delivered under perfect competition, i.e. the labeling regimes are non-distorting”. The authors also discuss the specific distortions that will occur under other labeling policy types. Based on this notion, voluntary government labeling programs such as LEED Home Certification,

Energy Star appliances, and US FDA Certified Organic are already benefitting consumers and policy should continue to encourage growth and expansion of these labeling programs. For any consumer trying to make environmentally conscious choices, these labeling programs are both credible and beneficial.

b. Energy taxation as a potential policy choice

A controversial potential policy measure to reduce CO<sub>2</sub> emissions would be implementation of a direct carbon tax. Nordhaus (2007) compares the price-based approach of a carbon tax to quantity-based approaches such as the Kyoto Protocol and finds that the tax approach has several advantages to a quantity approach. Segerson (2013) finds that taxes are favorable from an economic efficiency perspective compared to subsidies. Boyd et al. (1995) develop a macroeconomic model to show that carbon taxation would only be efficient if implemented with extreme care, as structural mistakes in a taxation policy could cause a negative net benefit. Although opinions vary on energy or carbon taxation as a policy, such taxes hold economically interesting properties and are worth discussing as an alternative policy option.

Segerson (2013, 186) discusses taxation from an economic efficiency perspective. “In economic terms, efficient decisions or allocations balance the associated societal benefits and costs. More specifically, the decision to increase an activity is efficient from an economic perspective if the aggregate benefit to society from that increase exceeds the aggregate cost to society. Likewise, the decision to reduce an activity is efficient if the societal benefits of the reduction exceed the societal costs. This concept can be applied to a wide range of possible activities, including producing or consuming a given good or service, generating pollution, or using a given resource (such as a type of energy or a specific natural resource, including water or land)”. Goods that cause indirect harm to the environment such as electricity produced from fossil fuels, gasoline, and disposable plastic bags, are priced so that they do not account for the environmental damage, thus they are priced so that they do not reflect the full social cost of the good. Taxation is one means of overcoming this issue (Segerson 2013, 186-187).

External costs of pollution depend not only on how much of the good is produced but also on how (using what processes) it is produced. Simply raising the price of a good will not necessarily provide incentive for the firm to change the way it is produced. “If prices were put on emissions rather than production, it would create an incentive for firms to reduce emissions in the most cost effective way, including switching fuel types if that is cost effective”. Thus, in order for price instruments to be cost effective in reducing externalities, they need to be implemented so as to apply to the specific activities



that generate the external cost (Segerson 2013, 187). “Faced with an emissions tax, each polluter will have an incentive to choose an emissions level where the marginal benefit it gets from emissions, that is, its marginal cost of reducing (abating) emissions, is equal to the tax. As long as all polluters face the same tax, then, although they might not all choose the same level of emissions, they will all choose levels of emissions that result in the same marginal cost of abatement” (Segerson 2013, 188). Note that all sectors must be subject to the same tax for it to be cost effective. Imposing a carbon tax on some sectors but not others would not ensure that the aggregate reduction in emissions is achieved at the lowest possible aggregate cost (Segerson 2013, 188-189).

Although such a cost effective tax would be a ‘first-best’ price instrument because it provides incentives for efficient decisions, implementing this type of tax would require emissions to be monitored so that the amount of tax can be calculated accurately. Monitoring may be simple in some contexts, but difficult and costly in others. For this reason, rather than imposing a direct emissions tax, policymakers sometimes impose a ‘second-best’ tax on an activity related to emissions but more easily monitored (Segerson 2013, 189). There are numerous examples of such taxes in practice, including “gas-guzzler” taxes on the production, purchase, or registration of motor vehicles that do not meet a given fuel economy standard, fees imposed on customers who use disposable bags in retail stores such as grocery stores, taxed on the purchase of commercial pesticides and fertilizers, and waste disposal fees, such as a bottle deposit (Segerson 2013, 189). Although less economically efficient, ‘second-best’ taxes may impose significantly lower administrative costs than ‘first-best’ taxes, which could lead to higher net benefits than an emissions tax if the loss in efficiency from not directly targeting emissions is relatively small (Segerson 2013, 190).

