Methodologies for Tracking Local Sustainable Development*

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ABSTRACT

Strategies that enable sustainability require methodologies for baseline development, measurement and comparison. This article considers methodologies used to track progress toward achieving the sometimes subjective goals associated with sustainability programs. Tracking systems are common for energy, water usage and carbon management but are rare for larger systems. When they are found, they typically use variables which lack statistical significance. While tracking systems devised to assess sustainability for national economies in regard to environmental performance exist, they are rarely designed for institutions, corporations and local governments. Local governments, in particular, often desire to know how their progress toward sustainability goals compares with their peers. Qualitative and quantitative variables, historical data, and peer group comparisons are used as the basis for a sustainability index. This tool can be applied to existing organizations and governmental entities.

Methodologies to track and rank governmental and organizational sustainability are relatively new phenomena. The methodologies available involve data sets using all types of variables. Most involve identifying indicators of sustainability and providing a means of comparison. Linking measurements of energy usage to variables that measure the impact of sustainability policies is one approach.

Using historical data, this article explores selected indicators of sustainability, considers variables that can be measured, and demonstrates how sustainability indices can be developed and interpreted. The process of developing an index by selecting variables and identifying relationships will be discussed in detail. Statistical methodologies will

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be brought to bear in the analysis to bring credibility to the construction of a sample sustainability index. The index developed will use both qualitative and quantitative variables. Quantitative analysis techniques will be used to interpret the differences and draw conclusions concerning the available data. U.S. Sunbelt cities will be used as examples. The data collected regarding them is used to search for commonalities and differences in their demographic patterns, energy impacts and environmental conditions by analyzing quantitative variables.

Based on the statistical analysis of the selected variables, the available data will be analyzed to demonstrate how conclusions can be drawn regarding the sustainability of cities. A two-group comparison reveals that some cities are more sustainable than others. The results of the analysis are interpreted, indicating that when local policies are directed toward influencing transportation or residential sector energy usage, their policies are likely to be effective and yield fruitful results. Finally, a new theory of divergence is supported indicating that there is a surprising disconnect between rates of policy adoption by cities and energy usage. The probable cause of this divergence is identified.

INDICATORS OF SUSTAINABILITY

Measures of energy and sustainability have been most commonly established at the macroeconomic scale. The Organization for Economic Cooperation and Development (OECD) uses environmental indicators for countries that include air emission intensities (CO_2, SO_2, etc.), waste recycling and socio-economic indicators such as energy, energy prices, population density, and transportation infrastructure densities among others [1]. United Nations methodologies incorporate techniques that divide indicators into social, environmental, economic and institutional categories [2].

International research into measurement and monitoring sustainability has provided interesting initiatives. A study by Columbia University and Yale University developed the Environmental Sustainability Index (ESI) gauging progress toward environmental sustainability for 142 countries. They fashioned "a set of 20 core indicators, each of which combines two to eight variables for a total of 68 underlying variables" [3]. Variables included levels of sulfur dioxide in the air and protection of land from development creating an index (from 0 to 100) that gauged the health of the environment [4]. The countries with the highest ratings were Finland, Norway and Canada. Another study by Oxford University focused on sustainability in highly consumptive societies [5].

Sustainability is multi-dimensional. The success of efforts to provide axiomatic solutions has been mixed [6] and suggests developing variables along four dimensions of sustainability that include: 1) the degree to which an opportunity for ecologically and environmentally appropriate development is available; 2) the degree of efficiency of use of natural resources; 3) the extent of management of urban growth; and 4) the extent to which the cultural framework provides equity for current and future generations while providing the opportunity for the improvement of the human condition.

While cities have provided a unit for study in the sciences, measuring sustainability at the scale of city is quite rare. Providing non-subjective variables can be challenging. Nijkamp and Pepping suggested that, "There is not a single unambiguous urban sustainability measure, but a multitude of quantifiable criteria."[7] Portney believes that sustainability relates to variables such as energy consumption, transportation, land use, community building and social justice [8]. Portney further observed that, "a city might be said to take sustainability seriously when its program is found to produce environmental improvements, and one city's initiative might be said to be more serious than other cities' initiatives if it produces a greater environmental benefit" [8]. He feels that until such comparative research is feasible, the measurement of taking sustainability seriously will "be based more on judgment than on rigorous objective standards." Apportioning methodologies to quantify the contributions of changes in population and per capita consumption of resources are used to gauge the impacts of resource use [9]. Commonly, environmental and demographic data are compiled for cities but lack use of statistical analysis (e.g., Sustain Lane) to support the ratings generated.

