An Evaluation Approach of Socio Economic Factors Affecting Household Energy Consumption

ABSTRACT

Residential energy consumption in the United States has been marked by a steady growth over the past decades, in spite of the implementation of various energy efficiency policies. To frame effective energy policies for the residential sector it is important to understand the cause and impact of factors affecting residential energy consumption. A vast majority of earlier research has explored the role of individual human factors that are responsible for the increase of household energy usage, whereas, a few studies have discussed the effect of standard-of-living and income on overall household energy consumption. However, there is a dearth of literature and research on plausible ways to modify and manipulate factors that influence household energy consumption. This paper builds on previous research by the authors that identified a list of factors affecting residential energy consumption and grouped them under five major categories, i.e. demographics, consumer attitude, economic variables, climate, and technology. The here presented investigation analyzes the root causes for each of the identified consumption factors such as household size, dwelling characteristics, etc. through Cause & Effect diagrams. Finally, all energy efficiency control elements under each of the energy consumption factors are generated and sorted using the Affinity Diagram method. Our research shows how the identified control elements govern energy consumption factors to a great extent. Ultimately these control elements will assist policy makers in ameliorating and targeting the most critical factors that will help to curb the increasing household energy consumption in the United States.

Introduction

The energy consumption of the residential building sector in the United States has witnessed a steady growth over the past few decades in spite of the implementation of various energy efficiency policies. While some results defeat the purpose of certain policies, at the same time they augment the importance of studying the factors that affect residential energy consumption in greater detail and in a more comprehensive fashion. The emphasis of the majority of previous researchers was to explore various individual factors that are responsible for the increase in household energy usage, whereas a few investigators have explored the effect of standard-of-living and income of individuals on overall household energy consumption. However, there is no instance of any systematic study of the causes of all the various factors affecting residential energy consumption.

Factors Affecting Energy Consumption

Potential reasons of the variation in residential energy efficiency consumption have been investigated in previous studies that only represent viewpoints of investigators analyzing specific problems. A systematic analysis of previous research studies was performed and the authors assembled a comprehensive list of energy consumption factors categorized in five main consumption categories that will be further employed in this study (Bhattacharjee 2010). The

causes and the remedial methods of these residential energy consumption factors have not yet been systematically identified. This research adopts the Cause & Effect (C&E) Diagram method to study root causes of each of the energy consumption factors that were identified in an earlier research study (Bhattacharjee 2010).

As mentioned earlier, this research investigates factors and underlying sub-factors affecting residential energy consumption by delineating them into five broader categories. The five categories are demographics, consumer attitude, economic variables, climate, and technology. These categories constitute the main categories of the core C&E diagram (Fig 1). Within each one of these categories, elaborate factors for residential energy consumption are then explored sequentially. The following section discusses the perspectives, major factors, minor factors, and sub factors of this C&E Diagram and the interrelationships among these entities. Due to space constraints we only elaborate on one exemplary branch within the context of this paper (i.e. Demographics) to discuss and demonstrate our approach. For the other four categories we just provide the individual branch C&E diagrams.

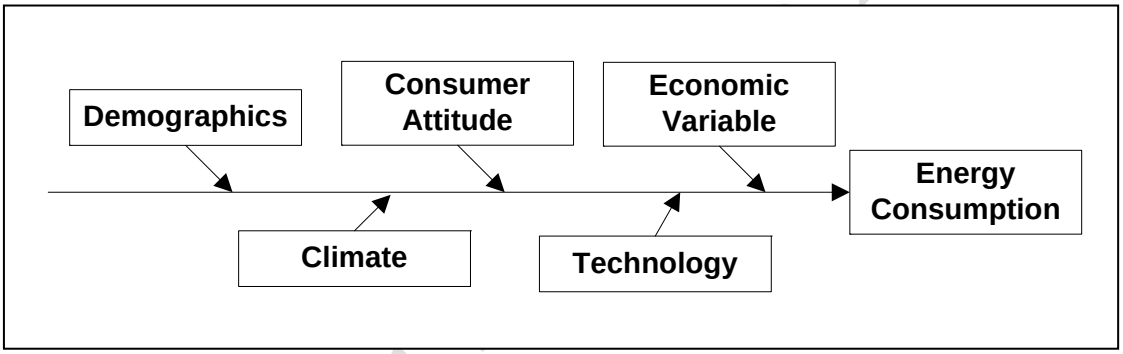

Fig 1. **The Core C&E Diagram of the Five Energy Consumption Categories**

Demographics

Existing literature reveals the importance of household demographic data such as household size, dwelling size, time spent at home, and level of urbanization in determining residential energy consumption (Tiwari 2000; O'Neill and Chen 2002). In a study concerning "300 families' home energy use" conducted by Morrison and Gladhart (1976) the most significant determinants of household energy consumption were family size, age distribution of household members, the number of wage-earners in the household, and the times in a day when the house is occupied by household members. These factors are now structured as sub-branches of the core household demographic branch as shown in the Fig 2.

