Looking at the Relationship between Household Electricity Consumption and Annual Household Income Using an Agent-Based Integrated Framework

By

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MPP Essay

Submitted to

Oregon State University

In partial fulfillment of

the requirement of the

degree of

Master of Public Policy

Presented September 20th, 2012

Master of Public Policy essay of <u>Evan Sorce</u> presented on September 20th, 2012

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Abstract:

Electricity is a vital energy source for modern life, and is used in almost every aspect of daily life. United States electricity consumption totaled nearly 3,886,403 gigawatt hours in 2011. Residential electricity consumption accounts for 37 percent of total electricity consumption in the United States. Between 1990 and 2007, the total volume of electricity sold in the United States grew at an average annual rate of 1.9%. The growth rate in residential energy usage was even higher, growing at an annual rate of 2.4% The oil shocks of the 1970s and major blackouts in 1965, 1977, and 2003 raised energy supply and security concerns. This paper uses the United States Energy Information Agencies Residential Energy Consumption Survey from 1997, 2001, and 2005 and an integrated framework of residential energy consumption to examine the relationship between annual household income and household electricity consumption. Even when controlling for various aspects of household electricity consumption, household annual income is found to be a significant factor in determining residential electricity consumption.

ACKNOWLEDGMENTS

I would like to thank my incredible committee members, Dr. David Bernell, Dr. Patrick Emerson, and Dr. Dwaine Plaza for their patience, support, and advice, throughout the course of this project. Special thanks to Dr. David Bernell, for chairing this committee and having the patience to work with me through many different thesis topics ideas and guiding through this academic endeavor. I would also like to give a special thanks to Breandan Jennings, whose willingness to spend hours with me working with my data was much appreciated and absolutely pivotal to the success of this project.

I would also like to thank my friends, and colleagues especially Carlos Algara and Michael Marsubian for your continued support and words of wisdom through this processes. Last but definitely not least, a big thank you to my parents Joe Sorce and Ilene Schwartz, whose patience, support, and love throughout my entire life have helped me get to where I am today.

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I. Introduction:

"Electricity is just another commodity in the same way that oxygen is just another gas"
-Former Secretary of Energy Hazel O'Leary (Savacool 2009).

Until the middle of the 20th century, public officials and electric utilities operated in the best of all worlds when it came to dealing with electricity generation and transmission. Costs associated with energy generation were declining, consumption and revenues were on the rise, and investors were pumping much needed capital into utility enterprises. In addition, planning problems were rare, energy demand was growing at a steady, predictable rate, generation siting was easy, and regulation was minimal (Kaufman, 1976; Golove & Eto 1996).

Two major events raised concerns and exposed major flaws that changed how the United States energy system was viewed and operated. The first event was the 1965 blackout in the northeastern United States and Canada, which left about 30 million people without power for up to 13 hours. This event created concern about the reliability of the electrical transmission system as well as concerns about load demand. These uncertainties led to the passage of the U.S Electric Power Reliability Act of 1967, and eventually to the creation of the National Electric Reliability Council (NERC). This body was established by the electric utility industry to create nine regional reliability councils responsible for regional planning and coordination (National Electric Reliability Council 2012). Although reliability, communication, and planning have vastly improved, events such as the 2003 blackout show that there are still problems associated with load demand and reliability of the grid.

The second major event was the 1973 Arab oil embargo in which the Organization of Petroleum Exporting Countries (OPEC) decided to increase oil prices by 70% in protest of the

United States' support of Israel in the Yom Kipper War (Yergin 1990, p.587). The embargo created oil shortages in the United States, triggering gas rationing, and had a serious impact on the economy. Government officials, as well as members of the public, were terrified about the prospect of future shortages, causing energy security to become a high priority. Presidents began emphasizing the importance of energy independence and security, oil price controls were implemented, CAFE standards were set, research into alternative fuels was implemented, and the Department of Energy was created in an effort to reduce American reliance on foreign oil (Department of Energy 2012).

To further complicate the issue, the cheapest and most abundant sources of energy, fossil fuels, release a large amount of CO_2 emissions. These emissions have grown by 20 percent over the last decade. As a result of this, global average temperatures on both land and ocean have risen. Some observable evidence of this includes the retreating of glaciers and an abnormal number of intense storms (Center for Climate and Energy Solutions, 2009). There is scientific consensus that increased concentrations of carbon dioxide and other greenhouse gases from burning fossil fuels are warming the earth. Although the amount of damage that can be attributed to global warming is unknown, there is some risk that it could be catastrophic. Most scientists argue that in order to stabilize greenhouse gas concentrations in the atmosphere, emissions need to be reduced by 50 to 80 percent from current levels (Center for Climate and Energy Solutions, 2009).

The solution to this problem is multifaceted. It is important to promote diversity of the energy supply through investing in renewable energy development, and ensuring that the transmission lines are robust. At the same time, demand management strategies such as energy efficiency and conservation are considered low hanging fruit. Both are vital to reduce energy

consumption as well as emissions, thereby reducing the threat of climate change without lowering the standard of life people in the United States and around the world have come to enjoy (Thollander, Palm, and Rohdin).

In order to effectively and efficiently reduce residential energy consumption, it is essential to understand how much electricity is consumed in the United States. In 2010, the United States consumed 3,886,403 gigawatt hours of electricity (Energy Information Administration, 2012). Overall, residential energy consumption represents approximately 37% of total electricity consumption, or 1,437,969 gigawatt hours. Between 1990 and 2007, the total volume of electricity sold in the United States grew at an average annual rate of 1.9%. The growth rate in residential energy usage was even higher, growing at an annual rate of 2.4% (Nakajima & Hamori 2009). Although there are some dips in electricity consumption, as shown during the economic recession of 2007-2010 for example, residential energy demand is expected to continue on this growth trend, attracting much attention by environmentalists and public officials (Jamasb & Meier 2010).

Before demand management can be addressed, it is necessary to know what actually impacts energy demand. This paper seeks to answer how annual household income impacts annual household electricity use, while controlling for other economic, sociological, engineering, and psychological factors to see if they diminish, increase or have no impact on the role income plays in residential energy use in the United States. This paper focuses exclusively on electricity consumption in the United States. The reason for focusing exclusively on electricity consumption is because 99 percent of households in the United States consume electricity. Furthermore, many appliances which are commonplace in American households, such as refrigerators, televisions, computers, lighting and air conditioners are exclusively powered by

electricity. This paper uses household-level data from a nationally representative survey, the Residential Energy Consumption Survey. The results show that household income does indeed have a significant impact on household consumption. The impact differs in significance depending on what is controlled for. It does, however, remain significant after controlling for physical environmental impacts, market impacts, house characteristics, lifestyle characteristics, and demographic characteristics.

The second section of this paper provides a brief discussion of household electricity consumption in the United States and a review of the relevant literature. Section 3 describes the methodology used in this paper. Section 4 describes the data used and explains the limitations of the study as well as the statistical models used and analysis performed. Section 5 presents the results of the data analysis of how annual household income impacts yearly household electricity consumption from regression results. Section 6 discusses the impact of the results and the application of the results to the agent-based integrated framework. Finally, Section 7 concludes the paper with a discussion of policy implications as well as possible future research on this subject.

II. Literature Review

The literature examines four views to explain how energy is consumed within residential households based on theories of economics, engineering, psychology, and sociology. Each of these different schools of thought sees different factors as the dominant influence on residential consumption (Lutzenhiser et. al, 2010; Kierstead, 2006).

A. **The Economic Prospective and the Impact of Income on Residential Energy**

   Consumption

The economic focused frameworks offer strong numerical analysis, and seek to explain energy consumption as an effect of utility maximizing behavior. The economic approach is usually used to understand the impact of taxes, price effects (price elasticity), and income levels on residential household energy consumption (Lutzenhiser et. al, 2010; Kierstead, 2006).

Income is a key driver of residential energy consumption. The more money a household has, the more it can afford to use a combination of energy and capital goods as a substitution for time. In other words, when buying an appliance such as a washing machine, the consumption good is selected to gain leisure time (Bengt, 2008). Saunders (2011) found that household energy consumption has increased across all income levels over the last 20 years despite declining real average incomes and increased energy efficiency gains in household use. Although Saunders found that energy use does increase with household income, it does not rise in one for one fashion (Saunders, 2011).

Furthermore, growth in personal incomes has resulted in an increased adoption rate of appliances. Earlier research of household electric power consumption, specifically Dergiades & Tsoulfidis (2008), Lin et. al (1987), Silk and Joutz (1997), and Nakajima, and Hamort (2010), calculated price elasticities of 0 to -2. This means that when electricity prices go up, people consume 0 to 2 percent less electricity, which shows that electricity is an inelastic good. This signifies that the price of electricity has little impact on household demand. Fell, Li, and Paul (2010) found that price elasticities vary across census regions, with the South region having the

most price-elastic demand with an elasticity of 1.02, and the Northeast region having the least price-elastic demand at -.82.