Cities are viewed as ecological organizations [10], as a focus for transportation and its impact on sustainability [11], as a means of comparing urban policies concerning sustainable development [12], and as a basis to compare sustainable attributes across cities [13]. Advantages of studying energy policies in the context of sustainable cities include: 1) urban areas are centers of economic activity exhibiting the attributes of scale and density; 2) spatial clustering suggests concentrated energy use; 3) cities have greater population densities; 4) most production, transportation and consumption activities occur in urban areas; 5) the city is a institutional decision making unit; and 6) the city is a "suitable statistical entry providing systematic data sets on environmental, energy and socioeconomic indicators" [7].

Assessments across cities are varied. A comparative analysis of twelve European cities by Nijkamp and Pepping assessed success factors of renewable energy policies and determined that policies can have a "double dividend character" in that environmental quality can be improved while reducing the costs of energy consumption [7]. In Germany, Merkel suggested four categories of indicators. These categories included ecosystems, energy use, economic life cycles and human health [14]. In the UK, the government issued a set of 120 indicators of sustainable development in 1996 and extended the list in 1999 to include a broad range of social issues [5]. In response to the worldwide increase in automobile dependence, a checklist has been proposed for "city sustainability" using economic efficiency, social equity, environmental responsibility and human livability as basic evaluation criteria [11].

Indicators of a sustainable community are often locally defined. The Sustainable Seattle program employs "bell-weather tests of sustainability" that reflect "something basic and fundamental to the long term economic, social or environmental health of a community over generations" [15]. Energy, fuel consumption, vehicle miles, nonrenewable energy use and renewable energy use are included as indicators. Sustainability indicators represent more than a collage of social, environmental and economic factors; they also illustrate integrating linkages among their domains [16].

A few Sunbelt cities have adopted specific local indicators. San Diego's Report Card of the San Diego Region's Livability is an example of a comprehensive planning approach, with sustainability listed among the principle objectives. It notes that "the conservation and efficient use of energy will play a very important role in our future if we are to maintain the amount and quality of desired services that energy facilitates" [17]. Santa Monica's resource indicators include a city-wide energy usage profile that is tracked annually and compared to targeted goals.

Indices have been proposed to measure attributes of sustainability. The Barometer of Sustainability is one example [18]. Portney provides an index of "Taking Sustainability Seriously" that includes 34 key indicators. Four of Portney's indicators deal directly with energy conservation and efficiency while several others consider indirect measures such as related transportation and environmental issues [18]. Those that concern energy use directly are: 1) instituting a green building program; 2) renewable energy use by local government; 3) availability of alternative energy to consumers; and 4) a local energy conservation effort or program. Green building programs are efforts to establish energy and environmental standards for existing buildings and new construction. An example of a transportation indicator is the existence of a policy supporting alternatively fueled city vehicles.

Other researchers fail to focus on energy variables as key components in measuring sustainability. For example, Maclaren proposes a set of 16 indicators whose goals include "living off the interest of renewable resources." However, energy is not included among the 16 suggested sustainability indicators [16]. Elsewhere Maclaren offers a detailed multistep approach to sustainability reporting with a typology of frameworks for the development of sustainability indicators using domain based, goal based, issue based with sector oriented and causal categories of indicators, again omitting energy as an indicator [19]. Interestingly, in the same article there are examples of energy being used as indicators in the Sustainable Seattle report [15] and in the United Kingdom's Local Government Management Model (1994). Occasionally researchers note the importance of energy as an indicator of sustainability (such as "green power"), then surprisingly proceed with their research and analysis without using any energy related variables [20].

Why is this happening when these are quantitative measures that are readily available? Energy use by states can be measured in gross expenditures, dollars per capita, units of energy use by energy type, gross energy consumed, energy use per capita, etc. Indicators of energy use in urban areas include transportation miles, commute travel times, number of vehicles per capita, local weather data, population, household size, area of enclosed space, etc. When central utilities are municipally owned, data on local utility usage are often available. While I respect their efforts, I suspect many urban researchers are simply confounded by how to properly use and interpret energy data and instead use incomplete analysis methodologies.