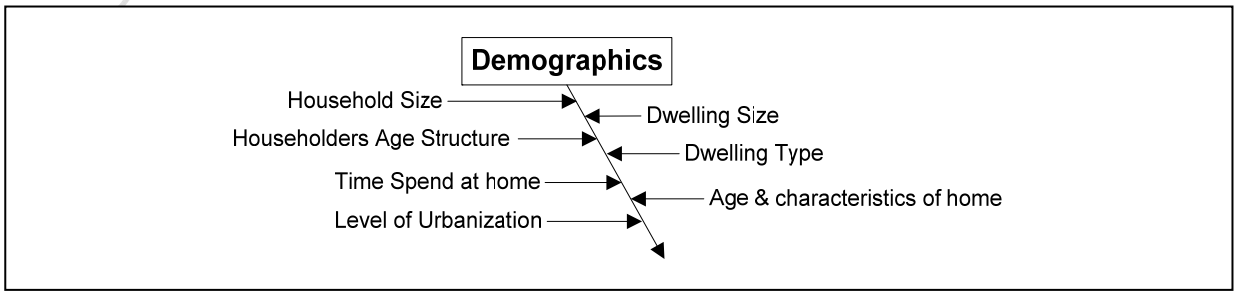

Fig 2. **Major causes in the Demographics category**

Household Size simply refers to the number of people per household. Many researchers argue that occupancy has the strongest influence on variation in energy consumption (Morrison and Gladhart 1976; Van Raaij and Verhallen 1983; Brown and Rollinson 1985; Schipper et al. 1985; Bouchelle et al. 2000; Pachauri 2004; Uitdenbogerd et al. 2007). To be more specific, Lenzen et. al. (2004) indicated a negative correlation between household size and energy consumption per capita which might be due to the shared use of consumer items by household members. Additionally, differences in household size might result from variations in cultural background, economic prosperity, family lifecycle, and income level.

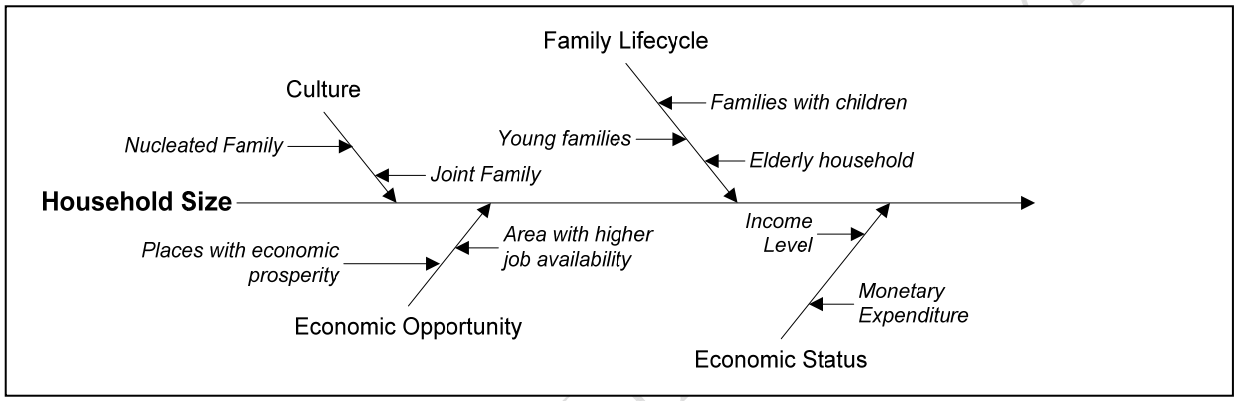

Fig 3. **Minor causes and sub-factors for Household Size**

Each of the here shown minor causes (e.g. Culture) represents a sub-branch of the particular major cause (i.e. Household Size), which in turn represents a branch in one of the five categories (here Demographics). In our research we then broke down these minor causes into individual sub-factors and studied in more detail. Due to space limitation we will only discuss one sub-factor in detail within the context of this paper. The discussion of all other sub-factors will be merged into the discussion of the respective minor cause.

Culture, for example, is here depicted as a sub-branch of household size as certain cultures still support the concept of families with a multitude of members living together (also known as joint family), whereas in other cultures, nucleated families are more predominant. Consequently, we often find family size being influenced by the cultural setting or background of household members. Sometimes a single member from a household moves to a place with better ***economic prosperity*** and/or ***areas with higher job availability***, which again causes a change in household size (Bhattacharjee and Reichard 2009). Interestingly, ***family life cycle*** is an important correlate of the household size. Family life cycle is defined by Van Raji and Verhallen(1983) as "a construct that combines age and household composition". Young families usually have less household members but with the birth of a child the size increases for some time, and decreases later again when the child grows up and leaves the home. Thus energy use tends to fluctuate over the family life cycle (Schipper et al. 1985).

The Householder's Age, as the next minor cause, has a strong influence on the residential energy consumption (Morrison and Gladhart 1976; Junk et al. 1987; Bouchelle et al. 2000; O'Neill and Chen 2002; Lenzen et al. 2004; Pachauri 2004; Tonn and Eisenberg 2007; Uitdenbogerd et al. 2007). A greater magnitude of the energy consumed by the elderly people is based on their health and comfort (Mileham and Brandt 1990). Some of the reasons postulated for the increase in per capita energy consumption with age are the lack of information & knowledge about energy conservation, energy usage patterns, inertia to change, and general wellbeing, which is often controlled by health and comfort.