B. Engineering Perspective, Physical Environments, and Household Characteristics Impact on Residential Energy Consumption

The engineering perspective focuses on the technologies of the domestic sector, and defines consumption by physical laws. Technologies of demand and supply are fundamental indicators for energy consumption changes, especially in the long term. While many models and policy instruments operate on this level, technology only partially explains residential energy consumption. The fact that technology development, technology choice, and technology performance depend on human behavior means that both technology and people must be considered in order to understand and potentially influence energy use, energy technologies, and structures (Lutzenhiser et. al, 2010; Kierstead, 2006).

i.   Impact of Region on Residential Energy Consumption

Regional energy systems differ in energy sources, efficiencies, characteristics of supply, transmission infrastructure, distribution systems, end use technologies and the characteristics of end users (Amato et. al, 2005). Additionally, structural differences between regional energy systems have appeared as the end use infrastructure and housing market have developed. This has led to a distinctive mix of heating and cooling requirements under traditional regional climate patterns (Amato et. al, 2005; Pressman, 1995). For example, apartment buildings in Boston are commonly built with heat retaining red brick, and few have central air conditioning. This is representative of the New England region on whole, where households are less likely to have air conditioning compared to other parts of the country (Amato et. al, 2005; Bebgt, 2008;

and Kaza, 2010). Van Raaj and Verhallen (1983) described patterns of residential energy behavior and found that much of the reported energy usage behavior was related to space heating and cooling.

ii.   Impact of the Type of Home on Residential Energy Consumption

Single family detached housing is the main housing type in the United States, and accounts for over 64 percent of the housing market. Preference for this kind of house, accompanied by low density and large lot development, is a main contributor to habitat destruction. The prevailing wisdom is that non-single family detached homes consume less energy because of shared walls and floors. Staley (2008) argues that multi-family residences have a 'U' shaped relationship with energy consumption. When common spaces such as corridors and parking garages in large multi-family units are accounted for, small apartment units consume less energy than large apartment units and single-family attached units (Staley, 2008; Kaza, 2010).

iii.   Impact of the Age of Home on Residential Energy Consumption

Following the oil price shocks of the 1970s, the United States introduced mandatory energy efficiency building codes and standards, focusing mainly on improved insulation to reduce heating and air conditioning costs. The United States also developed building performance standards, which take into account components and other factors from building orientation and design. Regular reviews and updating of these building codes and standards are based on the best available technologies and best practices. These reviews help ensure a steady and cost-effective strengthening of regulations (Sustainable Consumption and Production, 2007).

Improved building codes have led to more energy efficient houses per square foot than before these standards were put into place.

Kaza (2010) found that the age of the house has a sizable effect on heating energy consumption. Kaza found that at the upper tail, for every 20 years of age, heating energy consumption is increased by 5-14 Megawatt hours, compared to 0.9-2 MW hours at the lower tail. Some of this finding can be explained by the efficiency of the heating systems. Although this outcome suggests that it is important to reduce the average age of the housing market, there is some evidence that energy efficient households can make up the effect of age by weatherizing the home (Kaza, 2010).

iv.   *Impact of the Size of Home on Residential Energy Consumption*

Since 1950, the average size of new single-family homes has more than doubled, even as the average family size has decreased (Wilson & Boehland, 2005). This is a significant trend because the majority of energy end uses are correlated with the size of the home (Impact of increasing home size, 2011). As square footage increases, the usage of heating and cooling equipment rises, the number of lights used increases, and the likelihood that the household has multiple major appliances such as refrigerators increases (Impact of increasing home size, 2011). Although large homes require more energy to heat and cool, larger homes are more likely to have key energy efficiency features. Residents who live in larger homes are more likely to have better insulation and more efficient windows than those in smaller homes. These trends as well as other efficiency standards and policies work to reduce energy intensity in larger homes (Impact of increasing home size, 2011).

v. *Impact of Appliance Use on Residential Energy Consumption*

The way in which energy is consumed within US residential households has changed dramatically over the last thirty years. Although space heating still represents the majority of energy consumption in US households, the total amount used on space heating as well as its percentage of household energy consumption has dropped significantly since 1978. This reduction is largely attributed to minimum energy efficiency standards that were put into place (Dzioubinski & Chipman, 1999; Lowenberger et. al, 2012; Share of Energy, 2011).

Appliance efficiency standards bar the production, import, and sale of appliances and other energy consuming products that fail to meet the minimum standards. These standards reduce energy use, improve electricity system reliability, and help assure a level playing field for companies that strive to make more efficient appliances by eliminating products that are cheaper but less efficient (Lowenberger et. al, 2012). At the federal level, the Energy Policy and Conservation Act (EPCA) was passed and enacted in 1975. It created a nationwide program that involves testing procedures, labeling, and energy targets for consumer projects. In 1979, the EPCA was amended to require the Department of Energy to establish energy conservation standards for consumer products (Lowenberger et. al, 2012).

Meanwhile, California standards were so popular that laws requiring efficiency standards started appearing in states across the country. Fearing differing standards for states and the federal government, appliance manufactures worked with energy efficiency advocates to create national efficiency standards. These standards would cover most major appliances and would pre-empt state standards (Lowenberger et. al, 2012). Initial federal mandatory efficiency standards enacted between 1988 and 1994 for all major appliances and lighting have been one of

the most successful policies that states and the federal government have implemented to save energy. Since the Department of Energy's initial standards, there have been multiple updates to the program, expanding it to other appliances, and intensifying the standards for appliances covered.

Although total energy consumption by household has basically remained the same over the past 30 years, federal efficiency standards have reduced the energy needed to heat homes. Other efficiency improvements have led to a 31 percent reduction in energy use per household. This reduction in per household energy has been canceled out largely by two factors. The first is the massive increase in the number of housing units in the United States (76.6 million in 1978 compared to 111.1 million in 2005). The second reason has been largely attributed to an increased living standard, causing an increased adoption rate in ordinary households of large appliances and electronics as shown below. Additionally, there has been a substantial increase in the use of smaller technological appliances, such as personal computers and televisions. These trends overall have led to an increase over the last thirty years in the share of residential energy use by appliances and electronics in United States households. (Share of Energy, 2011; Fahrenthold, 2010; and Nakajima & Hamori, 2010).

Table 1: Penetration of Electric Home Appliances

Penetration of electric home appliances.

Electric appliance	1993 (%)	2001 (%)	2005. (%)
Refrigerator	99.9	99.8	99.9
Microwave oven	84.2	86.1	87.9
Electric oven	61.5	58.9	61.1
Electric range	61.4	60.0	58.7
Dishwasher	45.2	53.0	58.2
Clothes washer	77.1	78.6	82.6
Clothes dryer	56.6	57.1	60.5
Color TV	97.7	98.9	98.7
Personal computer	23.4	56.1	68.0
Air conditioner	68.4	77.5	84.0
Water heater	38.4	38.1	38.8

Note: the data are obtained from Residential Energy Consumption Survey by the U.S. Department of Energy's Energy Information Administration.

The use has nearly doubled from 17 percent in 1978 to 31 percent in 2005, as shown by the image below (Share of Energy, 2011; Dzioubinski & Chipman, 1999).

Figure 1: Chart of what Makes up the Consumption in Homes

Total energy use in homes

| 1978 | 2005 |
| quadrillion Btu and percent | quadrillion Btu and percent |

1978
Appliances and Electronics 1.77 (17%)
Water Heating 1.53 (14%)
Air Conditioning 0.32 (3%)
Total 10.58
Space Heating 6.96 (66%)

2005
Appliances and Electronics 3.25 (31%)
Water Heating 2.12 (20%)
Air Conditioning 0.88 (8%)
Total 10.55
Space Heating 4.30 (41%)
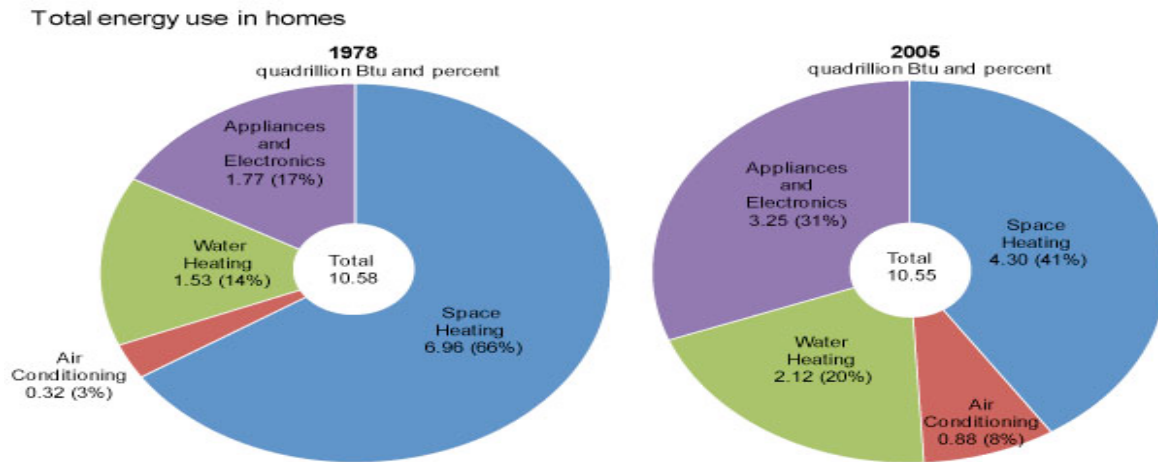
Source: U.S. Energy Information Administration, 1978 and 2005 Residential Energy Consumption Survey

C. Psychological Approach and the Impact of Lifestyle on Residential Energy Consumption

Psychological frameworks focus on what is called the "energy efficiency gap", and finding a way to motivate people to participate in energy saving behaviors. These frameworks often show that individuals' attitudes and values are related to social norms that influence behavior. This suggests that establishing energy saving actions as norms and witnessing others participate in these activities will influence the desired behavior in others. In other words, societal norms and values are reflected in the lifestyle of households (Lutzenhiser et. al, 2010).

