An Analytical Framework to Examine Whether Energy Efficiency Policies and Programs Address Factors that are Known to Influence Energy Consumption

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ABSTRACT

Energy conservation and the implementation of effective energy efficiency policies and programs have become imperative to curb the escalating consumption of energy. This paper presents a first component of a framework to analyze the effectiveness of the energy policies that seek to foster enhanced energy savings. It uses the US experience to showcase a possible application within the framework. To carry out this analysis, this paper begins by identifying socio-economic factors affecting energy consumption from a human behavior perspective. The framework uses four primary socio-economic actors that influence human behavior. They are defined as culture, economy, environment and technology. These actors represent the directions (axes) of a graphical analysis diagram. Various factors known to affect the energy consumption in the residential sector have then been positioned in this diagram based on the above mentioned influences. This mapping suggests that energy consumption is significantly influenced by economic conditions. The second part of this paper undertakes an exploratory analysis of energy efficiency policies and programs that are currently implemented in the United States and the United Kingdom and specifically target the residential sector. These policies and programs were then mapped according to their impact on the four human behavior influence directions that have been identified before. The results of this study show that a majority of federal energy policies and programs implemented in the United States are leaning towards technological advances and environmental awareness, whereas the policies and programs of the UK are more balanced and address all four directions. The demonstrated method can be used as a core component in our envisioned energy program evaluation framework and will offers single U.S. states and local governments a tool to identify gaps and effectively compliment the federal incentives and programs portfolio targeting specific factors.

Background

Energy consumption is guided by various factors, which in turn affect the energy efficiency of a particular nation. The average per capita energy consumption of the developed nations is a multiple of the consumption in developing countries (Dzioubinski and Chipman 1999, EIA 2009). To curb their soaring energy consumption, different nations have formulated many energy conservation programs and policies.

The total energy consumption of the United States in 2007 was 101,600 Trillion BTU, of which 21,753 Trillion BTU were consumed by the residential sector, 18430 Trillion BTU by the commercial sector, 32321 Trillion BTU by the industrial sector, and 29096 Trillion BTU in transportation sector (EIA 2008a). It is a common approach to combine the residential and the commercial sector under the single term "building sector". However, the total percentage of this sum is not representative, as a significant portion of the energy consumed by the transportation and industrial sector is actually used to transport and manufacture building materials. Architecture 2030 assessed this issue realistically and concluded that buildings account for almost half of the total energy consumption in the U.S. (Architecture2030 2008). It becomes obvious that building related policies and programs often reach beyond their original scope and will therefore have a significant impact on energy consumption as a whole.

Previous researchers have already identified several factors that affect the energy consumption, both in the residential sector and the commercial sector (Beccali et al. 2008; Blasco Lucas et al. 2001; Donovan and Fischer 1976; Joyeux and Ripple 2007; Mileham and Brandt 1990). Other papers discussed various methods to analyze the effectiveness of the energy efficiency policies and programs implemented by the U.S. Government (Limaye and Sharko 1974; Norberg-Bohm 2000).

The focus of this paper lies on 1) identifying a comprehensive list of factors that affect energy consumption and 2) to demonstrate a prototype of a visual method to evaluate the effectiveness of energy efficiency policies and programs against these factors from a human behavior perspective. We see human behavior in respect to energy consumption primarily influenced by the following four elements: cultural background, the economy, the local climate, and technological advances. These four elements also represent four directions that we define for our graphical analysis. Each factor that has been identified to affect energy consumption has been categorized and positioned in this diagram in respect to its main influences. In a second step, mostly federal energy efficiency policies and programs that are currently implemented in the U.S. and the U.K. respectively as examples are mapped against these four human behavior influences. Finally the portfolios of programs in the respective countries are analyzed to show how well they address the identified factors. This evaluation will be one core component within our framework that will offer a practical way for federal, states and local governments to indentify and close gaps that are not covered by federal incentives.

Human Behavior Parameters

Individual energy consumption is governed by different influences for each person. These influences directly control the behavioral pattern of human beings. Hans-Ulrich Zabel (Zabel 2005) found that human behavior is the product of “three constituting components: cultural shaping (cultural artifacts, education, socialization, and enculturation), genetic predisposition (pattern recognition based on instincts, needs, drives, etc.), and situational correctives”. In other words, the cultural setting in which a human being is brought up plays a fundamental role in shaping an individual’s behavior, and thus also the individual’s energy consumption.