Nordhaus (2007) bases much of his argument in favor of a carbon tax on a comparative analysis of price and quantity-based approaches, drawing on the substantial shortcomings of the quantity-based Kyoto Protocol throughout his argument, he argues that price approaches are more implementable and more likely to be efficient at reducing emissions on a large-scale. Nordhaus (2007, 36) proposes a mechanism called harmonized carbon taxes (HCT). Under this approach, there are no binding national or international emissions limits. Rather, countries would agree to penalize carbon emissions at an internally agreed-upon ‘carbon tax’ or ‘carbon price’. Conceptually, such a tax would be “a dynamically efficient Pigouvian tax that balances the discounted social marginal costs and marginal benefits of additional emissions”. Because of this conceptual simplicity, Nordhaus (2007, 35-36) argues it may be more simple to design an efficient tax than an efficient quantity mechanism. “Unlike the quantitative

approach under the Kyoto Protocol, there would be no country emissions quotas, no emissions trading, and no base period emissions levels. Because carbon prices would be equalized, the approach would be spatially efficient among those countries that have a harmonized set of taxes” (Nordhaus 2007, 35). Details about burden sharing would require further study and negotiations. “It would be reasonable to allow participation to depend upon the level of economic development. For example, countries might be expected to participate fully when their incomes reach a given threshold (perhaps \$10,000 per capita), and poor countries might receive transfers for early participation. The issues of sanctions, the location of taxation, international trade treatment, and transfers to developing countries under an HCT are important details that require discussion and refinement” (Nordhaus 2007, 35).

Nordhaus (2007, 42-43) suggests that an emissions tax is more efficient in the face of uncertainty because of the relative cost-benefit linearity. Additionally, he argues that the tax approach provides less opportunity for corruption and financial issues than quantitative limits, because it creates no artificial scarcities to encourage rent-seeking behavior. The one major drawback to such a tax would be that it is “an unfamiliar ground in international environmental agreements”; this argument should not be belittled as international political agreement on any issue is difficult if not impossible. Perhaps Nordhaus’s idealized international HCT could be implemented on a smaller scale at first as a trial, for example across all sectors of one country as Segerson (2013, 188) suggests. In this context, the tax would not lose its efficiency property but would be able to be observed and studied in practice before being potentially implemented internationally. Nordhaus’s argument is economically sound but his optimism regarding the potential for international political agreement is a challenging assumption to overcome.

Boyd et al. (1995) take a more cautious perspective on the implementation of an emissions tax, conduct a net benefit analysis using computable general equilibrium (CGE) modeling to evaluate the cost and welfare impacts of carbon taxation. The authors note that the welfare costs of reducing CO<sub>2</sub> emissions via taxation are significantly influenced by the structure of the tax policy (Boyd et al. 1995, 4).

Boyd et al. (1995, 4) analyze the optimal carbon tax level “in a scenario in which the government keeps the carbon tax revenue so that the size of government increases and assume that this tax revenue would have otherwise been raised by a non-distorting lump-sum tax”. “This public finance assumption will generate higher cost estimates than alternative assumptions; for example that raising revenue with a carbon tax would avoid the necessity of producing the revenue with some other distorting tax or that carbon tax revenues would be offset by lowering distorted taxes elsewhere in the economy. Even for

these public finance assumptions, the net benefits of carbon taxation will be positive over some range when environmental benefits are explicitly monetized". Boyd et al. (1995, 4) state that the piece's "contribution to the literature is to add an explicit monetization of the environmental benefit side of the equation to provide a broader analysis of carbon taxation net benefits".

The model has fourteen producing sectors which produce domestic goods and exports from three primary production factors, and the outputs of other industries; six domestic consumer classes differentiated by real income; a government sector; and a foreign sector (Boyd et al. 1995, 5). The environmental benefit side of the assessment is based on an EPA supported project. To derive environmental damage estimates, the study assumes that the marginal damages associated with fossil-fuel emissions were equal to average damages and that average damages were constant per unit of emission (Boyd et al. 1995, 8). Total dollar benefits are calculated for reducing fossil fuel emissions from their current level to that dictated by environmental standards. "Aggregating figures by the total fuel consumption level, the estimates imply that the total environmental damages caused by fossil fuel consumption in the US ranges anywhere from trivial (.2% of GNP) to extremely high (4% of GNP) in the upper bound case (Boyd et al. 1995, 8-10). The midpoint of 2% GNP is regarded as the base case estimate implies a significant economic cost associated with current level of fossil fuel consumption (Boyd et al. 1995, 10).