The extensive use of hydrocarbon energy has spawned a wide range of issues that are difficult to manage at the local level. Some potential variables can be difficult to measure and track due to lack of quantifiable local data. Pollution and climate change provide examples that have long been discussed in the literature and remain unresolved [21].

Ranking Cities Using Qualitative Indicators

A sustainability ranking of the 25 Sunbelt cities with the largest populations can be based on qualitative data. For example, the presence or absence of policies used by a city can be applied to develop a sustainability ranking system. The policies themselves are judged to be "sustainable" and the assessment involves a survey process to identify if the policies are present. Such rankings can be based on each city scoring a single point for each of the sustainability indicators (in this example ten) with the possible scores ranging from 0 to 10. The policies used for this ranking are equally weighted. Equally weighting the policies assures that no one policy or set of policies dominates the rankings. For example, from research, it was determined that two of the cities in the sample, Los Angles and San Diego have policies in place in each of the ten categories of variables. As a result, both cities achieved the highest possible score of 10. Miami, which lacks one energy policy indicator, received a total score of 9, the only city to receive this score. Charlotte had the lowest score of 1, with only one environmental policy found. Oklahoma City has two policies in effect, with one in the environmental policy category and one in the organizational participation category. The mean number of policies found among the cities (N=25) was 5.8 while the mode was 7. The cities are ranked based on the total scores in Table 1.

Ranking cities based on rates of policy participation can be helpful if the goal is simply to assess if policies are present. However, this process is of limited use if the goal is to determine and measure the impact of the policies. Such qualitative assessments rarely address the question of whether or not there is evidence that any individual policy or set of policies works better than others in meeting sustainability goals. For this, qualitative assessments are needed which involve applying the rigor of statistical analysis.

Analysis Using Quantitative Indicators

The types of policies available and selected by the cities vary widely in both form and application. Cities and local governments may choose to institute sustainability programs for a wide range of reasons. If policies hope to improve sustainability then what kinds of measures of energy use can be used to gauge improvement at the local level?

Table 1. U.S. Sunbelt cities ranked by policy adoption [22].

	Energy	Local Policy	Organizational Participation	Environmental Programs	Policy Score
Los Angeles	3	2	3	2	10
San Diego	3	2	3	2	10
Miami	2	2	3	2	9
Houston	3	1	2	2	8
Austin	3	1	2	2	8
Tucson	2	1	3	2	8
Atlanta	1	2	3	2	8
Phoenix	2	2	1	2	7
Dallas	2	1	2	2	7
San Antonio	2	2	1	2	7
Las Vegas	3	0	2	2	7
Long Beach	2	2	1	2	7
Albuquerque	2	1	2	2	7
Fort Worth	1	1	2	1	5
Tulsa	1	1	1	2	5
Jacksonville	1	2	0	2	5
Memphis	1	1	0	2	4
Nashville/Davidson	1	1	0	2	4
Fresno	1	1	1	1	4
Mesa	1	1	0	2	4
El Paso	1	1	1	0	3
New Orleans	0	1	0	2	3
Virginia Beach	0	1	1	1	3
Oklahoma City	0	0	1	1	2
Charlotte	0	0	0	1	1

For the analysis, measures of urban policies can be studied as independent variables and energy usage is the dependent variable. Urban policies are considered to be a cause that results in changes in energy use (effects), thus impacting urban sustainability. The analysis considers two aggregate measures (per capita energy usage and per capita energy costs) of the primary dependent variable plus the subcategories of total energy use which include the transportation and residential sectors. Data for energy costs, total energy use and sector energy use was obtained from the Energy Information Administration's *State Energy Data 2000*.*

*Statewide average per capita data was used as no data was available that would provide a specific energy cost and energy usage value, aggregate or economic sector, for each individual city within each state.

Per capita energy costs (E_C): This is the statewide average annual per capita cost of energy during the year 2000 in units of year 2000 U.S. dollars. Lower energy costs can be an indication of greater urban sustainability since access to the energy source is more equitable. Per capita energy costs are an aggregate measure of the results of energy pricing. Cities that are in states with higher per capita energy costs may be considered less sustainable. Substantially higher per capita energy costs may indicate that resources are in short supply in a given locality or that resources are being diverted from social needs to provide energy.