According to the U.S Energy Information Administration, the United States represents 5 percent of the world's population, but accounts for about 18 percent of the world's total energy consumption. This high standard of living has found its way into our societal norms and values. An individual is viewed as successful if he has a big house and new, powerful appliances. Many psychological factors and lifestyle factors encourage wasteful electricity consumption and slow

alternative energy systems. Factors such as comfort, freedom, control, trust, ritual, and habit shape individual's attitudes towards the consumption of energy. Multiple studies of American couples have shown that their "comfort" was the single most important determinant of their energy use. In other words, the most inelastic and consistent component of energy use did not occur with a price change of energy, but a change in what households consider comfort. Habits are also a problem, because they are automatic behaviors that impede reasoned actions which could reduce energy consumption (Steg and Velk, 2009). Additionally, individuals often discount energy efficiency improvements because they are committed to what they have been doing. Individuals often do this by downgrading information that implies that change is needed (Sovacool, 2009; Becker et. al 1981; and Lutzenhiser & Gossard, 2000).

D. Sociology Approach and the Impact of Demographic Determinants on Residential Energy Consumption

Sociological frameworks are based on context and the idea that household life as well as energy consumption is part of larger patterns and processes (Lutzenhiser et.al, 2010). These frameworks often focus on demographic determinants and patterns of energy consumption.

A number of demographic factors, such as size of household, age of homeowner and levels of urbanization, have a direct and indirect impact on residential household consumption.

i.   Impact of the Household Size on Residential Energy Consumption:

In recent decades, the proportion of smaller households to the total number of households has expanded at a much faster pace than the increase in population size. Per capita energy use generally declines with increased household size. In fact, two-person households use about 17 percent less total energy per person than do single-person households, and three-person

households use more than a third less energy per person than do people living alone (O'Neil & Chen, 2002). As a result, total residential energy consumption in the United States has increased substantially despite the population growth slowing (Jiang & Hardee, 2011).

There are several reasons why this pattern might exist. The literature focuses on three potential possibilities. The first is that per capita income falls with household size. As mentioned earlier, income is strongly correlated with energy use, and could be a contributing factor to the household result. Second, larger households are more likely to contain children, and households with children use 44 percent less residential energy then households with just adults. Finally, as discussed in greater detail below, energy consumption typically changes with the age of the householder, which can also be used as a marker for the life cycle stage of the family. Therefore, if the distribution of households by age varies across household size, age could contribute to the household size pattern (O'Neil & Chen, 2002; Jiang & Hardee, 2011).

E. *Impact of Homeowners Age on Residential Energy Consumption:*

Residential household electricity use consistently increases with the homeowner's age until the age of 65. Overall, aged households (60 or older) use about one-third less electricity on average than younger households, although aged households spend a larger proportion of their income on energy. This is due to the fact that a large proportion of elderly adults survive on low or fixed incomes (Warriner 1981; Yamasaki & Tominaga; 1997). A large percentage of aged household's electricity consumption is used on essential needs such as lighting, refrigeration, water heating, and cooking. Furthermore, aged households are more dependent on reliable and continuous supplies of energy for health reasons, making it more difficult for them to cut back on energy consumption than other age groups (Wariner, 1981). Younger households commit a far

lower percentage of their consumption to these services (Wariner, 1981). Aged households spend a greater amount of time at home compared to younger households. This is largely because the members of these households are retired. Aged households also usually live in older homes that are not well insulated and weatherized (Warriner, 1981; Yamasaki & Tominaga, 1997; Liao & Chang, 2002; Jiang & Hardee, 2010). When looking at electricity on a per capita basis, aged households consumed more electricity per capita than younger households. This is largely because aged households have fewer household members. These two tables below, in British Thermal Units (BTU), show how households whose homeowners are over the age of 60 consume less total electricity, although per capita consumption is more.

Table 2. Average household energy consumption for different age groups (BTU)

Age= Age is the age of the household head.

Age[a]	Electricity
18–24	2,7912.61
25–34	3,2923.47
35–44	4,0298.62
45–59	4,0122.81
60–	2,9824.70

Data source: Liao, H.C & Chan, T.F. (2002). Space- heating and water-heating energy demands of the aged in the US. *Energy Economics, 24, 267-284.*

When looking at individual appliance ownership, aged households are no less likely to own major energy-intensive appliances; however they use more natural gas and fuel oil, but less electricity for space heating. Aged households rely more heavily on space heating energy as they become older. Homeowners over 80 years of age use more energy of all kinds for space heating. In addition to the demands on space heating, the elderly demand less hot water than the younger

groups. Aged households also consume less energy on air conditioning and other electric appliances than every other age group with the exception of the 25-34 year old age group (Liao & Chang, 2002; Jiang & Hardee, 2011).

A growing trend not just in the United States, but worldwide, is that the population is aging. This trend is likely to increase in future decades with the proportion of the aged group increasing worldwide from 10 percent in 2005 to 22 percent in 2050. This will have a profound impact on the residential electricity consumption in this country (Jaing & Hardee, 2011; Liao & Chang 2002).

F. *Impact of the Urbanization of a Household on Residential Energy Consumption:*

The location of households in cities, suburban areas, or rural areas has an impact on energy use patterns. There are distinct differences in transport energy consumption. People who live outside of the city usually spend more time commuting back and forth from work. There are also variations in electricity consumption within residential households. This can be caused by a number of factors, including households with larger floor space outside the city, smaller households, different beliefs and values, and a variation in lifestyles due to divergences in living costs (Sudarshan & Sweeney, 2008; Sanquist et. al, 2012). As rural people become more urbanized, their lifestyles and consumption patterns (including energy) change with their rising income (Jaing & Hardee, 2010).

Sanquist et. al (2012) used the U.S Residential Energy Consumption to identify five lifestyle factors and behavioral patterns associated with air conditioning, laundry usage, personal computer usage, and climate control usage. They found that suburban households have the highest levels of air conditioning and PC usage. When looking at town and urban households, the

level of consumption is substantially lower, indicating that higher density and smaller living spaces are associated with reduced electricity consumption regardless of the climate of the area. In their study, Sanquist et. al (2012) found that lower laundry and appliance usage did not appear to be driven by lower average household size or proportion of single occupant homes, but that people who live in the city may rely more on external services such as Laundromats. They also spend less time in the home, which would reduce PC usage. The study found that rural electricity consumption is higher for many factors, such as more time in the home, lower use of external services than urban households, and the lack of access to natural gas. This requires rural homes to be more reliant on electricity to meet all of their energy needs (Sanquist et al, 2012).

Methods

i. *The Path to an Integrated Framework to Explain Household Electricity Consumption*

Although specific disciplinary models have made significant contributions to what we understand about residential energy consumption, there are serious limitations to all of them (Kierstead, 2006; Lutzenhiser et. al, 2010). Energy scares in the 1970s showed that the anticipated energy savings from conservation programs were not being realized due to a lack of understanding of the network of interactions between technology, policy and consumers. "Integrated" frameworks attempted to address the limitations of the previous conceptualizations of residential energy consumption by outlining a complicated network of interactions between technology, economics, society, culture and other factors (Kierstead, 2006). There are two large barriers to the widespread use of integrated frameworks. The first is that specific disciplinary approaches are ingrained into research and funding structures, making it difficult for

multidisciplinary frameworks to be taken seriously. Secondly, the integrated frameworks are often not practical or successful because they are too rigid (Kierstead, 2006).

A successful integrated framework must be useful in both the theoretical and practical sense, so that academic debate can be quickly transformed into policy solutions. It also must provide a way to align as many of the disciplines as possible, while allowing these elements to interlink. Finally, it must be inclusive enough to place all the attributes in a broad sense of residential energy consumption and flexible enough to explore the details of each specific topic (Keirstead, 2006). Oxford professor Dr. James Keirstead proposed the integrated framework shown below. The agent-based model is becoming a common technique for simulating complex social systems. By modeling the connections between individual agents and their environment at a micro-level, it allows macro-social behaviors to emerge. This framework has parallels with the "bottom-up" modeling which includes some physical sciences as well. The advantage of this is that researchers can use their disciplinary expertise to specify a certain type of agent or environment within the model. The goal is to not look at individual agents themselves, but at the properties of the system which emerge from the interactions of these agents with other types of agents and with their environment, all governed by basic micro-level rules. It is effective because it does not focus on specific relationships between specific interactions, but how every interaction works within the equation (Keirstead, 2006).