In policy simulations, energy taxes were imposed on the three primary fuels in proportion to their carbon content (coal, oil, and gas respectively) (Boyd et al. 1995, 10-11). Taxes were applied on both domestic energy producers and energy importers, yielding a de facto broad-based consumption tax on primary fossil fuels. Primary producers were taxed on the assumption that the transaction costs of tax admin would be relatively low for the relatively few producers in the industry (Boyd et al. 1995, 11-12). Imports were taxed for three reasons – (1) if imports are not taxed, energy demand would shift away from domestic producers to importers which would be inequitable to domestic producers (2) increased reliance on imports would have a negative impact on national security (3) increasing import demand would have the unintended side effect of increasing world energy prices and fuel production elsewhere in the world, partially offsetting the policy objective to reduce global CO<sub>2</sub> emissions (Boyd et al. 1995, 12).

Figure 1 below plots the environmental benefits associated with low (LEVB), medium (MEVB), and high (HEVB) case estimates against the welfare cost of CO<sub>2</sub> emissions reductions, under the assumption that energy is not substitutable with other production factors (Boyd et al. 1995, 12-13) "Environmental benefits are close to linearly relates to CO<sub>2</sub> emissions reductions, while welfare costs increase at an

increasing rate, reflecting the increasing economic burden imposed on energy markets as energy taxes become more stringent” (Boyd et al. 1995, 13). For example, “reducing CO<sub>2</sub> emissions by the first 0.4 billion tons (about at 7% reduction) imposes insignificant costs, while the next 0.4 billion-ton reduction (about a 14% overall reduction) costs about 3.5 billion. Thereafter, reducing CO<sub>2</sub> emissions becomes increasingly expensive. CO<sub>2</sub> emissions reductions on the order of 2 billion tons (slightly less than 35% reduction) cost around \$110 billion international welfare, are 2.4%. Welfare costs increase strikingly for CO<sub>2</sub> emissions reductions greater than 35%” (Boyd et al. 1995, 13).

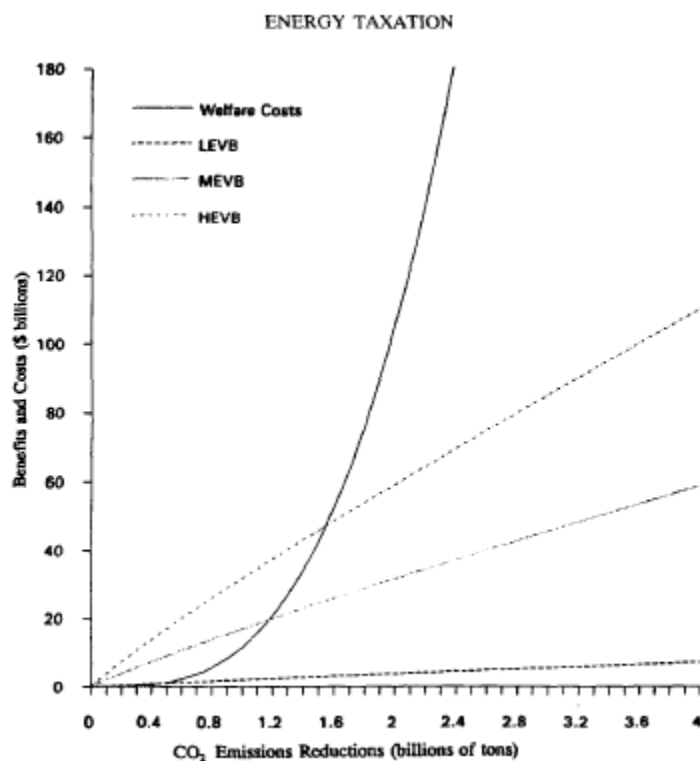


FIG. 1. Environmental benefits and welfare costs of CO<sub>2</sub> emissions reductions: LS case.