Per capita energy usage (E): This variable quantitatively expresses the statewide average annual per capita energy use during the year 2000 in common units of energy consumed (million kilojoules per year). Less energy use is accepted as an indication of greater urban sustainability since less is demanded of the system to maintain equilibrium. To the extent that system efficiencies are comparatively equal, lower energy use suggests less pollution emission potential in the state where the city is located. Cities that are in states with higher per capita energy use may be considered less sustainable as more energy is required to maintain equilibrium. Higher energy use suggests potentially greater pollution potential. It also requires energy to produce and manufacture energy, especially fossil fuels. Oklahoma, Texas and Louisiana are oil exporting states and their per capita energy use is higher in part due to the energy required to extract, produce, process, refine and transport marketable oil based products that is used by other states. Per capita energy use is often used as sustainability measure. Reducing per capita energy usage has been identified in the literature both as a goal and indicator of sustainable cities [16, 23, 24].

The Energy Information Administration reports the gross energy usage for four economic sectors: residential, commercial, industrial and transportation. For this analysis, two subsets of this data, per capita energy usage (E), transportation sector energy usage (E_T) and residential energy use ($E_{R,}$) are considered the most relevant since many urban policies focus on these sectors.

Transportation sector per capita energy usage (E_T): This variable quantitatively expresses the statewide average annual per capita energy usage by the transportation sector during the year 2000 in common units (million kilojoules per year). This measure of energy use has been noted in the literature as being linked to urban density and urban land area [23].

Residential sector per capita energy usage (E_R): This variable quantitatively expresses the statewide average annual per capita energy usage by the transportation sector during the year 2000 in common units (million kilojoules).

Many of the cities in this study are among the principle cities and population centers in their respective states. In a number of the Sunbelt states, these cities represent a substantial percentage of the total state population. For example, the use of state averages is considerably legitimized in states such as Arizona and Texas since the cities in these states constitute a major percentage of their state's population. On the other hand, the use of state averages are less representative of states like Florida, since only a small fraction of the state population is represented by the cities in this study. Using data from the 2000 U.S. Census, the cities involved in this study often hold a large portion of their state's population. For example, studied cities in the following states hold the following total portions of state population: 17.2% of the population in California, 29.0% of the population in Texas, 26.1% of the population in Oklahoma, 42.9% of the population in Arizona, 23.9% of the population in Nevada, 24.7% of the population in New Mexico, and 6.9% of the population in Florida.

The indicators of urban policy used for the analysis include energy usage, transportation, environmental impact and demographic indicators that are based on the selected variables. The selected variables provide quantitative data for each of the indicators along each of the identified dimensions.

Indicators of residential energy use sample and gauge both the use of energy in the residential sector and the extent of use of alternative energy. Residential energy use was chosen for consideration since many residential alternative energy technologies are commercially available and packaged for ease of installation (e.g., solar water heating systems, photovoltaic roofing shingles, etc.). The independent variables selected to measure residential energy usage include homes heated by alternative fuels and single occupant residences. The values were compiled using data from the 2000 U.S. Census.

Homes heated by alternative fuels: This is the percentage of homes in the subject city in the year 2000 that are heated by alternative fuels (wood, solar, other renewable sources) plus those that do not require fuels for heating purposes. The ability to heat one's residence with renewable energy or to construct a residence that does not require a conventional heating source, is inherently more sustainable than depending on fossil fuels (oil, natural gas, coal) for residential heating. Using renewable substitutes for non-renewable fuels has been identified in the literature as an indicator of sustainability [25] as has renewable resource harvest rates [16] and the share of consumption of renewable resources [24].

Single occupant residences: This variable is the percentage of residences in the city that have only one occupant. While appliance energy use may vary, a residence requires roughly the same amount of energy for space heating and cooling regardless of the number of occupants. While single occupant households may be smaller in floor area than residences for larger families, it is logical that a proliferation of single occupant households in a city would cause higher residential energy use per capita than would be found in cities with a lower percentage of single occupant households.

When a city develops and provides alternative means of transportation, it is possible for urban residents to meet all or a portion of their transportation needs by means other than personal vehicles. This is evidenced by the number of households who have one or no automobiles. In addition, cities that are planned in a manner that allow shorter commute times can reduce the energy impact of automobiles. The independent variables used as indicators to assess transportation include: 1) travel time to work; 2) alternative means of transport; and 3) household vehicles. The values for these variables were compiled from data found in the 2000 U.S. Census. A description of each of these variables follows.