The climatic environment in which a person lives not only affects the need for heating or cooling, but also plays a role in defining an individual’s response behavior to different environments. Comfort levels are perceived differently for people living in different climates (e.g. temperature settings). Even if people live in the same climate, their behavioral response is different if they grew up or lived for a long time in a different climate.

Availability of technology to an individual is another important factor guiding the behavior of that person. The ease with which technology is available will determine the amount of technology a particular individual will use. For example the millennial generation which is growing up in this age of computers cannot think of their life without them. On the other hand, earlier generations are still adverse towards using computers in their daily activities. It is needless to say that the energy consumption of these two groups of people will vary significantly.

Finally, the economic status of an individual plays a central role in a person’s consumer behavior. A healthy economy is essential to fulfill people’s needs and also to assure efficient distribution of resources. Due to the increasing involvement of technology in our day to day life, the economic system now decides the consumption of technology and in turn affects the consumption of energy (Zabel 2005).

For our evaluation model we defined the following four core directions that influence human behavior in terms of energy consumption: cultural background of the individual, local climate in which the individual is living, technological advances and the availability of technology to an individual, and last but not least the economic status of the individual. We argue that the economy and the environment are often perceived as antagonists in our society and thus placed these parameters on opposite sides along the horizontal axis. However, the environment can have a direct influence on cultural background of a certain group. Furthermore technological advancement can be beneficial or harmful to the environment. There is also a strong connection between technology and economy. On the other hand, we argue that technological advances are often rejected by a culture or its people. Therefore we set the parameter *People/Culture* and *Technology* at opposite sides along the vertical axis. Figure 1 shows a representation of these four parameters. This diagram makes it also visible that technology can affect a culture in two ways, through economic change but unfortunately also through environmental changes cause by our technologies.

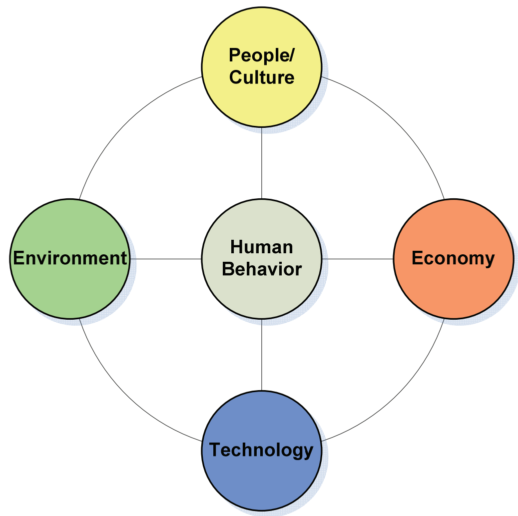

Figure 1. Diagram representing the core parameters that influence human behavior

Factors Affecting Energy Consumption

For this paper we restrict the focus on factors influencing the energy consumption of the residential sector and consequently also study only energy policies targeting this sector. The residential sector was responsible for 21% of the total U.S. Energy Consumption in 2007 and comprises of more than 90 million single-family, multifamily and mobile homes (EIA October 1995). Energy is used in the residential sector for various purposes, e.g. space heating, space cooling, water heating, lighting, electronics, refrigeration, laundry, cooking, and other appliances. The Building Energy Data Book 2008 published by DOE provides the distribution of energy consumption based on the purpose of use (DOE September 2008). The energy demand is shaped by a variety of factors, including type of housing unit, location and climate (EIA October 1995). The core factors affecting residential energy consumption have been identified and placed as follows:

Household Size

Household size refers to the number of people per household. Matthew Bouchelle indicated that occupancy has the strongest influence on variation in energy consumption (Bouchelle et al. 2000). Differences in household size can result from a cultural background: in certain cultures the concept of big families still exists, while in other cultures nucleated families are more predominant. On the other hand we can observe the pattern of people moving to places with better economic prosperity and/or areas with higher job availability, which in the long run also influences household size due to space limitations. Thus we placed the factor *Household Size* in the sector between *People/Culture* and *Economy*.