Figure 2 Dr. Keirstead's agent based integrated framework for residential energy consumption
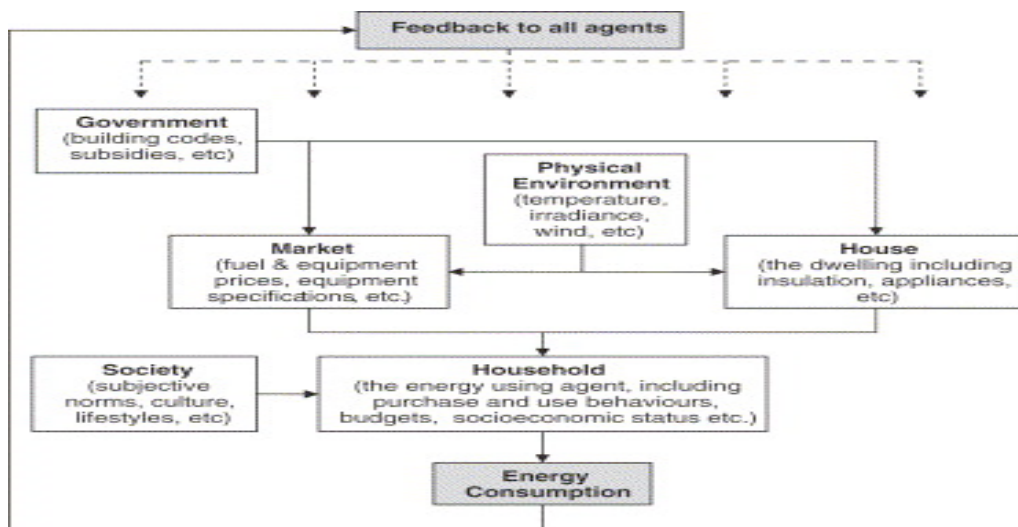
This paper seeks to use an integrated framework that takes from each agent in Keirstead's agent based framework, and use it to look at the relationships between specific factors of household electricity consumption, and how they participate with each other. This will enable us to get a clearer understanding of how electricity is consumed within the residential sector in the United States. The data analysis for the models in this paper was done by Ordinary Least Square Regression.

III. Data:

The Residential Energy Consumption Survey (RECS) is a nationally representative in-home survey conducted approximately every four years by the Energy Information Agency, which is a part of the Department of Energy. The RECS provides detailed information about the appliances used in the home as well as information about the demographic characteristics of the household, the housing unit itself, weather characteristics, and energy prices. In addition, RECS reports state of residence for households living in New York, California, Florida, and Texas, and

Census division for all other households. The RECS is a national area- probability sample

survey. This data set consists of 15,104 respondents across the 1997, 2001, and 2005 data sets.

This data was then put into seven different models to examine the relationship between

the dependent variable (KWH) and the main independent variable (Money CTR), with the rest of

the variables as control variables. The variables are explained in order below.

IV. Variables

- **KWH**

This variable represents the amount of Kilowatt Hours of Electricity used per year. This

variable is the dependent variable in the model. The minimum for this variable is 0 and the

maximum is 92,332. The mean of the variable is 10,589.33 and the standard deviation is

7,341.183.

- **MoneyCTR**

The Residential Energy Consumption Survey asks certain demographic questions including

annual household income. This variable is a mean centered version of the respondents'

household income. This is the main independent variable. The minimum for this variable is

-10.54 and the maximum is 13.46. The mean of the variable is .0020 and the standard

deviation is 6.9894.

- **Region 1**

The Energy Information Agency uses Census Divisions to divide up the states. Region 1 is

the New England Census Division, which includes Connecticut, Maine, Massachusetts, New

Hampshire, Vermont, and Rhode Island. This is a dummy variable which is coded 0 for cases not in this division and 1 for cases that are. The mean of the variable is .0847 and the standard deviation is .27851

- **Region 2**

Region 2 is the Middle Atlantic Census Division, which includes New Jersey, New York, and Pennsylvania. This is a dummy variable which is coded 0 for cases not in this division and 1 for cases that are. The mean of the variable is .1394 and the standard deviation is .3464

- **Region 3**

Region 3 is the East North Central Census Division, which includes Illinois, Indiana, Michigan, Ohio, and Wisconsin. This is a dummy variable which is coded 0 for cases not in this division and 1 for cases that are. The mean of the variable is .1382 and the standard deviation is .3451.

- **Region 4**

Region 4 is the West North Central Census Division, which includes Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. This is a dummy variable which is coded 0 for cases not in this division and 1 for cases that are. The mean of the variable is .0763 and the standard deviation is .2655.

- **Region 5**

Region 5 is the South Atlantic Census Division, which includes Delaware, the District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West

Virginia. This is a dummy variable which is coded 0 for cases not in this division and 1 for cases that are. The mean of the variable is .1434 and the standard deviation is .3505.

- **Region 6**

Region 6 is the East South Central Census Division, which includes Alabama, Kentucky, Mississippi, and Tennessee. This is a dummy variable which is coded 0 for cases not in this division and 1 for cases that are. The mean of the variable is .0847 and the standard deviation is .2785.

- **Region 7**

Region 7 is the West South Central Census Division, which includes Arkansas, Louisiana, Oklahoma, and Texas. This is a dummy variable which is coded 0 for cases not in this division and 1 for cases that are. The mean of the variable is .0950 and the standard deviation is .2932.

- **Region 8**

Region 8 is the Mountain Census Division, which includes Arizona, Colorado, Idaho, and Montana. This is a dummy variable which is coded 0 for cases not in this division and 1 for cases that are. The mean of the variable is .0806 and the standard deviation is .2722.

- **Region 9**

Region 9 is the Pacific Census Division, which includes Alaska, California, Hawaii, Oregon, and Washington. This is a dummy variable which is coded 0 for cases not in this division and

1 for cases that are. This variable is our reference variable for region in our model. The mean of the variable is .1576 and the standard deviation is .3643.

- **fCoolDays**

This variable measures the number of degrees and days below the base of 65 degrees. It is an objective way to understand the climate where the respondent lives. The minimum is 0 and the maximum is 5,954.00. The mean of the variable is 1,340.7816 and the standard deviation is 989.7613.

- **fHotDays**

This variable measures the number of degrees and days above the base of 65 degrees. The minimum is 0 and the maximum is 11,672. The mean of the variable is 4,346.8886 and the standard deviation is 2169.9202.

- **YEAR97**

The Residential Energy Consumption Survey is conducted every four years. This variable is a dummy variable that seeks to look at what year each respondent filled out the survey. It also allows us to look at the levels of consumption over different points of time. This specific variable is for the year 1997. The minimum is 0 and the maximum is 1. 0= respondent did not participate in the survey in the year 1997 and 1= respondent participated in the survey in the year 1997. The mean of the variable is .3906 and the standard deviation is .4879. The YEAR05 variable is the reference variable in this model.

- **YEAR01**

The Residential Energy Consumption Survey is conducted every four years. This variable is a dummy variable that seeks to look at what year each respondent filled out the survey. It also allows us to look at the levels of consumption over different points of time. This specific variable is for the year 2001. The minimum is 0 and the maximum is 1. 0= respondent did not participate in the survey in the year 2001 1= respondent participated in the survey in the year 2001. The mean of the variable is .3193 and the standard deviation is .4662. The YEAR05 variable is the reference variable in this model.

- **YEAR05**

The Residential Energy Consumption Survey is conducted every four years. This variable is a dummy variable that seeks to look at what year each respondent filled out the survey. It also allows us to look at the levels of consumption over different points of time. This specific variable is for the year 2001. The minimum is 0 and the maximum is 1. 0= respondent did not participate in the survey in the year 2005, and 1= respondent participated in the survey in 2005.

- **KWHPRICE**

This variable is the price of a kilowatt hour in the respondent's census division and year they took the survey. The variable was adjusted for inflation to reflect the worth of a dollar in 2005, and was rounded to the nearest cent. The minimum value is .07 and the maximum is .15. The mean of this variable is .1016 and the standard deviation is .2312.

- **SingleFamilyDetachedHome**

This variable is a dummy variable that asks if the respondent lives in a single family detached home. The variable is coded 0 for no and 1 for yes. The mean of this variable is .6221 and the standard deviation is .4849.

- **SingleFamilyAttachedHome**

This variable is a dummy variable that asks if the respondent lives in a single family attached home. The variable is coded 0 for no and 1 for yes. The mean of this variable is .0871 and the standard deviation .2820.

- **MOBILEHOME**

The Residential Energy Consumption Survey asks respondents what kind of building they live in. This variable is a dummy variable that asks if the respondent lives in a mobile home. The variable is coded 0 for no and 1 for yes. The mean of this variable is .0667 and the standard deviation is .2495.