Figure 1 Boyd et al. 1995, 13

Figure 2 below plots the net benefits of CO<sub>2</sub> emissions reductions – “the vertical subtraction of the environmental benefit and welfare cost curves plotted in Figure 1. For each of the environmental damage estimate cases, net benefits rise to a maximum (the optimal point) and then decline to zero, ultimately becoming negative” (Boyd et al. 1995, 13). “For the LEVB case, the optimal level of CO<sub>2</sub> emissions reductions is around 0.30 billion tons, about a 5% reduction. Net economic benefits associated with this level of carbon reduction are only around 1.1 billion per year” (Boyd et al. 1995, 13).

“For the MEVB case, the optimal CO<sub>2</sub> emissions reductions are on the order of 0.68 billion tons, about a 12% reduction. Associated welfare benefits of around \$8.8 billion, a 0.20% national welfare increase, are about eight times higher than in the preceding case” (Boyd et al. 1995, 14). “For the HEVB case, optimal CO<sub>2</sub> emissions reductions are about 0.85 billion tons, about a 15% decrease. The associated net benefit of around \$21 billion represents a national welfare increase of about 0.5%” (Boyd et al. 1995, 14). In total, “optimal CO<sub>2</sub> emissions reductions vary from 5-15% and national welfare improves from 1 billion to around 21 billion, depending on differing estimates of the environmental benefits associated with the CO<sub>2</sub> emissions reductions” (Boyd et al. 1995, 14).

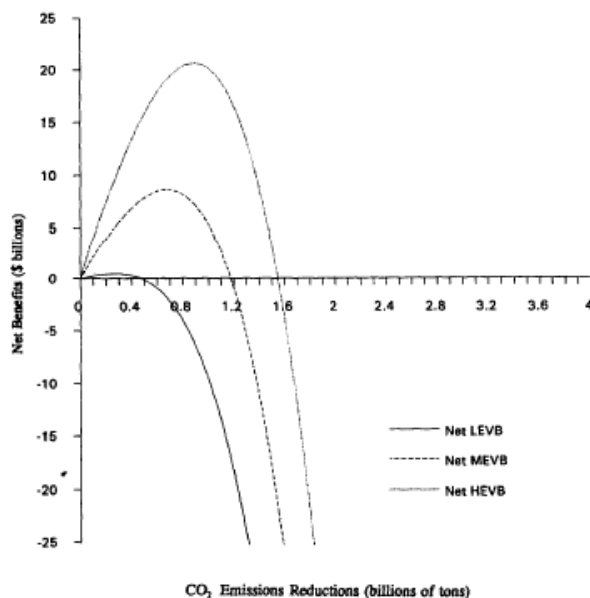


FIG. 2. Net benefits of CO<sub>2</sub> emissions reductions: LS case.

Figure 2 Boyd et al. 1995, 14

Although Boyd and coauthor’s assessment of optimal taxation would need to be recalculated with present-day energy prices to give a more accurate portrayal of optimal taxation, the model nevertheless provides important policy takeaways. The piece shows that if net benefits are the principle criterion for policy formulation, energy prices are lower than optimal. “Caution with respect to high levels of energy taxation is suggested, as it is possible to overshoot the appropriate tax level if policy makers do not have complete information” (Boyd et al. 1995,21). “For example, if the economy was described by the LS, LEVB case, a mistaken assessment that the optimum tax level was 34% instead of 20% would move the economy into a negative net-benefit range” (Boyd et al. 1995, 21-22).

Given the dynamics of changing energy prices, it might seem that this caution is best exercised to the point where it would be unreasonable to impose such taxes in an effective manner. Conversely,

Boyd et al. (1995, 22) also point out that because energy is underpriced given environmental damage costs, “reducing energy consumption and CO<sub>2</sub> emissions in the current time frame will yield net economic benefits. Deferring policy action until after the negotiation of an international climate agreement, or until some future period when global warming risks are better understood, will impose net economic costs”. Although reducing CO<sub>2</sub> emissions by means of taxation will clearly provide net benefits over some range, additional research is needed to more precisely specify the boundaries.