Climate

More than 40% of the energy expenditure in the residential sector in most OECD countries is used for space heating (DOE September 2008). We can assume that people living in the U.S. share a similar culture and have access to similar technology. The differences of energy consumption observed across climates makes it obvious that local climate has a major influence on the total amount energy consumed in the sector. The factor *Climate* is largely independent of cultural behavior, technological advancements, and economic condition and is therefore placed all the way out on the *Environment* axes.

Consumer Habit

Living habits also have a profound influence on total energy consumption. Newman and Day (Newman and Day 1975) mention that poor people consume less energy than groups with higher income due to their different lifestyle. Day-to-day habits and practices of consumers might originate to some extent in the climate where they live. However, over years the adaption to a climate becomes part of a people's culture. We can also observe that set-point temperatures for air conditioning units differ even in countries with comparable climate. Apparently, humans get accustomed to otherwise uncomfortable environments, if they are exposed to them just long enough (e.g. too cold set point temperatures of A.C. systems in hot climates, just because owners can "afford" it). Sooner or later a practice that originated in a status symbol suddenly becomes a life style. A person's life style is directly reflected in his/her consumer behavior and is influenced by the cultural as well as the economic background. For that reason we placed this factor *Consumer Habits* right between *People/Culture* and *Economy*.

Population Density

Population Density refers to the number of people that inhabit a specific area. The higher the populations density (i.e the higher the number of people per square mile) the less will be the energy consumption per capita. Though an increase of population density increases the total energy consumption of a nation, overall it actually decreases the energy consumption per capita. The factor *Population Density* is mainly dependent on the parameters *People/Culture* and *Economy*. People tend to move to cities with better economic conditions. Culture can also be a driving force when it comes to population density.

Availability of Fuel

Fuel Availability refers to the types and the amounts of fuels that are available in certain areas. This factor strongly depends (besides the obvious geographical/geological availability that can't be influenced), on the availability of technology and the economic condition of a region. Technological advancements and infrastructure investments can directly support the availability of fuel in certain places. Furthermore, unearthing and production of fuel also depends on technological advancements. This justifies the placement of the factor *Fuel Availability* within the *Economy-Technology* sector, with a closer proximity to the technology axis.

Affordability of Fuel

Fuel Affordability refers to the cost of fuel related to the income level of a society. This means that fuel affordability will not only depend on the price of crude oil but also on additional taxes, or surcharges for infrastructure and technology investments. As mentioned above, technological advancements make the process of fuel production more efficient. However, more efficient production also leads to lower cost and ultimately makes fuel more affordable. On the other hand, fuel prices can be directly controlled through state mandates or taxes. For that reason we position *Fuel Affordability* also within the *Economy- Technology* sector – but in contrast to fuel availability we move fuel affordability closer to the economy axis.

Construction Type

Improved construction techniques can for example reduce infiltration of air and thus also reduce the amount of energy spent on heating and/or cooling. Selecting a construction type for a building also depends on technologies currently available in a market. Further more it depends on the affordability of a certain type of construction, which again depends on the income level of clients and is ultimately influenced by the economy. On the other hand, climate conditions are a guiding factor for deciding on a particular construction type. This is the reason for placing the factor *Construction Type* directly on the *Technology* axis, with branches reaching into both influence areas, *Economy* and *Environment.*

Housing Unit Type

The type of housing can be a single family house, a town house, a multi-family house, an apartment, or even a mobile home. The by far most prevalent housing 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 housing type, consuming more BTU per household than any other household type (EIA October 1995). The housing unit type depends to a large extent on technology and economy. Better technologies and better economic conditions attract a larger population. The higher the population in an area, the higher is the demand for multifamily housing/condominiums. For this reason we placed the factor *Housing Type* right in the middle of the *Technology-Economy* sector.

Housing Unit Size

Mileham and Brandt have found that the size of a dwelling is the best predictor of money spent on energy, since 21% of the variation in energy costs is attributed to the size of the dwelling (Mileham and Brandt 1990). According to Morrison et al. (1978) the number of rooms in a dwelling contributes towards the total energy consumption of a house (Morrison and Gladhart 1976). The size of the dwelling is determined by income level of the family and cost of land. This justifies placing the factor Housing *Unit Size* right along the *Economy* axis.