- **ApartmentBuildingWith2To4Units**

This variable is a dummy variable that asks if the respondent lives in an apartment building with 2 to 4 units. The variable is coded 0 for no and 1 for yes. The mean of this variable is .0731 and the standard deviation is .2603.

- **ApartmentBuildingWith5OrMoreUnits**

 This variable is a dummy variable that asks if the respondent lives in an apartment building with 5 or more units. The variable is coded 0 for no and 1 for yes. The mean of this variable is .1510 and the standard deviation is .3581.

- **TotSqFt**

The Residential Energy Consumption Survey asks about household characteristics. This variable looks at the total square footage of respondents' homes. This variable has 7 coded responses, its minimum is 1 and its maximum is 7. 1= respondent's house is between 100 heated square feet and 599 heated square feet. 2= respondent's house is between 599 and 999 heated square feet. 3= respondent's house is between 1,000 and 1,599 heated square feet. 4= respondent's house is between 1600 and 1999 heated square feet. 5= respondent's house is between 2,000 and 2,399 square feet. 6= respondent's house is between 2,400 and 2,999 heated square feet. The minimum is 1 and the maximum is 7. The mean of this variable is 4.1783 and the standard deviation is 1.9991.

- **HAGE**

The Residential Energy Consumption Survey asks respondents specifics about respondent's households. This variable is the year the respondent's home was built. The variable has nine different coded responses. The minimum is 1 and the maximum is 9. 1= home was built before 1940, 2= home was built between 1940 and 1949, 3= home was built between 1950 and 1959, 4= home was built between 1960 and 1969, 5= home was built between 1970 and 1979, 6= 1980 and 1989, 7= between 1990 and 1995, 8= homes built between 1996 and

1999, 9= home built after 2000. The mean of this variable is 3.9245 and the standard deviation is 2.0496.

- **FCentAC**

This variable is one of the three dummy variables created to see the impact the type of air conditioning unit has on residential energy consumption. This certain variable shows how many of the respondents have central air conditioning as their lone source of air conditioning. This variable has two coded responses. 0= respondent does not have central air conditioning and 1= respondent has central air conditioning. The minimum is 0 and the maximum is 1. The mean of this variable is .4698 and the standard deviation is .4991.

- **FBothAC**

This variable is the second of the three dummy variables created to see the impact the type of air conditioning unit has on residential energy consumption. This certain variable shows how many of the respondents have central air conditioning as well as additional wall units. This variable has two coded responses. 0= respondents do not have central air conditioning and wall units and 1= respondent has central air conditioning and wall units. The mean of this variable is .2619 and the standard deviation is .4397.

- **FWallAC**

This variable is the last of the three dummy variables created to see the impact the type of air conditioning unit has on residential energy consumption. This certain variable shows how many of the respondents have just wall units. This variable has two coded responses 0= respondent does not have wall units and 1= respondent does have wall units. The minimum is

0 and the maximum is 1. The mean of this variable is .0092 and the standard deviation is .0955.

- **fDryer**

The survey asks respondents if they have an automatic clothes dryer in their household. This variable is a dummy variable that asks this question. The variable is coded with 0 if the respondent does not have a clothes dryer and 1 if the respondent does. The mean of this variable is .7325 and the standard deviation is 44,269.

- **fDishWash**

The survey asks respondents if they have an automatic dishwasher in their household. This varipable is a dummy variable that asks this question. The variable is coded with 0 if the respondent does not have an automatic dishwasher and 1 if the respondent does. The mean of this variable is .5088 and the standard deviation .4999.

- **fTV**

This variable shows how many color television sets are present in a respondent's home. The minimum is 0 and the maximum of this variable is 13. The mean of this variable is 2.2562 and the standard deviation is 1.2096.

- **fComp**

This variable is a dummy variable that shows if a household owns a personal computer (laptop or desktop) or not. The minimum of this variable is 0 and the maximum is 1. The mean of this variable is .5030 and the standard deviation is .5000.

- **fAgeFri1**

This variable is an ordinal variable that shows the age of the main refrigerator in the household. The minimum of this variable is 1 and the maximum is 9, and is in order of most efficient to least efficient. 1= the age of the refrigerator is less than 2 years old, 2 = the age of the refrigerator 2 to 4 years old, 3 = the age of refrigerator is 5 to 9 years old, 4= the age of the refrigerator is 10 to 19 years old, 5 = the age of the refrigerator is 20 years or older, 6 is coded as Don't know and 9 is legitimate skip. The mean of the variable is 2.9330 and the standard deviation is 1.2295.

- **fSizeFri1**

This variable is an ordinal variable that shows the size of the main refrigerator in the household. The minimum of this variable is 1 and the maximum is 5, and is in order of most efficient to least efficient. 1= very small (10 cubic feet or less), 2= small (11 to 14 cubic feet), 3= medium (15 to 18 cubic feet) 4=large (19 to 22 cubic feet), 5= vary large (more than 22 cubic feet). The mean of this variable is 3.4149 and the standard deviation is .5931.

- **fNumFrig**

This variable shows the number of refrigerators in the household. The minimum number is 0 and the maximum number is 3. The mean of this variable is 1.1860 and the standard deviation is .4221.

- **FWHeatAge**

This variable shows the age of the water heater in the household. This variable is a categorical variable in which the minimum is 1 and the maximum is 5, and is in order of

most efficient to least efficient. 1= the age of the water heater is less than two years old, 2=
the water heater is 2 to 4 years old, 3= the water heater is 5 to 9 years old, 4= the water heater
is 10 to 19 years old, 5= water heater is 20 years or older. The mean of this variable is 2.6909
and the standard deviation is 1.4040.

- **FWaterHeaterSize**

This variable shows the size of the water heater in the household. This variable is a
categorical variable in which the minimum is 0 and the maximum is 4, and is in order of
most efficient to least efficient. 0= the household does not have a separate water heater, 1=
the household has a tankless water heater, 2= household has a small water heater (30 gallons
or less), 3= household has a medium water heater (31 to 49 gallons), 4 = household has a
large water heater (50 gallons or more). The mean of this variable is 2.7792 and the standard
deviation is 1.1035.

- **fNumFreeZ**

This variable shows the number of separate freezers used in a household. The minimum is 0
and the maximum is 3 separate freezers. The mean of the variable is .4987 and the standard
deviation is .5931.

- **AgeFrzr**

This variable is a categorical variable that shows the age of the main separate freezer that is
used in the household. The minimum is 1 and the maximum is 5, and is in order of most
efficient to least efficient. 1= the freezer is less than 2 years old, 2= the freezer is 2 to 4 years

old, 3= the freezer equals 5 to 9 years old, 4= the freezers is 10 to 19 years old, and 5= 20

years or older. The mean of this variable is 3.4452 and the standard deviation is 1.2204.

- **fSizFreez**

This variable is a categorical variable that shows the size of the main separate freezer

available in the household. The minimum of this variable is 1 and the maximum is 5, and is

in order of most efficient to least efficient. 1= the size of the freezer is very small (10 cubic

feet or less), 2= the size of the freezer is small (11 to 14 cubic feet), 3= the size of the freezer

is medium (15 to 18 cubic feet), 4= the size of the freezer is large (19 to 22 cubic feet) and

5= very large (more than 22 cubic feet). The mean of this variable is 2.9604 and the standard

deviation is 1.0092.

- **Finsul**

The Residential Energy Consumption Survey asks respondents how well insulated overall is

their home or apartment. This variable is the response to the question above. The variable

has four different coded responses. 1= well insulated, 2= adequately insulated, 3= poorly

insulated, 4= no insulation (if volunteered). The minimum is 1 and the maximum is 4. The

mean of this variable is 1.8305 and the standard deviation is .7612.

- **HeatType**

The Residential Energy Consumption Survey asks about the type of fuel respondents' use in

their household. This variable is a dummy variable that looks to see if a respondent heats his

home with electricity or with any other source. The variable is coded 0= all other sources and

1= electricity. The mean of the variable is .5257 and the standard deviation is .0955.

- **fCity**

This is a dummy variable that is created to see the impact of the level of urbanism on residential household energy consumption. The level of urbanism is determined by the respondent. According to the literature, households that live in the city consume less energy than households that live in towns, suburbs or rural areas. Therefore, the variable for city is a reference group for the level of urbanism. The minimum of this variable is 0 and the maximum is 1. 0= respondent does not live in a city, and 1= respondent lives in the city. The mean of this variable is .4593 and the standard deviation is .49836.

- **fTown**

This is a dummy variable that is created to see the impact of the level of urbanism on residential household energy consumption. The level of urbanism is determined by the respondent. The minimum of this variable is 0 and the maximum is 1. 0= respondent does not live in a town, and 1= respondent lives in a town. The mean of this variable is .1859 and the standard deviation is .3890.

- **fSuburbs**

This is a dummy variable that is created to see the impact of the level of urbanism on residential household energy consumption. The level of urbanism is determined by the respondent. The minimum of this variable is 0 and the maximum is 1. 0= respondent does not live in a suburban area, and 1= respondent lives in a suburban area. The mean of this variable is .1714 and the standard deviation is .3769.