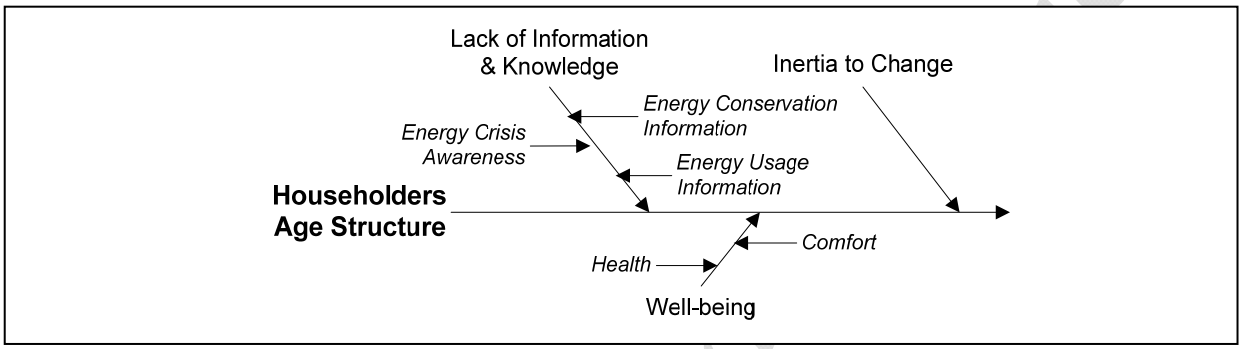

Fig 4. **Minor causes and sub-factors of Householder's Age Structure**

Time Spend at Home. Energy consumption has a direct correlation with the time spent at home by occupants. The more prolonged the duration of time spent at home the greater is the energy need of an individual for day to day activities. Households with young couples sans children and both partners employed full time in an office based setting tend to have a low level of energy use as compared to the families with either a stay at home or work from home parent (Van Raaij and Verhallen 1983). The Family Life Cycle significantly influences the time spent at home (Brown and Rollinson 1985; Tonn and Eisenberg 2007).

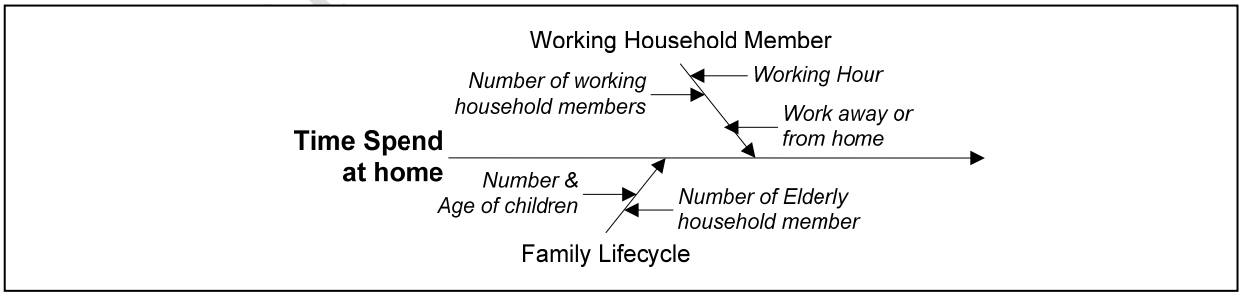

Fig 5. **Minor causes and sub-factors of Time Spend at Home**

Level of Urbanization. Urbanization is defined by the United Nations as the movement of people from rural to urban areas with a population growth equating to urban migration. Rapid urbanization causes a rise in the per capita energy consumption (Dzioubinski and Chipman 1999;

Lenzen et al. 2006; Mehrzad et al. 2007; Cai and Jiang 2008; Pachauri and Jiang 2008). One of the major reasons for urbanization is human migration towards avenues of abundant ***economic opportunities***. Another reason for the shift from rural to an urban setting can be an improved ***standard of living*** (i.e. with the improvement in health facilities, type of fuel used, types and number of appliances used, and comfort level).

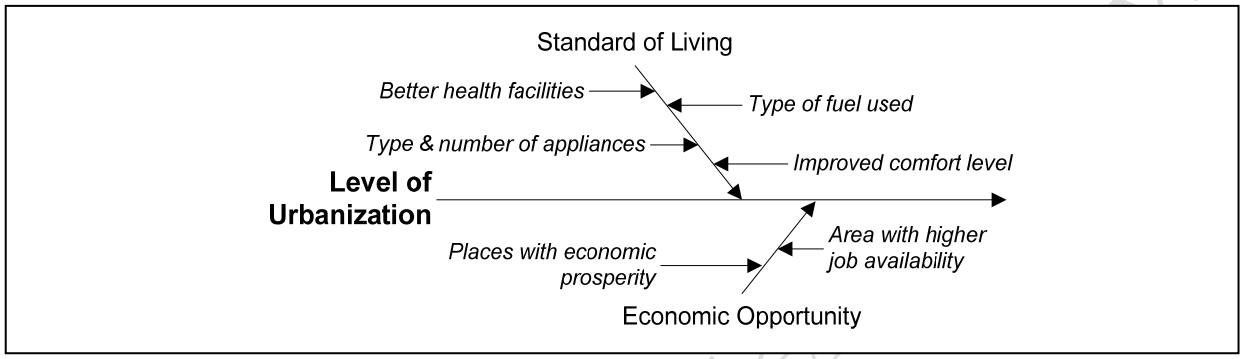

Fig 6. **Minor causes and sub-factors of Level of Urbanization**

Dwelling Size. Mileham and Brandt(1990) have found that the size of a dwelling is the best predictor of money spent on energy as almost one fifth (21%) of the variation in energy costs is attributed to the size of the dwelling. The number of rooms in a dwelling is directly related to the total energy consumption of a house (Morrison and Gladhart 1976).

The higher the population density (population density = number of people per square mile) the lesser the space available for individual housing. In spite of economic prosperity, Japanese people frequently live in smaller apartments or houses as compared to people in the United States. The explanation for this behavioral pattern among the Japanese is their population density, which does not approve a bigger and spacious house as it does for United States residents. United States families start with smaller houses at the beginning of their journey, but gradually shift to bigger homes with the increase in household size and economic prosperity.