## V – Final Remarks

Throughout this analysis we have been able to determine that an economically and environmentally balanced residential consumption bundle for both the economy and the environment is a mix of investment in technology and voluntary simplifying. Even with thorough analysis, a strict preference towards voluntary simplicity or investments in technology is difficult to derive abstractly and the impacts on carbon, energy, and financial savings are generally ambiguous. I would like to leave readers with remarks regarding the underlying philosophies behind both ideas. Perhaps the strongest point of value in voluntary simplicity (aside from the economic and environmental impacts) is the philosophy behind the lifestyle. Although investment in technology promotes innovation and is valuable in many ways, it does not represent a shift in thought about humanity’s relationship with the environment. From an economic perspective, investing in efficient and alternative technologies at the commercial level is the clear choice. The large-scale of the commercial sector does not make simplicity an economically or even socially viable choice within this space. However, the value of simplicity in the residential sector is truly in the changing preferences and attitudes that make for a more mindful consumer.

Investment in technology represents attempting to compensate for energy use and waste while making the same consumer choices and maintaining the same habits. Some individuals who invest in technology, though certainly not all, may be willing to invest to save money in the long-term but are not motivated by the environmental good; even if they are somewhat motivated by it, they may not be mindful enough of their habits. Choi and coauthors (2009, 33) discuss this idea in discussion of rebound effects, systematic behavioral issues that explain why actual energy savings fall short of expected savings based on benchmark standards. In the instance of a direct rebound effect, “take-back” involves increased energy use concurrent with deployment of an energy efficiency measure. This typically represents a 15-30% decrease in energy savings, but for a very unmindful consumer, can be up to 50% (Choi et al. 2009, 33). Perhaps more difficult to pinpoint and avoid is the indirect rebound effect, which

occurs if end users redeploy money saved through energy efficiency to purchase or consume energy in another form, causing no net decrease in overall energy consumption (Choi et al. 2009, 33). Here we see that although there is great value in investing in efficient or alternative technology at the residential level, the full-potential of this value is only realized if the consumer is also mindful of his or her actions and habits.

A unique and valuable quality to voluntary simplicity is that it represents a true shift in thought towards a more careful, conscious, symbiotic relationship between people, earth, and the local community. The nature of these relationships is far more sustainable than maintaining the current mindset towards endless progress. As we have illustrated in our analysis, a large increase in the number of voluntary simplifiers in the US would not halt or harm economic progress; rather, it would lead to more locally focused economies, changes in demand towards ethical and organic products, and an improved overall relationship between people and earth. This inherent value to voluntary simplicity brings endless intangible benefits.

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Figure 1

Table 3  
Summary statistics

Variable	Mean	Standard deviation	Minimum	Maximum
Credit taken (dummy variable)	0.057	0.233	0	1.000
Conservation expenditures	39.130	261.590	0	16,970
Credit (dollars)	5.040	28.710	0	301.000
AGI ( × 1,000)	22.660	19.860	–278.990	271.150
Homeowner (dummy variable)	0.315	0.464	0	1.000
Heating degree days	4.849	2.035	0.783	10.420
Change in unemployment rate (%)	0.540	1.040	–2.000	4.600
Price	0.026	0.074	0.019	0.048
Tax price	0.974	0.074	0.730	1.000

*Notes:* Summary statistics are for the 112,974 observations over the three-year period 1979–1981.