- **fRural**

This is a dummy variable that is created to see the impact of the level of urbanism on residential household energy consumption. The level of urbanism is determined by the respondent. The minimum of this variable is 0 and the maximum is 1. 0 = respondent does not live in a rural area, and 1= respondent lives in a rural area. The mean of this variable is .1834 and the standard deviation is .3870.

- **fOwnAge**

The Residential Energy Consumption Survey asks respondents a series of demographic questions. This variable looks at the age of the homeowner. The minimum is 16 and the maximum is 97. This variables mean is 49.4249 and the standard deviation is 17.7425.

- **fHomeMem**

The Residential Energy Consumption Survey asks respondents a series of demographic questions. This variable looks at the number of people who live in a respondent's household. The minimum is 1 and the maximum is 15. The mean of the variable is 2.6439 and the standard deviation is 1.4734.

V. Results

In order to properly look at the impacts of each aspect of the integrated framework, a step regression was used starting with the main relationship as the first model. The second model added regional environmental and market effects to the main relationship as controls. The third model added house characteristics as controls to the previous models, and finally model 4 added demographic determinates as controls to the previous model.

The integrated framework used in this statistical analysis found that household annual income does indeed have a significant impact on annual household electricity consumption. The framework also found that there are regional differences in the average level of electricity consumed. Furthermore, heating days to 65 as well as cooling days to 65 were statistically significant, showing additional evidence of regional differences in electricity consumption.

The framework also found that certain home characteristics have significant impacts on household electricity consumption. For example the square footage of the home had a dramatic impact on the amount of electricity consumed; the bigger the house the more electricity the household consumed. Differences of how households cool their homes have a substantial impact on household electricity consumption. Households who cool their homes with central air conditioning consume more electricity than households who use central air along with wall units. The saturation of appliances, especially kitchen appliances, has grown in the last 30 years and has a tremendous impact on electricity consumption. Age and size of these appliances also have an important impact. The younger the appliances are, the more efficient they are due to government standards.

The integrated framework shows that demographic determinants have impacts on electricity consumption. The urbanization of the household has a significant impact. The more rural the household is, the more electricity the household consumes, with rural households consuming 646 kWh more electricity than urban households.

Model 1: The Main Relationship, Annual kWh and Annual Income:

This OLS regression is a step regression examining the relationship of the dependent variable (KWH) and the main independent variable (MoneyCTR), which is a categorical

measure of income centered about the mean. Model 1 shows that the average person across the case years consumes 13,199.115 kWh per year. This model also shows that for every one unit increase in income there is a 180.274 kWh increase in electricity consumption. Or, for every one unit increase in income, there is a 1.3% increase in electricity consumption. The n in this regression is 13,150, and is significant. The adjusted r-square of this model is 0.0260 and the relationship is significant.

Model 2: Additions of Regional, Environmental, and Market effects (Price Elasticity):

The second model addresses regional, environmental, and market effects impacting household energy consumption. The controls added to the model include the census division the respondent lives in, the exterior climate impact, the price of electricity in the region, and the year the respondent participated in the survey. The model uses the Pacific region as the reference group for census division, and 2005 as the reference year. This model has an adjusted r-squared of 0.184. The change of the r-square of this model and the r-square of the previous model is statistically significant.

The significance of the main effect stayed consistent with the previous model. The Census division that the respondent lives in has a significant impact on kWh consumption, and the impact differs depending on what Census division the respondent lives in. A respondent who lives in the New England Census Division consumes 4,233.303 kWh less per year than the reference group; this is the equivalent of powering a 4 person water heater for 13.5 months (Typical electric usage). This relationship is significant.

Respondents in all of the other census divisions consume less electricity than those in the reference group, and all the relationships are significant. Respondents in the New England

Census Division use 2,659.983 kWh less/year, those in the East North Central Division consume 2,510.32 kWh/year less, respondents in the West North Central Division consume 1,984.522 kWh less per year, the East South Central Division uses 3,176.545 kWh less, and respondents in the Mountain Division consume 3,233,019 kWh less than the reference group.

The numbers of degrees days above 65 degrees and below 65 degrees both have a significant impact on the number of kWh consumed per year. This model shows that every one unit increase in the number of degrees and days below 65 adds 2.510 kWh to the amount of electricity consumed, and this relationship is significant. The number of degrees and days above 65 degrees is also significant. For every one unit increase in the number of degree days, there is an increase of .480 kWh of electricity consumed. This relation is significant as well.

The impact of the year in which the respondent took the Residential Energy Consumption Survey is significant. The reference group is respondents who completed the survey in 2005. Respondents who filled out the survey in 1997 consumed 2,287.48 less kWh per year than the reference group, and this relationship is significant. Respondents who filled out the survey in 2001 consumed 2,150.577 more kWh per year than the reference group, this relationship is also significant.

Model 3: House Characteristics:

The third model adds controls to address home characteristics. These controls include the type of home, the estimated total square footage of a respondent's home, the year the home was built, and over a dozen appliance variables such as the kind of air conditioning system that is present, the presence of an automatic dishwasher, automatic clothes dryer, and the number of color televisions in the household. Adding these controls to the model increases the adjusted r-

square of the model to 0.406. The significance of the change between the r-square of the current model and the r-square of the previous model is significant.

This model demonstrates that the relationship of the main effect is less significant than the previous model, but still remains significant. The significance of Census division is different than in the previous model. The East North Central Census Division and Mountain Census Division were less significant than the previous model. However they were still statistically significant. The significance of the number of degree days above and below 65 degrees stayed consistent with the previous model. The significance of year was consistent with the previous model.

The type of home had little impact on the main effect. The results also show that compared to respondents who are in the reference group, respondents who live in mobile homes consume 1,349.1740 kWh per year more.

The estimated total square footage of the respondent's home has a significant impact on residential kWh consumption. The literature indicates that the greater the square footage of a home, the more energy it will consume. The model shows this to be true. For every 1 unit increase in total square footage of a home, kWh consumption increased by 393.930 kWh per year or 2.9% of the average kWh consumed in the average household across the case years. This relationship is significant.

Cooling consumes a large proportion of residential energy consumption. Respondents who had central air conditioning in their homes increased their energy consumption by 2,211.341 kWh per year, which is significant. Respondents who had both central air conditioning and wall

air conditioning units in their home increased their energy consumption by 844.565 kWh per year, which is significant.

As mentioned in the literature review, appliance use is rapidly becoming a larger percentage of total residential energy consumption. Furthermore, household appliances are becoming less expensive and more prevalent. This allows households in the lower income bracket to have certain appliances that were not traditionally available in low income housing. Respondents who own an automatic clothes dryer consume 1,635.517 kWh per year more electricity than respondents who do not own an automatic clothes dryer. Respondents who own an automatic dishwasher consume 1,187.184 kWh per year more energy than respondents who do not own an automatic dishwasher. This relationship is significant. For every additional color television set that a respondent owns, the amount of electricity the respondent's household consumes increases by 1,002.494 kWh per year, and this relationship is significant. The number of refrigerators in a respondent's household has a significant impact. For every one additional refrigerator, the household's electricity consumption increases by 1,361.941 kWh per year. This relationship is statistically significant. The number of separate freezers in a household has a significant impact as well. For every additional separate freezer in the household, the amount of electricity the household consumes increases by 1,639.211 kWh per year. This relationship is significant. The size of the main separate freezer has a significant impact. For every additional category of size the main freezer increases, the household electricity consumption increases by 473.895 kWh per year. This relationship is significant. The size of the main water heater also has a significant impact. For every additional category of size the main water heater increases, the household electricity consumption increases by 960.832 kWh per year. This relationship is significant.

Model 4: Adding Demographics to the Model:

The final model adds demographic variables into the model. These controls include the level of urbanism of the respondent's neighborhood, the age of the homeowner, and the number of people who live in the household. This model uses city as the reference point for level of urbanism. Adding these controls to the model adds 3.3 percent to the adjusted r-square from the previous model, giving a total adjusted r-square of .439. The difference between the significance of the current model and the previous model is significant. The final model is shown below.