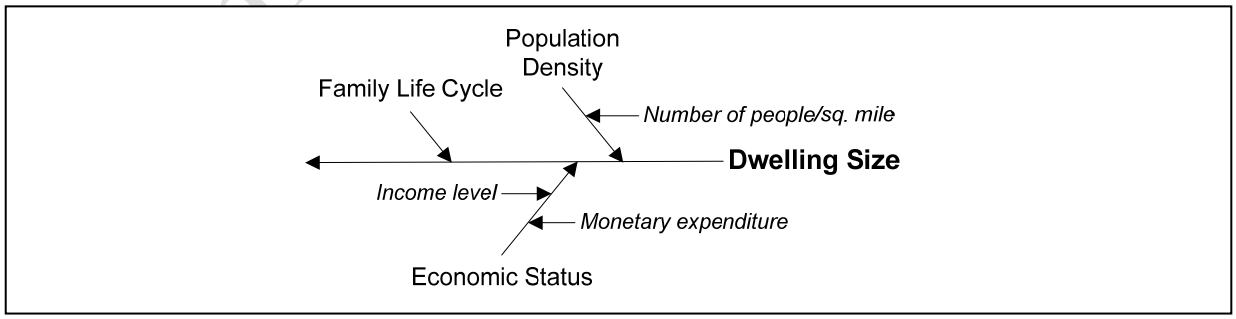

Fig 7. **Minor causes and sub-factors of Dwelling Size**

Dwelling Type (Single or Multifamily). The different types of dwellings include single family houses, town houses, multi-family houses, apartments, or even mobile homes. By and large the most prevalent dwelling type in the residential sector of the United States is the single family detached housing unit. These single family detached homes are the most energy intensive dwelling type, consuming more BTU per household than any other type of housing (EIA 1995). The dwelling type depends to a large extent on economic status of the householder, population density, and housing location.

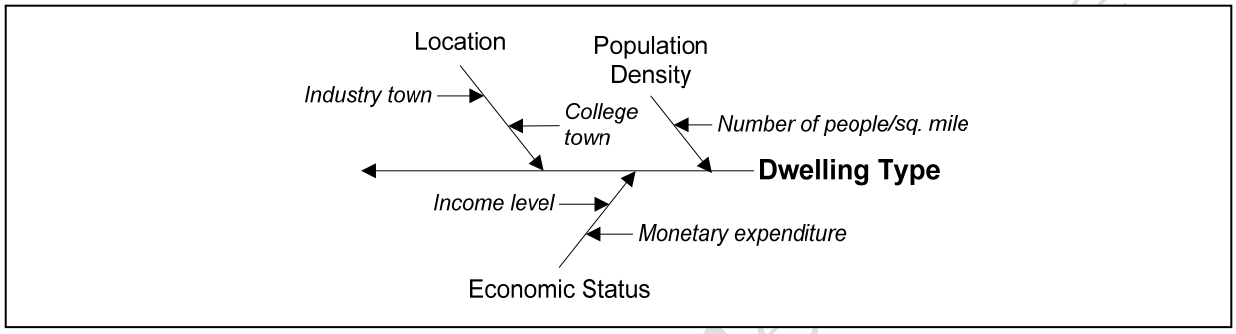

Fig 8. **Minor causes and sub-factors of Dwelling Type**

Age and Characteristics of Dwellings. According to some researchers an increased vintage of a dwelling also goes along with a considerably increased amount of energy consumed for space heating and/or cooling (Junk et al. 1987; Mileham and Brandt 1990; Tiwari 2000). Old houses often lack energy efficiency and commonly require capital investment for incorporating conservation measures such as insulation and storm windows. The here defined term Dwelling Characteristics refers to the degree of a home's insulation, its wind exposure, the glazing type, the efficiency of HVAC systems, etc., all of which directly influence energy end use (Van Raaij and Verhallen 1983; Schipper et al. 1985; Beccali et al. 2008).

Mileham and Brandt (1990) found old people to be less handy at home improvements and to require help from other people, which imposes additional cost. As noted by Smiley (1979), older people are discouraged to invest in energy conservation measures considering a shorter expected life span, while often forcing them to dwell in timeworn homes.

Consumers are often times not aware of their energy consumption patterns. Neither are they aware of modalities to reduce energy consumption. The monthly utility bill usually does not include a breakdown of the consumption by the individual equipment. Thus consumers are mostly unaware about their energy consumption patterns regarding individual items. Kempton and Layne (1994) suggested in their research that utility companies need to provide more information in their utility bills if they expect consumers to use energy rationally.

Misplaced (or split) incentives refer to cases where the economic benefit of a home's energy efficiency improvement does not accrue to the person who invests for it. Typical examples of such cases are landlords who are reluctant to invest in new improved energy efficient technologies as the economic benefit of that investment will be enjoyed by the tenants of the house (Golove and Eto 1996).