Equipment Affordability of new and improved appliances

Equipment affordability refers to the cost of new and improved appliances in accordance to the wage level of a society. Affordability refers to both, price and supply of equipment. Technology is a driving factor in this respect, as technological improvements can simplify the production process and thus lower the manufacturing cost. On the other hand the market (or in our terms the economy) has its own dynamic. In a global market the same equipment can show a wide range of different prices depending on marketing strategies targeted by manufacturers and businesses. Thus we position the factor *Equipment Affordability* again right between *Economy* and *Technology*.

Income Level

Dzioubinski and Chipman conclude that an increase in income also leads to a change in lifestyle. In accordance with income changes, households tend to move from the cheapest and least convenient fuel sources (e.g. biomass) to more convenient and often also more expensive types of energy (e.g. LPG, natural gas, electricity).(Dzioubinski and Chipman 1999). Through technological advancements, the number of businesses can increase and hence increase employment opportunities. This usually also strengthens the economy of a region, which in turn will be directly reflected in the income level of people. Thus we placed this factor on the *Economy* axis with a branch reaching out to both influences, *Technology* and *People*.

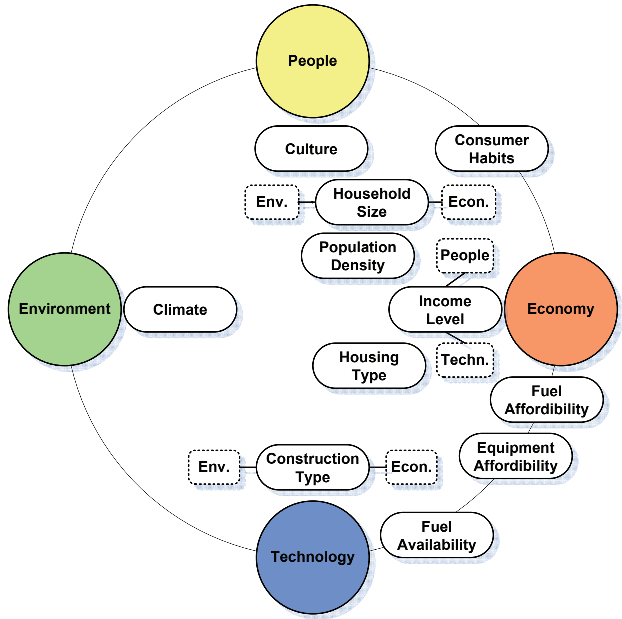

Figure 2. Factors affecting energy consumption in the residential sector

Exploratory Analysis of Energy Efficiency Policies and Programs

In the following step this paper investigates major energy policies that were initiated by the federal governments of the U.S. and the U.K. in the past three decades. We are aware that in the U.S. many programs take place on the state level. The focus on federal policies should allow single states in the U.S. to evaluate their own incentive/program portfolio and compare it with single national European portfolios. At this stage only U.K. policies have been studied and mapped as an example while other countries will follow in the future. The policies are studied and categorized based on their type. The types were defined as economic incentives, education and awareness, mandatory regulations, regulatory standards for new home owners, financial help, and voluntary agreements.

Economic Incentives

Figure 3 shows that about 10% of all major federal energy efficiency policies that are implemented in the U.S. facilitate economic incentives as a tool to achieve their goals.