Table 3 OLS Regression Result for Model 4

	Model 4	
(Constant)	-6272.092**	(2024.071)
Annual Income Centered Around the Mean	68.113***	(25.864)
Census Division		
Pacific Census Division (Reference)		
New England Census Division	-4160.23***	(604.352)
Middle Atlantic Census Division	-2546.018***	(489.556)
East North Central Census Division	-1676.349**	(584.525)
West North Central Census Division	-2023.829**	(677.334)
South Atlantic Census Division	-19.829	(587.959)
East South Central Census Division	2153.1*	(794.462)
West South Central Census Division	1119.083*	(636.092)
Mountain Census Division	-1624.731*	(642.753)
Number of degrees and days below 65	1.576***	(0.129)
Number of degrees and days above 65	0.325***	(0.101)
Year		
2005 (Reference)		
1997	816.735*	(324.147)
2001	877.958***	(259.75)

KWHPRICE KWH Price Per Region	-6071.595	(13793.38)
Type of Home		
Single Family Detached Home (Reference)		
Single Family Attached Home	-303.387	(391.777)
Mobile Home	1306.667**	(430.980)
Apartment Building with 2 to 4 Units	-198.799	(616.372)
Apartment Building with 5 or more Units	-298.067	(747.308)
Physical Characteristics of the House		
Level of Insulation in Home	-180.745	(132.206)
Main Heating Fuel for Home	-4991.322***	(218.411)
Estimated Total Square Feet	380.286***	(55.392)
Year Home is Built	31.951	(53.809)
Type of Air Conditioning System		
Household has Only Central Air System	2628.035***	(290.024)
Household has Both Central Air System and Wall Units	1013.249***	(288.741)
Household has Just Wall Units	1560.802	(859.276)
Impact of Appliance Use in Household		
Household has Use of an Automatic Clothes Dryer	1670.536***	(363.612)
Household has Use of an Automatic Dishwasher	1336.142***	(219.17)
Number of Color Television Sets in Household	1002.494***	(80.672)
Number of Refrigerators in Household	1361.941***	(199.254)
Age of Main Refrigerator	-89.899	(82.499)
Size of Main Refrigerator	259.837	(147.572)
Number of Separate Freezers in Household	1639.211***	(277.825)
Age of Main Separate Freezer	-57.885	(80.077)
Size of Main Separate Freezer	473.895***	(98.882)
Age of Main Water Heater in Household	2.282	(6.934)
Size of Main Water Heater in Household	960.832***	(114.489)
Level of Urbanism		
Respondent Lives in a City (Reference)		
Respondent Lives in a Town	588.472***	(158.998)
Respondent Lives in a Suburb	634.551***	(168.046)
Respondent Lives in a Rural Area	646.726***	(177.818)
Age of Household	-17.556*	(7.244)
Members of Household	77.653***	(77.653)

R^2	0.439
*p<.05 **p<.01***p<.001 Standard errors in parenthesis	

The level of significance of the main effect has decreased, but still remains significant. The level of significance of Census Division is different from the previous model. East North Central Census Division and West North Central Division increased in significance, while East South Central Census Division lost significance from the previous model. The level of significance of degree days above and below 65 degrees is consistent with the previous model. The level of significance of year changed from the previous model. Although the significance of the year 2001 stayed the same, the significance of year 1997 decreased from the previous model. The level of significance for the type of home is consistent with the previous model. The level of significance for electricity as main type of heat source is consistent with the previous model. The significance level of estimated total square feet is also consistent with the previous model. The significance of the type of air conditioning unit present in respondent's home is different from the previous model. Households with both a central air system and wall units increased in significance from the previous model. The level of significance of household use of an automatic clothes dryer, household use of an automatic dishwasher, number of color television sets in household, number of refrigerators, number of separate freezers in household, size of main separate freezer, and size of main water heater in household all stayed consistent with the previous model.

The level of urbanism has an impact on kWh consumption. Respondents who live in a town consume 655.711 more kWh than respondents who live in a city, which is the reference

group, and this is statistically significant. Respondents who live in the suburbs use 979.935 more kWh of energy compared to those in the city. This relationship is also significant.

The results show that for every year older respondents get, they consume 17.556 less kWh of electricity per year. This relationship is significant. The number of people living in the home has a significant impact on electricity consumption. The results show that for every additional person living in the household, energy consumption increased by 1,004.204 kWh of electricity per year and this relationship is significant.

Discussion:

This paper examines the relationship between yearly household electricity consumption and yearly household income using the U.S Energy Information Administration's Residential Energy Consumption Survey. Specifically, an agent-based integrated framework was used to identify the different relationships that make up residential energy consumption, which relationships are significant, and if income is still significant when considering all of these secondary factors.

The framework shows that household income has a significant impact on household electricity consumption. This finding is consistent with the literature and reflects conventional wisdom on the issue. Higher income families are more likely to have a larger home, as well as more electronics and appliances in their home.

There is an ongoing debate among experts on a phenomenon known as the rebound effect. The idea behind this is that a drop in energy consumption through the use of more efficient products leads to a drop in pollution, and the upfront capital investments needed to purchase the efficient products are recouped through lower energy bills. But the savings has the

potential to encourage people to use the products more than they would if the products were less efficient (Tollefson, 2011). There are two different kinds of rebound, direct rebound, and indirect rebound. Direct rebounds occur when the consumer chooses to use more of the resource instead of realizing the energy cost savings. For example, a person with a more efficient central air conditioner in their household may choose to lower the setting on the thermostat because it costs less to operate. Indirect rebounds occur when the consumer chooses to spend the money saved by buying other goods which use the same resource. For example, a household that saves money through their efficient air-conditioner may use the money saved to buy a big screen television that consumes electricity as well. Research has found that both direct and indirect rebound effects exist, but the effects are rather meek. Generally, the effects of direct rebound are 10% or less. Indirect effects are a little hard to calculate, but most estimates are around 11%. The two types of rebound, therefore, can be combined at about 20%. Overall, this rebound effect has little impact when you consider that 80% of the savings from energy efficiency leads to actual realized reduced energy use (Nadel, 2012).

Regional effects such as census division and the number of degree days above and below 65 degrees were found to have a significant impact on household electricity consumption. A large portion of household electricity use comes from heating and cooling of homes. If planners understand the impacts of temperature on household electricity consumption, they can better understand where to site for future residential use. Both of these findings are consistent with the literature (Van Raaj & Verhallen, 1983; Amat et.al 2005; and Bebgt, 2008).

The type of home was not shown to be statistically significant. This goes against conventional thinking which would say that those households in detached single family homes would not only consume the most electricity, but would be significant contributors to household

electricity consumption. Controlling for such factors as square footage of the home, type of appliances available in the household, the level of insulation, and the age of the home diminishes the significance of the type of home. This finding is consistent with some of the literature (N. Kaza, 2010; Holden and Norland 2005), although there is great debate in this area.

This framework found that some of the physical characteristics of the home are significant while others are not. The effect of total square footage is consistent with the literature, and indicates that for every square foot increase in home size, household electricity consumption increases. The level of insulation and the age of the home were not found to be significant. Both of these findings are interesting because they are not consistent with the literature. This may possibly be explained by other variables in the model such as size of home, the saturation of certain appliances, the type of heating fuel in the home, and the age of the householder.

The type of air conditioning has a significant impact on the amount of electricity a household consumes. This finding is consistent with the literature. More specifically, households that had only a central air system consumed substantially more electricity than households with both central air conditioning and wall air conditioning units, and individuals with just wall units. This is explained by examining how households use their air conditioning. Households with just central air systems continually run the air conditioning for the entire house. Households who have both can turn off the central air and just cool the individual rooms most used, reducing their electricity consumption. Although households that have both a central air system and wall units use considerably less electricity than homes with just central air, they still use tremendously more electricity than households with just wall units, and are still statistically significant.

The percentage of household energy consumption attributed to appliance use has increased greatly over the last twenty years. There are multiple factors for this trend. The first is that appliances are becoming more affordable; appliances that were traditionally only prevalent in high income households are now found in lower incomes homes. The second reason is that the energy saved from efficiency standards has led households to purchase more appliances, thereby increasing the impact of appliances on household energy consumption. The presence of certain appliances such as an automatic clothes dryer and automatic dishwasher in the household was statistically significant. The number of color televisions, refrigerators, and freezers, and the size of the water heater were also statistically significant in affecting household energy consumption. These findings are consistent with past studies.

This paper found that demographic determinants overall are statistically significant. The age of the householder is statistically significant and shows that as the age of the householder increases, the household's electricity consumption decreases. This is consistent with the literature, and makes sense for two reasons. The first is that the older the household is, the less likely they still have dependents living in the home. The second is that older people tend to live in smaller homes than people with large families (O'Neil & Chen, 2002; Jiang & Hardee, 2011; Yamasaki & Tominaga, 1997). The number of household members has a significant impact on household energy consumption. This finding is consistent with the literature (O'Neil & Chen, 2002; Jiang & Hardee, 2011). The level of urbanism of the respondent's home is statistically significant. This is consistent with various studies throughout the literature (Sanquist et. al, 2012; Sudarshan & Sweeney, 2008).

Conclusion:

Limitations:

There are several limitations to this research project. This research is only looking at electricity consumption (kWh), not total household energy consumption. It does not include natural gas consumption, other heating sources, or transportation fuel consumption. Although this eliminates the fuel that is used in 61 percent of the homes in the United States (natural gas), as well as energy used for transportation (which accounts for 28 percent of total energy use), not all households use natural gas or drive cars. However, as mentioned earlier in the paper, over 99 percent of homes make some use of electricity. Furthermore, only space heating, water heating, cooking, and clothes drying offer a choice of equipment across fuels. Almost everything else including air conditioning, lighting, refrigerators, televisions, computers, and other devices are exclusively powered by electricity (Heating fuel choice, 2012).

The Residential Energy Consumption Survey is a national level survey and is rich with national level data. However, drawing conclusions that are effective at the local level is difficult at best, and might not be reliable.

By creating extra variables (dummy variables), the degrees of freedom of the model were increased. This artificially inflated the significance of the model. In order to account for this, the adjusted r-squared was used to explore the significance level of the model.