Hassett & Metcalf 1995, 212

Figure 2

Table 4  
Regression results

Variable	(1)	(2)	(3)	(4)	(5)
Tax price	0.978 <sup>b</sup> (0.350)	-2.428 <sup>b</sup> (1.183)	-2.271 (1.489)	-2.081 <sup>a</sup> (1.063)	-2.552 <sup>b</sup> (1.195)
Price	-5.111 (6.354)	11.541 (10.170)	26.434 <sup>b</sup> (13.26)	0.255 (0.258)	10.454 (10.290)
AGI (× \$1,000)	0.0006 <sup>b</sup> (0.00008)	0.0110 <sup>b</sup> (0.0024)	0.0109 <sup>b</sup> (0.0027)	0.792 (0.111)	0.0111 <sup>b</sup> (0.0024)
Homeowner*	1.508 <sup>b</sup> (0.035)	0.948 <sup>b</sup> (0.089)	—	0.917 <sup>b</sup> (0.089)	0.947 <sup>b</sup> (0.089)
Heating degree days	0.144 <sup>b</sup> (0.0009)	0.201 <sup>b</sup> (0.051)	0.079 (0.098)	0.200 <sup>b</sup> (0.052)	0.204 <sup>b</sup> (0.052)
California*	-0.456 <sup>b</sup> (0.103)	-0.774 (0.626)	—	-0.785 (0.632)	-0.792 (0.625)
Change in unemployment rate (%)	-0.037 <sup>b</sup> (0.014)	-0.017 (0.021)	0.026 (0.030)	-0.016 (0.021)	-0.016 (0.021)
Trend	-0.162 <sup>b</sup> (0.027)	-0.186 <sup>b</sup> (0.041)	-0.291 <sup>b</sup> (0.058)	-0.170 <sup>b</sup> (0.042)	-0.182 <sup>b</sup> (0.042)
Lead tax*	—	—	—	—	0.070 (0.095)
Constant	-4.764 <sup>b</sup> (0.378)	—	—	—	—
Fixed effects	no	yes	yes	yes	yes
Sample size	74,792	12,915	8,496	12,915	12,915

<sup>a</sup> Significant at the 90 percent level.<sup>b</sup> Significant at the 95 percent level.

Note: Regression results are for individuals in the 50 states plus the District of Columbia followed over the three-year period 1979–1981. Standard errors are reported in parentheses. An asterisk on a variable indicates a dummy variable. Tax price, price, and AGI are in logs in column 4.

- The change in sign for the price and tax price coefficient between columns 1 and 2 above suggests the importance of correlated fixed effects (Hassett & Metcalf 1995, 214)

Figure 3

Emissions from each good are defined as follows  
good are defined as:

$$E_{ikt} = \theta_{ikt} \tilde{x}_{it}$$

where  $\tilde{x}_{it}$  is the real consumption of good  $i$  in period  $t$ ,  $\theta_{ikt}$  is the emission of substance  $k$  per unit of real consumption of good  $i$  in period  $t$ .<sup>3</sup> Index  $i$  defines goods,  $k = \text{CO}_2, \text{SO}_2, \text{NO}_x$ .

Emissions from the various subgroups of goods can now be written as:

$$E_{rkt} = \sum_{i \in r} E_{ikt} = \sum_{i \in r} \theta_{ikt} \tilde{x}_{(r)(i)t},$$

where  $r$  denotes groups of goods, i.e.  $r=1, \dots, n$ . Total emissions from private consumption are then:

$$E_{kt} = \sum_r E_{rkt}, \quad k = \text{CO}_2, \text{SO}_2, \text{NO}_x$$

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Figure 4

The change in emissions due to a price change of good  $j$  is then:

$$\frac{\partial E_{kt}}{\partial p_{jt}} = \sum_i \frac{\partial \tilde{x}_{it}}{\partial p_{jt}} \frac{\partial E_{kt}}{\partial \tilde{x}_{it}} = \sum_i \frac{\partial \tilde{x}_{it}}{\partial p_{jt}} \theta_{ikt}, \quad k = \text{CO}_2, \text{SO}_2, \text{NO}_x$$

After some manipulations, we can express the emission change in elasticity form as:

$$\frac{\partial E_{kt}}{\partial p_{jt}} \frac{p_{jt}}{E_{kt}} = \sum_i \theta_{ikt} \varepsilon_{ij} \frac{\tilde{x}_{it}}{E_{kt}}, \quad k = \text{CO}_2, \text{SO}_2, \text{NO}_x,$$

where  $\varepsilon_{ij}$  is the price elasticity of good  $j$  with respect to price  $i$ . Similarly, we obtain the emission change due to a change in total expenditures:

$$\frac{\partial E_{kt}}{\partial y_t} = \sum_i \frac{\partial \tilde{x}_{it}}{\partial y_t} \frac{\partial E_{kt}}{\partial \tilde{x}_{it}} = \sum_i \frac{\partial \tilde{x}_{it}}{\partial y_t} \theta_{ikt},$$

or

$$\frac{\partial E_{kt}}{\partial y_t} = \frac{y_t}{E_{kt}} = \sum_i \theta_{ikt} \varepsilon_{yi} \frac{\tilde{x}_{it}}{E_{kt}}.$$

where  $y_t$  is the total expenditure in period  $t$  and  $\varepsilon_{yi}$  is the expenditure elasticity of good  $i$ .