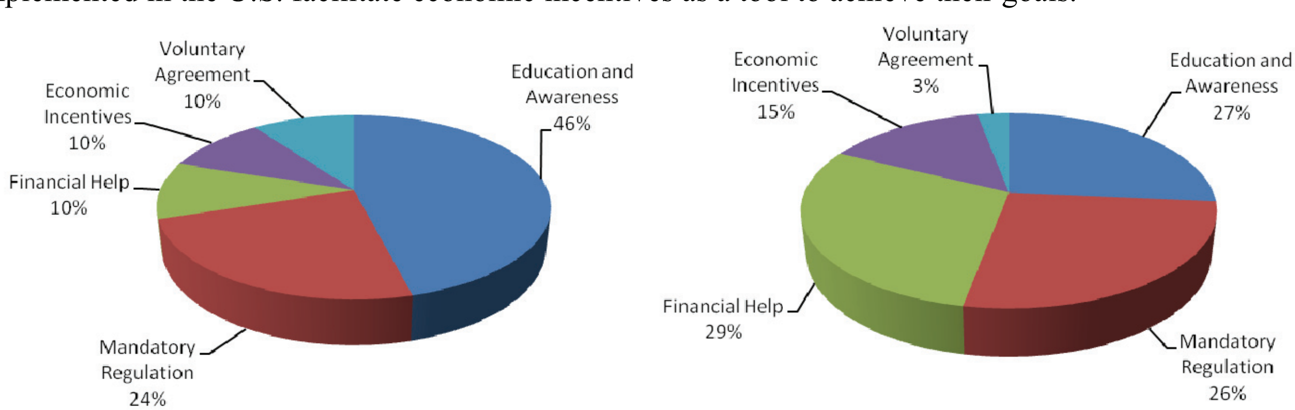

Figure 3. Percentage of energy efficiency policy types implemented in U.S. (left) and the UK (right) for the residential sector

At this stage this represents the pure number of programs and does not reflect the resources destined within each program. The final model in the framework will include a weighing model to account for actual resources allocated to a program. Economic incentives are usually either tax credits, or calls for competitions resulting in monetary support. The 'Bright Tomorrow Lighting Prize' for example is a competition, urging the lighting industry of the U.S. to come up with a LED replacement for the widely used 60W incandescent bulb and the 4.75 inch diameter halogen reflector lamp. The Energy Policy Act of 2005 on the other hand is an action taken by the U.S. Government towards energy efficiency and using tax credits as a tool. The U.K. implemented economic incentives already in 2000 in form of a reduced VAT for energy saving materials. Later on, other policies with economic benefits were implemented, e.g. the Low Carbon Buildings Programme, or the Stamp Duty Relief for Zero Carbon Homes.

Education and Awareness

More than 45% of all national energy efficiency policies implemented in the U.S. focus on increasing awareness. Energy Star, a label established by EPA in 1992 was a first step to promote and market energy efficiency. Other initiatives to increase awareness were the Energy Smart Campaign, the Building America program, and the Builders Challenge. Compared to the U.S., we find in the U.K. a smaller percentage of policies focusing mainly on awareness. The first implementation of a policy that emphasizes on awareness was initiated in 1997 as the Market Transformation Programme, which also included mandatory energy labeling for appliances.

Mandatory Regulations

Mandatory regulations regarding the use of energy efficiency technologies can follow two different approaches. One approach is to regulate the industry to achieve a certain amount of efficiency in the products they bring on the market. The other approach is to issue regulatory standards and codes that require new home owners to achieve a certain amount of efficiency in their homes, or to install appliances that have a certain standard of efficiency. Typical examples of mandatory regulations implemented in the U.S. are the National Appliance Energy Conservation Act and the New Efficiency Standards for Furnaces and Boilers. The U.S. has a central International Energy Conservation Code addressing all nine climatic zones. This code is updated in regular intervals and all states have to update their individual building codes based on the latest version. Similar initiatives can also be found in the UK in form of policies, e.g. the Planning and Energy Act of 2008.

Voluntary Agreements

A considerable number of programs were voluntary agreements between the industry and EPA or DOE. One example of these voluntary agreements is the Climate Leaders program and was signed in 2002. This program is an EPA partnership that encourages individual companies to develop strategies for reducing emissions and increasing energy efficiency. The only program of this type in the UK is the Voluntary Agreement on the Phase Out of Incandescent Light Bulbs, introduced in 2007.

Financial Help

Federal grants to improve energy efficiency can be either provided to the industry or directly to individual home owners. Typical representatives of this type of policies in the U.S. are the Low Income Home Energy Assistance Program (LIHEAP) and the Federal Support for Home Weatherization. Both provide financial help to the low income groups. Quite in contrast to the U.S., this category of energy efficiency policies is predominant in the U.K. on a federal level, where 10 implementations of financial support policies have been issued since 1999.

Analysis

The primary goal of all studied policies and programs is to achieve energy efficiency. This can be accomplished through the improvement of technology and/or through changing people's behavior. Tools that can be used to change human behavior are education and awareness campaigns, regulatory measures, economic incentives, or financial help. Tools that can help to improve technology are for example mandatory regulations, economic incentives, financial help, or voluntary agreements.