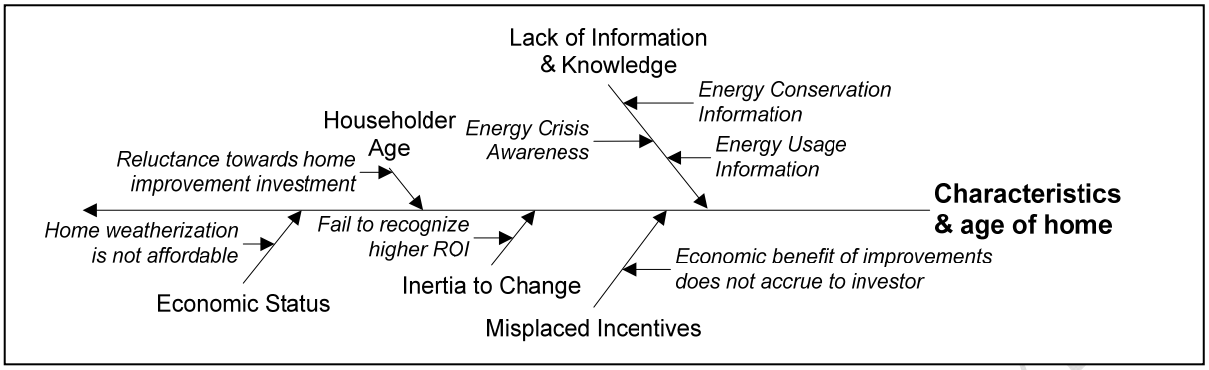

Fig 9. **Minor causes and sub-factors of Characteristics & Age of Home**

The process demonstrated throughout this section of the paper described the sequential steps to generate energy consumption factors under the Demographics category. The entire cause and effect diagrams for all categories are shown from Fig 11 to Fig 14. In cases where a cause factor is identified under several different domains, it is listed in each instance to provide a comprehensive view for each section. In other words, there are factors that lead to an increase in residential energy consumption under different circumstances.

Identifying Control Elements under the Consumption Factors

After the identification of the root causes of each of the energy consumption factors, the control elements which govern the factors are generated. These control elements in turn now influence the energy consumption factors. Therefore, if a policy maker wants to target a particular factor, the policy maker needs to target the control elements under that factor. Fig 10 to Fig14 show the sequential diagrams including the derived energy consumption control elements from the individual energy consumption factors under each of the demographics, consumer attitude, economic variables, climate, and technology categories. In a first step all elements that affect energy consumption are identified from the categorized factors. The elements are then formed from key words of the major factor or descriptive names. The ultimate identification of control elements is carried out by extracting highlighted key words from the C&E diagrams and sorting them under each of the major factors. The aforementioned process is executed by developing affinity diagrams. Affinity diagrams are used to gather large amounts of data and to organize them into groups based on their relationship.