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Figure 5

Table 1  
Expenditure shares and emission shares in 1997

	Percentage share of total expenditure	Percentage share of CO <sub>2</sub> emissions	Percentage share of SO <sub>2</sub> emissions	Percentage share of NO <sub>x</sub> emissions
Car transport	11.7	60.9	21.9	67.4
Public transport	1.5	1.9	1.5	4.2
Other transport	1.6	1.1	0.7	1.3
Electricity	5.0	7.2	24.5	2.9
Oil	1.2	11.1	13.8	2.6
District heating	1.8	3.2	10.9	1.3
Food	19.0	6.4	10.0	11.1
Beverage	6.9	0.6	1.2	0.7
Recreation	6.9	1.6	3.8	2.9
Clothes	7.5	0.8	1.4	0.9
Medical treatment	3.9	0.4	0.7	0.4
Domestic appliances	7.2	1.1	2.2	1.1
Other goods/services	25.8	3.6	7.6	3.1
	100.0	100.0	100.0	100.0

The emissions from transport and heating are direct, whereas the emissions from all other goods are indirect.

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Figure 6

Table 3  
Percentage change in demand and emissions due to an increase in energy efficiency of 20% for transport and heating

Percentage change	Transport	Heating	Transport and heating	Transport $\Delta$ CO <sub>2</sub> =0	Heating $\Delta$ CO <sub>2</sub> =0	Transport and heating $\Delta$ CO <sub>2</sub> =0
$\Delta$ Car transport	0.92	4.18	5.53	0.21	1.68	1.91
$\Delta$ Public transport	-0.42	2.00	1.85	-0.38	1.36	1.21
$\Delta$ Other transport	-1.76	3.74	2.26	-1.32	3.74	2.78
$\Delta$ Electricity	2.09	0.84	3.43	1.03	-0.81	0.69
$\Delta$ Oil	2.94	1.18	4.85	-3.48	-10.51	-14.42
$\Delta$ District heating	3.41	1.37	5.64	4.40	3.66	8.88
$\Delta$ Food	-1.09	1.58	0.48	-0.76	2.30	1.62
$\Delta$ Beverage	-2.24	3.28	1.00	-1.57	4.78	3.36
$\Delta$ Recreation	3.98	1.18	5.19	2.14	-2.63	-1.27
$\Delta$ Clothes	3.60	1.07	4.69	1.94	-2.38	-1.15
$\Delta$ Medical treatment	0.82	0.25	1.06	0.45	-0.58	-0.28
$\Delta$ Domestic appliances	3.73	1.11	4.86	2.01	-2.46	-1.19
$\Delta$ Other goods/services	2.23	0.67	2.90	1.20	-1.49	-0.72
<i>ΔCO<sub>2</sub></i>						
Transport group	0.83	4.10	5.36	0.17	1.71	1.91
Heating group	2.72	1.10	4.49	-0.79	-5.14	-5.86
Provisions group	-1.19	1.73	0.53	-0.79	2.35	1.66
Diverse group	2.91	0.87	3.79	1.57	-1.93	-0.93
Total effect	1.26	3.05	4.72	0	0	0
<i>ΔSO<sub>2</sub></i>						
Transport group	0.76	4.03	5.21	0.13	1.72	1.89
Heating group	2.62	1.06	4.32	0.51	-2.54	-1.73
Provisions group	-1.21	1.76	0.54	-0.79	2.36	1.67
Diverse group	2.93	0.87	3.81	1.58	-1.94	-0.94
Total effect	1.79	1.82	4.03	0.44	-0.87	-0.35
<i>ΔNO<sub>x</sub></i>						
Transport group	0.79	4.05	5.26	0.15	1.70	1.89
Heating group	2.67	1.07	4.40	-0.09	-3.74	-3.63
Provisions group	-1.16	1.68	0.51	-0.78	2.33	1.65
Diverse group	3.10	0.92	4.04	1.67	-2.05	-0.99
Total effect	0.88	3.30	4.53	0.15	1.09	1.24
$\Delta$ CO <sub>2</sub> tax				36.25	76.30	134.20

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