Table 1 and Table 2 list the respective policies implemented in the U.S. and the U.K. including their targeted audience and their program type that were studied for this paper. These policies have been mapped according to their impact on the four directions within the evaluation diagram.

Table 1. List of energy efficiency policies and programs implemented in the U.S. that target the residential sector.

No	Policy	Year	Type	Target
1	Bright Tomorrow Lighting Prize	2008	E	I
2	Builders Challenge	2008	A	P
3	Energy Improvement and Extension Act 2008 - Tax Incentives	2008	E	P, I
4	National Data Center Energy Efficiency Information Programme	2008	A	P, I
5	New Federal Buildings Regulations	2008	M	I
6	Energy Independence and Security Act of 2007	2007	M	I
7	GreenChill Advanced Refrigeration Partnership	2007	A, V	P, I
8	Air Conditioners - Upgraded Efficiency Standards	2006	M	I
9	Energy Policy Act - Energy Efficiency Tax Credits Implemented	2006	E	P
10	Energy Star - Upgraded Energy Efficiency Standard for Dishwashers	2006	M, A	P, I
11	Federal-State Partnership for Efficient Buildings	2006	A, F	P
12	Federal Support for Home Weatherization	2006	F	P
13	Federal Support for Solid-State Lighting Research	2006	F	I
14	Federal Tire Efficiency Study Published	2006	A	P, I
15	Furnaces and Boilers - New Efficiency Standards	2006	M	I
16	National Appliance Energy Conservation Act	2006	M	I
17	Energy Policy Act of 2005 (Energy Bill)	2005	F, E, A, M	P, I
18	Energy Star	2005	A, V	P, I
19	Building America	2004	A, V	P, I
20	"Designed to Earn the ENERGY STAR" Label	2004	A	P
21	Energy Star for the Home	2004	A	P
22	Regional Measures for Energy Efficiency - Self-Generation Incentive - CA	2003	F	I
23	Smart Energy Campaign - Energy Savers	2003	A	P
24	Climate Leaders	2002	V	I
25	Mobile Air Conditioning Climate Protection Partnership	1999	A, V	P, I
26	Energy Star	1992	A, M	P, I
27	Low Income Home Energy Assistance Program (LIHEAP)	1974	F	P

Type: Economical (E), Awareness (A), Mandatory (M), Voluntary (V), Financial (F)
Target: Environment (E), People (P), Economy (E), Technology (T)

Table 2. List of energy efficiency policies and programs implemented in the UK that target the residential sector.

No	Policy	Year	Type	Target
1	Community Energy Savings Programme (CESP)	2008	F	P
2	Energy Saving Scotland Home Help	2008	A	P
3	Planning and Energy Act 2008	2008	M	I
4	Act on CO2 advice line	2007	A	P
5	Smart Metering and Billing	2007	A	P
6	Stamp Duty Relief for Zero Carbon Homes	2007	E	P
7	Technology Strategy Board	2007	A	I
8	Voluntary Agreement on the Phase Out of Incandescent Light Bulbs	2007	V	I
9	Building Regulations Part L	2006	M	P
10	Low Carbon Buildings Programme	2006	E	P, I
11	Market Transformation Programme - Publication of Appliance Efficiency	2006	M	I
12	Market Transformation Programme - (SEEEM) Membership	2006	A	I
13	Microgeneration Strategy	2006	F	P, I
14	Northern Ireland - Efficiency Upgrade for Building Regulations	2006	M	P
15	Anglo-Swedish Initiative for Greener Buildings	2005	A	P, I
16	Implementation of EU Energy Performance of Buildings Directive (EPBD)	2005	M	P, I
17	Code for Sustainable Homes	2004	M	P, I
18	Landlords' Energy Saving Allowance (LESA)	2004	F	P
19	Large-scale PV Demonstration Project	2002	F	I
20	Scotland - Household microgeneration grants	2002	F	P
21	Community Energy Programme	2001	A	P
22	Decent Homes	2001	M	P
23	Northern Ireland Warm Homes Scheme	2001	F	P
24	Scottish Government Central Heating Programme	2001	F	P
25	Energy Labelling for New Buildings	2000	M	I
26	Reduced VAT for energy saving materials	2000	E	I
27	Wales Home Energy Efficiency Scheme (HEES)	2000	F	P
28	Warm Front Scheme	2000	F	P
29	Scottish Government Warm Deal Programme	1999	F	P
30	Market Transformation Programme, including Energy Labelling for Appliances	1997	A	P
31	Northern Ireland - Energy Efficiency Levy	1997	M	I