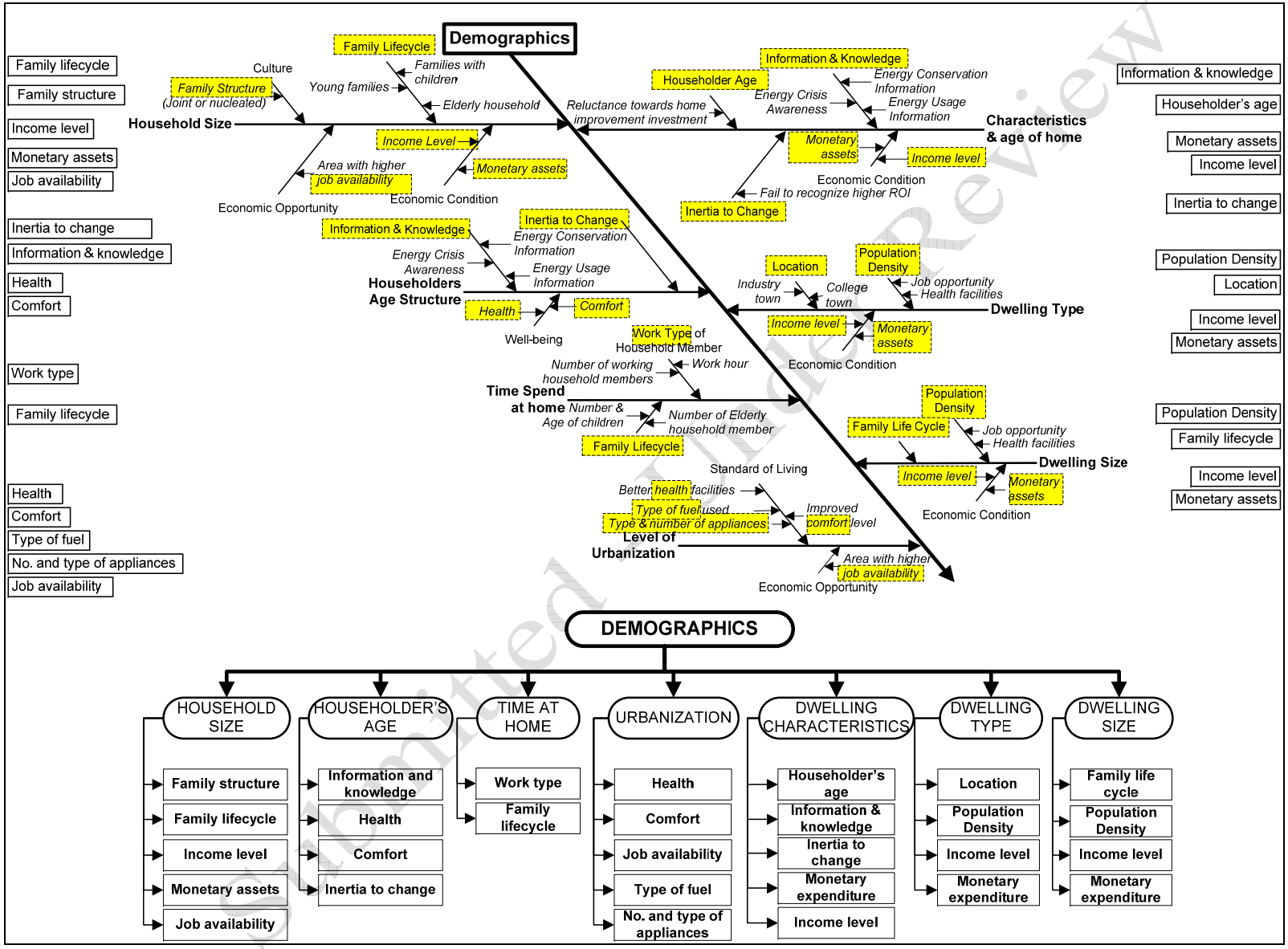

Fig 10. **C&E Diagram and Control Elements under Demographics**

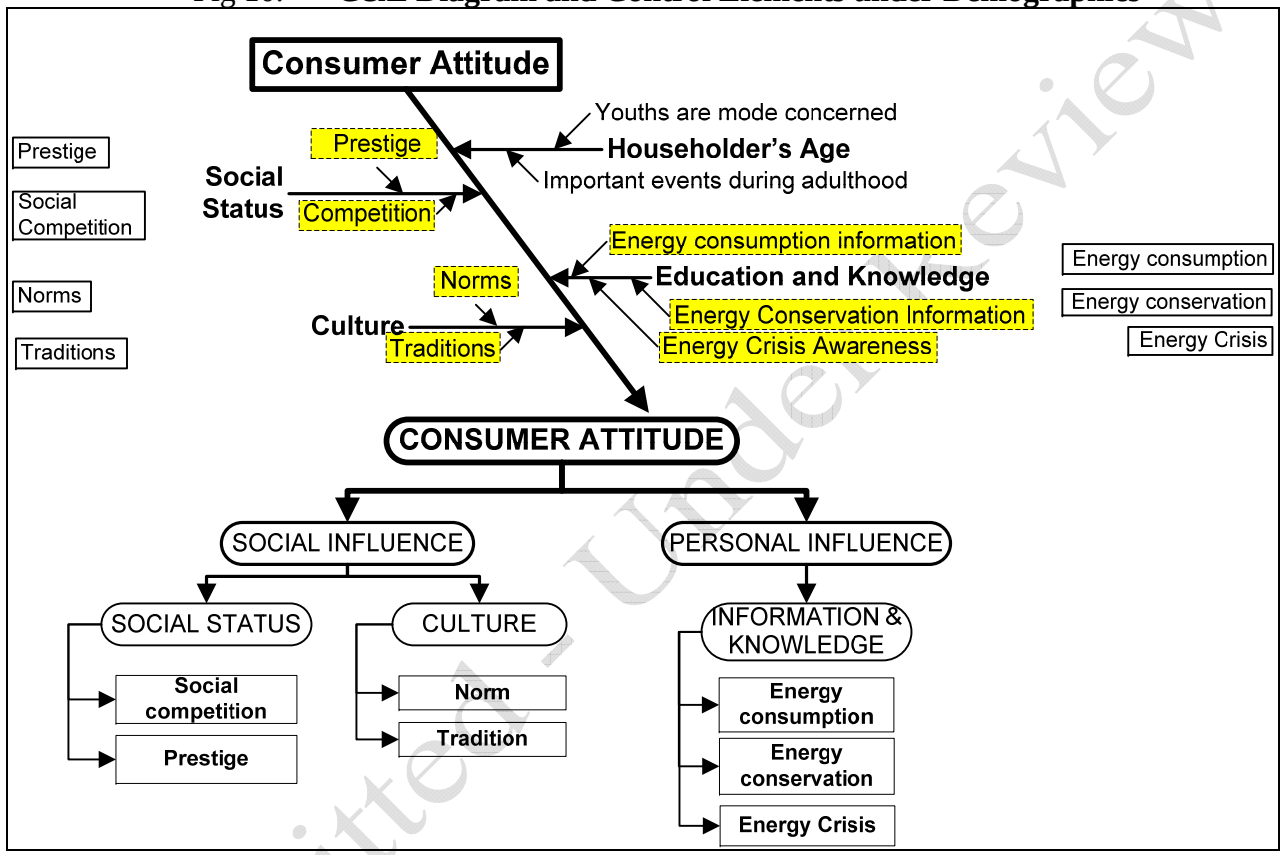

Fig 11. **C&E Diagram and Control Elements under Consumer Attitude**

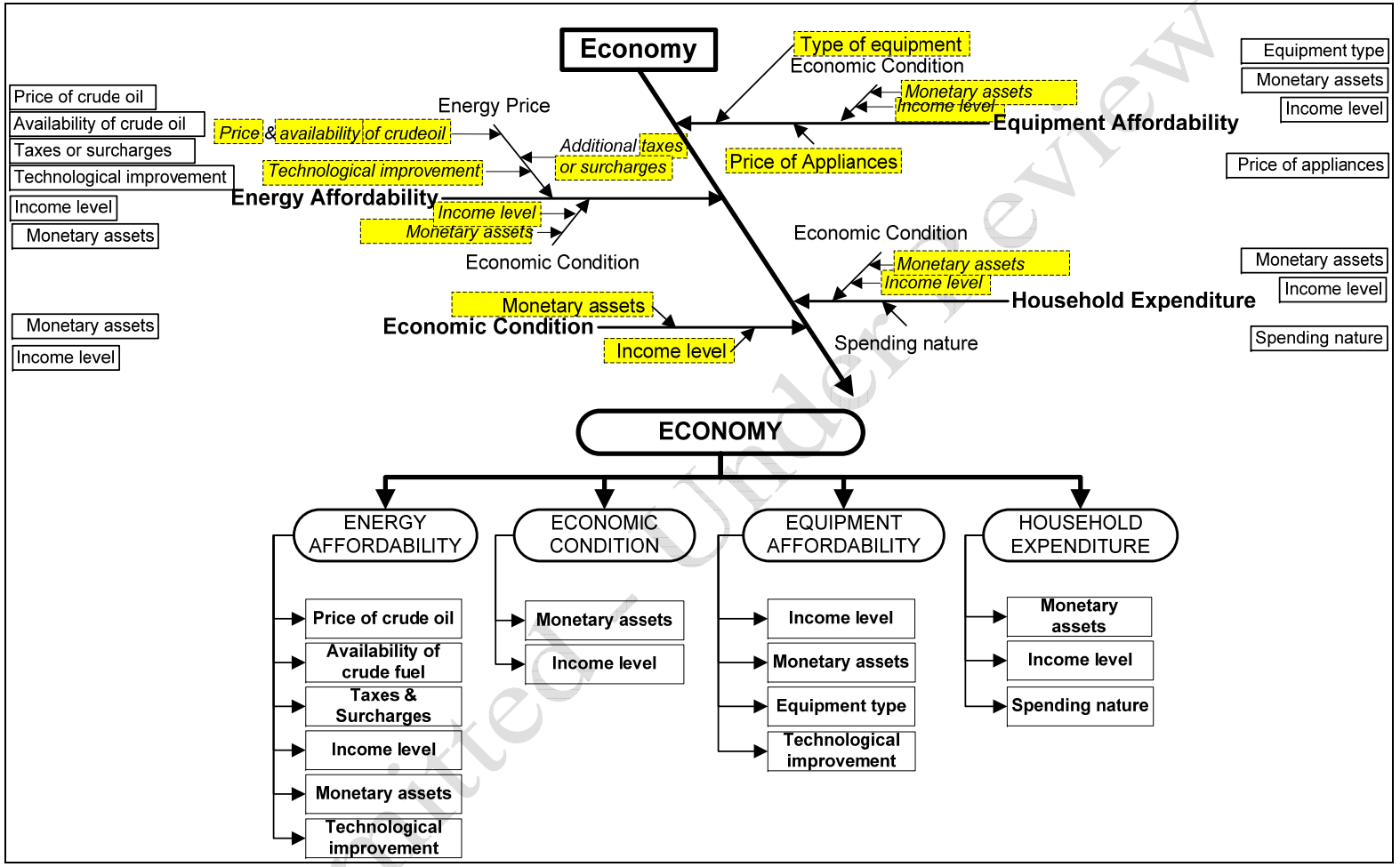

Fig 12. **C&E Diagram and Control Elements under Economic Variables**

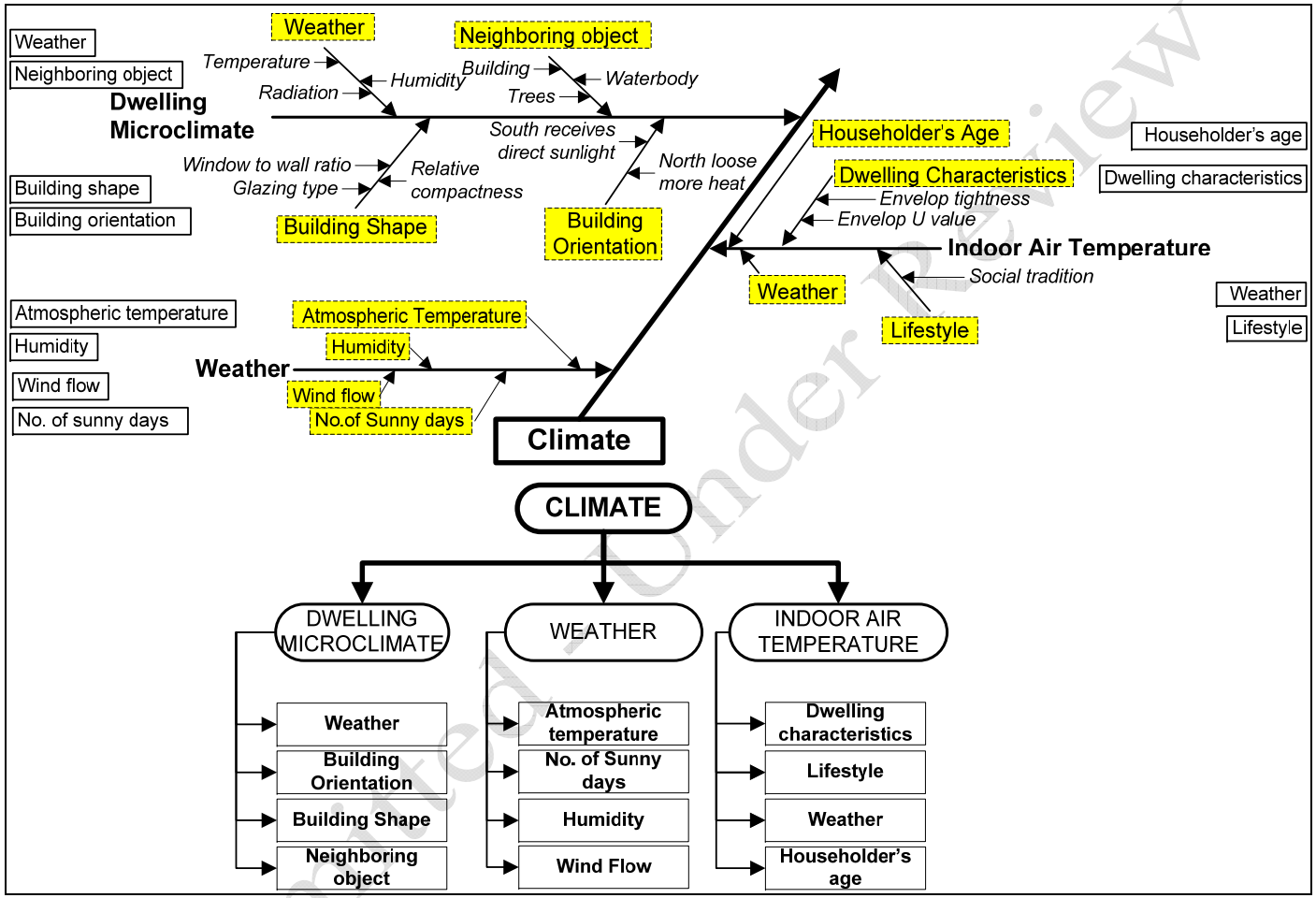

Fig 13. **C&E Diagram and Control Elements under Climate**

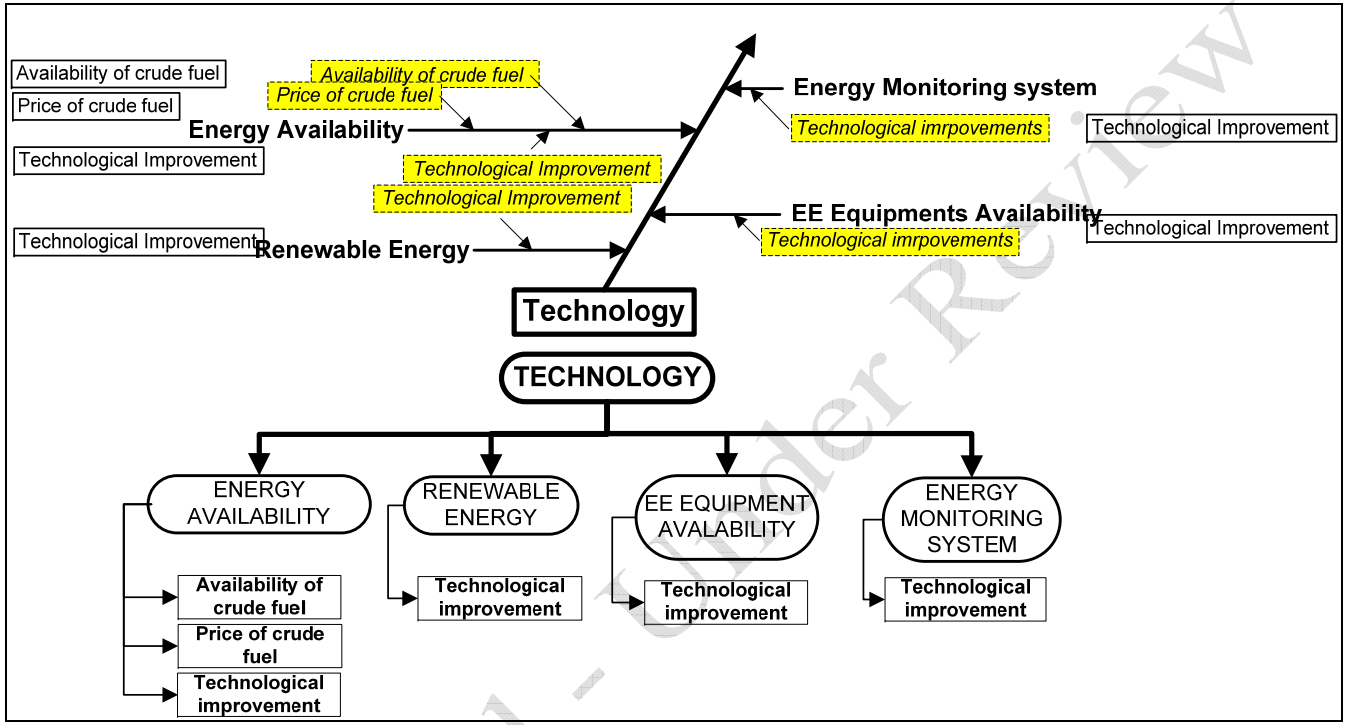

Fig 14. **C&E Diagram and Control Elements under Technology**

In the process of identifying control elements from major factors all instances are listed, in case more than one element has been identified. If the same element is generated from multiple major factors under the same or a different category, it is also represented in each individual diagram. This simply reflects that one single element could affect residential energy consumption under different circumstances.

Conclusion