One result from the statistical analysis is difficult to explain. The analysis found that respondents who use electricity as their main heating source over other sources such as natural gas consumed 5,120.669 less kWh per year than respondents who do not use electricity as a main type of heating. This is contrary to the literature as well as conventional wisdom. Although this is

outside the scope of the paper, preliminary results show that there is strong correlation between income and age of house, strongly influencing this variable in the negative direction.

Because of the way that the HAGE variable was coded over the years of the survey, there is no way of determining in the 2005 data which houses were built in 1995. As such, this research treated all houses as not being built in 1995, knowing full well that this is not true.

Another limitation is due to the fact that the Energy Information Agency continually seeks to improve the survey in as many ways as possible. This usually includes asking different or new questions that examine additional aspects of residential energy consumption as part of the survey. This makes it difficult to use all of the variables believed to be important in determining household energy consumption, because not all questions were the same across the surveys.

The final limitation is that the Residential Household Consumption Survey did not give respondents the opportunity to designate "no answer" to the survey questions. This artificially inflated answers to these questions because people may pick answers that are not totally accurate.

Policy Implications:

In order to reduce the impact of climate change, the United States must reduce its global greenhouse gas emissions by as much as 80 percent. A large portion of these reductions can be met by increasing residential saturation of energy efficient technologies, as well as weatherization and other home renovations. These changes have the potential to reduce energy use while not sacrificing the quality of life that Americans have grown accustomed to (Gardner & Stern, 2008). The federal government along with state, local and non-governmental organizations has used two different strategies to address this. The first strategy is implementing

policies that reduce barriers to energy efficiency, such as government regulations and mandates. The second strategy is to implement policies that that seek to reduce investment and installation costs, thereby making energy efficient products that have lower lifetime costs at a competitive cost. Often these policies are financial incentives such as tax credits or rebates (Doris, Cochran, and Vorum, 2009).

Government regulations and mandates such as building codes and appliance standards set a minimum requirement that the industry must meet or else get fined. These policies save energy and give industry direction and certainty, allowing industry to develop additional ways to exceed the minimum standards. Government required labeling on household products is also an effective government regulation. These labels provide essential information related to energy efficiency and consumption to consumers to allow them to make informed decisions. The strength of these government regulations is that positive impacts are achieved without consumers having to change their behavior. The regulations are applied to the manufacturers and contractors while the benefits are realized by the consumers in energy savings.

The critics of these policies argue that the government should not get involved, and that industry innovation will eventually develop more efficient products. Another criticism is that these policy evaluations and standards often ignore or underestimate the rebound effect, whereby energy efficiency improvements decrease the cost of the service, thereby increasing demand and lessening the amount of savings that are realized (Gillingham, Newell, and Palmer 2009). Critics argue that these regulations place an unnecessary burden on manufactures and contractors, and cost hundreds of millions of dollars, which is usually passed on to the consumers (Doris, Cochran, and Vorum, 2009). A 2003 study found that although the cost of regulations and standards implemented between 1988 and 2003 have been estimated at between $200-$250

million dollars, models show that these standards will reduce energy consumption by 8-9 percent between 1988 and 2050 over a no-standards baseline. The study concluded that the benefits of these policies outweigh the costs 2.75:1 (Meyers et. al., 2003).

It is clear that household income has an impact on the amount of electricity consumed in the household. There is considerable literature showing that energy efficiency technology has high up-front capital costs, therefore household income can be a barrier to reducing electricity consumption (Gardner & Stern, 2009; Madrid & James, 2011; Granade et. al, 2009; International Energy Agency, 2008; and Doris, Cochran, and Vorum, 2009). Members of households in the lower income brackets, who on average spend 15 to 20 percent of their total monthly income on energy costs, find it more difficult to afford renovations to their homes to make them more energy efficient (Madrid & James, 2011). Furthermore, households often discount how fast and how large the payback is on their investment in energy efficiency renovations (Bazerman, 2009; Dietz, 2010; Sovacool, 2009; Attari et. al, 2010, and Dietz et. al 2010). The accepted belief is that large organizations can save enough money through energy actions to recoup the cost of renovations, but few individual households are in the same position. Financial incentives such as tax incentives, loan subsidies, deferred-payment loans, and rebates for home retrofits provided by local, state, and federal governments and local utilities can address this barrier and help offset some of the costs associated with energy efficiency renovations for households (Gardner & Stern, 2009; Doris, Cochran, and Vorum, 2009).

Critics argue that these incentives are a waste of government money, and the people who use them would have invested in the technology without the incentives. Studies such as Carpenter and Chester's in 1984 found that although 86 percent of those who were surveyed said they were aware of the incentives, only 35 percent of those surveyed took advantage of them.

Of those who took advantage of the incentives, 94 percent said they would have invested in the technology without the incentives (Gillingham, Newell, and Palmer, 2009). While many studies have shown that the financial incentives are indeed effective, more research needs to be done to see the extent of their effectiveness.

Both regulations and incentives are effective in reducing barriers to energy efficiency technology. Of the two, regulations (standards and mandates) are far more effective simply because they do not require the consumer to change any habits or do anything differently. Although financial incentives give people another reason to invest in energy efficient technologies, they still require individuals to invest effort into making a change.

Concluding Remarks

This paper provides an analysis of the impact of annual household income on annual household electricity consumption using Dr. Keirstand's agent-based framework for domestic energy consumption. The results show that even when controlling for other factors that contribute to household electricity consumption such as physical environmental factors, marketing factors, household characteristics, and demographic factors, income is still statistically significant. More research and better data can be used to explore this relationship in greater depth. The new questions in the 2009 Residential Energy Consumption Survey ask more specific questions about weatherization renovations and energy audits. The addition of the 2009 data with the 2001 and 2005 data will allow for the inclusion of Energy Star Appliance questions that were not available in the 1997 survey. Use of the 2009 survey will allow for analysis of the effectiveness and impact of energy efficiency and weatherization financial incentives that were

included in the 2005 Energy Policy Act as well as the impact of the 2007 Energy Independence and Security Act passed by Congress.

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VIII. Appendixes

Table 4 Descriptive Statistics- Independent Variables

Variables		Mean	Std. Dev.	Minimum	Maximum
MoneyCTR		00.0020	06.9894	-10.54	13.46
Region 1		0.0847	0.2785	00.00	01.00
Region 2		0.1394	0.3464	00.00	01.00
Region 3		0.1382	0.3451	00.00	01.00
Region 4		0.0763	0.2655	00.00	01.00
Region 5		0.1434	0.3505	00.00	01.00
Region 6		0.0847	0.2785	00.00	01.00
Region 7		0.0950	0.2932	00.00	01.00
Region 8		0.0806	0.2722	00.00	01.00
Region 9		0.1576	0.3643	00.00	01.00
FCoolDays		1340.7816	989.7613	00.00	5984.00
FHotDays		4346.8886	2169.9202	00.00	11672.00
YEAR97		0.3906	0.4879	00.00	01.00
YEAR01		0.3193	0.4662	00.00	01.00
YEAR05		0.2901	0.4538	00.00	01.00
KWHPRICE		0.1016	0.2312	00.07	00.15
SingleFamilyDetachedHome		0.6221	0.4849	00.00	01.00
SingleFamilyAttachedHome		0.0871	0.2820	00.00	01.00
MOBILEHOME		0.0667	0.2495	00.00	01.00
ApartmentBuildingWith2To4Units		0.0731	0.2603	00.00	01.00
ApartmentBuildingWith5OrMoreUnits		0.1510	0.3581	00.00	01.00
Finsul		1.8305	0.7612	01.00	04.00
HeatType		0.5257	0.0955	00.00	01.00
TotSqFt		4.1783	1.9991	00.00	07.00
HAGE		3.9245	2.0496	01.00	09.00
FCentAC		0.4698	0.4991	00.00	01.00
FBothAC		0.2619	0.4397	00.00	01.00
FWallAC		0.0092	0.0955	00.00	01.00

fDryer		0.1510	0.7325	00.00	01.00
fDishWash		0.5088	0.4999	00.00	01.00
fTV		2.2562	1.2096	00.00	13.00
fComp		0.5030	0.5000	00.00	01.00
fNumFrig		1.1860	0.4221	00.00	03.00
fAgeFri1		2.9330	1.2295	01.00	06.00
fSizeFri1		3.4149	0.7044	01.00	05.00
fNumFreez		0.4987	0.5931	00.00	03.00
fAgeFrzr		3.4626	1.2342	01.00	06.00
fSizFreez		2.9604	1.0092	01.00	05.00
fWHeatAge		2.6909	1.4040	00.00	05.00
fWaterHeaterSize		2.7792	1.1035	00.00	04.00
fCity		0.4593	0.4593	00.00	01.00
fTown		0.1859	0.3890	00.00	01.00
fSuburbs		0.1714	0.3769	00.00	01.00
fRural		0.1834	0.3870	00.00	01.00
fOwnAge		49.4249	17.7425	16.00	97.00
fHomeMem		2.6439	1.4734	01.00	15.00