Type: Economical (E), Awareness (A), Mandatory (M), Voluntary (V), Financial (F)
Target: Environment (E), People (P), Economy (E), Technology (T)

The results of the mapping for the U.S, shown in Figure 4 indicate that a majority of the federal energy efficiency policies and programs are either education and awareness programs, or mandatory regulations for the industry. At this stage the model lacks a weighing factor to include the overall investment and the achieved output. However, if we assume for now (to demonstrate the visual method) that the studied policies were more or less equal, we could derive that only few policies focus on economic incentives. The analysis of factors affecting energy consumption in Figure 2 suggested on the other hand, that the economy holds the biggest potential to effectively influence energy efficiency.

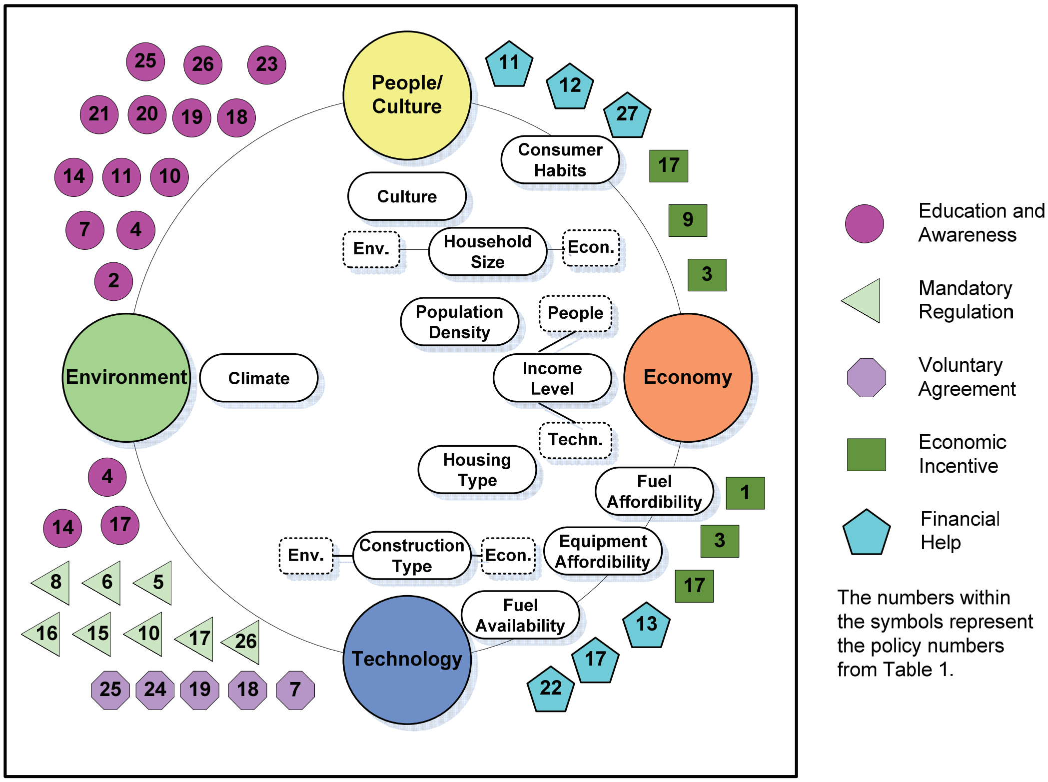

Figure 4. U.S. energy efficiency policies mapped against human behavior parameters.