This paper presents the development of a holistic view of factors that affect residential energy consumption from a human behavior perspective. The cause factors were identified and grouped under five categories and then converted into success factors for future implementation into energy efficiency policies.

This research adds a holistic view of the influence of human behavior on energy consumption to the existing body of knowledge. The research successfully performs an analysis of identifying factors that have contributed to an increase in residential energy consumption. It then identified a list of control elements under each category, which can now be used to compare and evaluate existing energy efficiency policies. Furthermore the developed control elements can be referenced to specifically target individual consumption factors in future implementations of energy efficiency policies. In future research we will ultimately be able to identify the impact of a particular energy efficiency policy on specific energy consumption factors by using these control elements.

The here in detail discussed Demographic category seems to have the largest number of control elements associated with it. Financial and knowledge related control elements seem to be most significant, as they appear to have the greatest number of instances. Incentive based energy policies and government subsidies can help control the financial elements. Knowledge based elements can be overcome through implementation of energy awareness programs. Normative policies can control elements resulting from personal behavior.

Future research will look into current energy policies in a local (statewide) context and study the energy consumption factors targeted by individual states/regions. This approach is expected to provide insights about gaps in policies and policy portfolios that are already implemented for a jurisdiction, and will help in the creation new and/or adoption of existing policies.

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