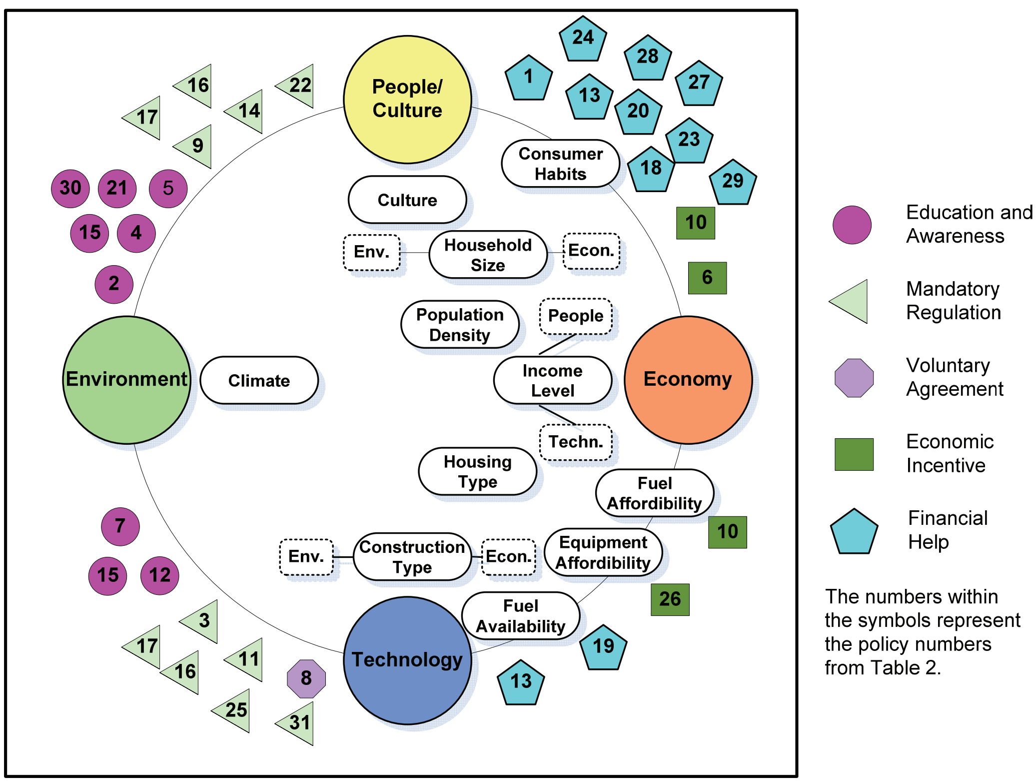

Figure 5. UK energy efficiency policies mapped against human behavior parameters.

Figure 5 shows the respective mapping for policies implemented in the U.K. Under the policies considered in this paper, the U.K. seems to have a more evenly distributed set of policies across all four quadrants. Again, at this stage this mapping is purely looking at numbers of programs without including any weighing factors. The more balanced distribution could suggest a concerted approach for preparing and introducing policies on a national level. Compared to the U.S. by number of programs, it is becomes evident that mandatory regulations are more prevalent in the U.K. The UK Government encourages the industry to advance energy efficient technologies but at the same time also makes it mandatory for its population to shift to energy efficient products.

This mapping method will be a core component of our evaluation framework. These preliminary results already indicate the important role of individual states to balance the federal portfolio and supplement incentives and programs on the economy side. Some states have stepped up as leaders in this effort. California alone, for example, is expected to spend more than 1 Billion Dollars per year in energy efficiency programs over the next 3 years. Individual U.S. states can add their local incentives and programs to the above mapping and use it as a tool to compare their portfolio to the following assessment of the U.K., and once implemented to many other countries with similar context.

Future Research

The model approach introduced within this paper represents a first step of an evaluation framework that is envisioned by the authors. Future research will investigate measurables to develop weighing models for different types of programs, which will better address the quantitative effectiveness of energy efficiency programs rather than the schematic assessment demonstrated within this paper. The theoretical approach of graphically grouping and mapping energy efficiency programs for buildings can also be used to analyze policies targeting other sectors. However, the future focus of our research will mainly investigate building related policies. The building sector alone contributes towards almost half of the total energy consumption in the United States (Architecture2030 2008). We believe that this model can also be used by developing countries to compare their energy efficiency programs with those of a further developed nation.

Conclusion

The method shown in this research is first step for an exploratory framework that will help policy makers and other decision makers (1) to understand the main factors/barriers influencing energy consumption and efficiency, (2) to evaluate their current programs towards these factors/barriers, (3) to compare their portfolios to those from other countries with similar context, (4) to identify gaps and links in their portfolios, (5) and to benefit from lessons learned by other countries. Each country can then scale the effectiveness of a planned (and already studied) measurement through an assessment of the impact of the related efficiency parameters in their own socio-economic context.

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