Travel time to work: This variable is the mean travel time (one way) to or from work in minutes during the year 2000 for the city being studied. Less travel time to work is an indication of greater urban sustainability. Vehicles that are driven less use less fuel, resulting in the creation of less air pollution during commuting periods. Substantial commute times can be indicative of decentralized development patterns and traffic congestion, thus contributing to increases in vehicular energy use. Reducing commute times to and from work has been suggested to be a goal of sustainable cities [23].

Alternative transportation: This is a quantitative value indicating the percentage of residents in the subject city who used public transport or walked to their places of employment plus those who chose to work from home (e.g. home office users, stay-at-home employees, telecommuters, among others, etc.) during the year 2000. This indicator provides a snapshot of the size of the non-commuting population, combined with an estimate of the size of the population that does not necessarily require a vehicle simply to go to work. A larger percentage value is indicative of decreased energy usage as less dependence on personal vehicles is required for income generation. Smaller percentage values indicate that a greater number of people need to use personal vehicles to reach their primary places of employment. Reduced dependence on personal vehicles for commuting purposes improves urban sustainability by reducing energy usage and pollution from vehicular sources. The level of alternative transit use has been noted in the literature as being related to sustainability and urban form [26]. The extent of use of public transportation systems has been found in the literature to be a sustainability indicator [16, 23, 27].

Household vehicles: This variable is the percentage of households with no or only one vehicle per household in the subject city for the year 2000. While it may be argued that a smaller number of household vehicles suggests lower economic status and a larger number of household vehicles reflects greater household wealth, it is also likely that design of the urban infrastructure provides lesser or greater needs for private vehicles. Higher percentages may indicate greater urban sustainability as the residents of urban environments have less demanding requirements for vehicles to accommodate transportation requirements. Lower percentages are indicative of a greater need for and utility of multiple personal vehicles. Reducing private ownership of vehicles can be considered to be an indicator of improved sustainability [1].

Urban areas are located in places with widely varying climates that may tend to disperse air pollution, concentrate air pollution or have neutral impact. The impacts of pollution vary in type of pollutants, location of source, distribution and impact. Atmospheric pollution is an indicator of inefficiencies in combustion processes, such as those associated with carbon based fuel consumption. Combustion fuels such as coal and oil are significant contributors to atmospheric pollution. Alternative fuels create no or negligible atmospheric pollution. Cities located in coastal locations with offshore afternoon winds such as Jacksonville, Florida often experience fewer problems with atmospheric pollution than inland cities like Fresno, California which has continuing and extensive problems with atmospheric pollution. The independent variables used to assess air pollution include the air quality index (AQI) and days unhealthy and unhealthy for sensitive groups. The impact of environmental climate conditions can be represented in part by the variable cooling degree days. Descriptions of these variables are provided below:

> *Air quality index (AQI):* This is mean value of the daily local or regional air quality index (AQI) for the subject city for the year 2000. Higher values for the AQI indicate poorer air quality due to pollution. The indicator ranges from a low of 0 to a high of 500 and is used by the U.S. Environmental Protection Agency (USEPA) to gauge and compare air quality across cities and regions. Air quality levels are typically monitored and compiled by state government entities and reported to the USEPA. AQI values ranging from 0 to 50 are considered "good" and pose little or no health risk. AQI values ranging from 51 to 100 are considered "moderate" yet have levels of pollutants that may pose a "moderate health concern for a very small number of people" [29]. AQI values above 101 are ranked progressively as "unhealthy for sensitive groups," "unhealthy," "very unhealthy" and "hazardous" [29]. An AQI value in the "good" range indicates that daily air quality conditions are not problematic or are being successfully addressed by local or regional mitigation efforts. Greater urban sustainability is a natural result. While a given city may have an annual mean value in the "good" range, it will likely experience a number of peak days when the air quality is poorer. Atlanta, as one example, has an annual mean AQI value of 61 for the year 2000 with daily peaks reaching index values of 206. Air quality

has been identified as an objectively verifiable measurement of sustainability in cities [1, 15, 27].*

Days unhealthy and unhealthy for sensitive groups: This value is the total number of days in the year 2000 during which air quality in the city was categorized as either unhealthy or unhealthy for sensitive groups. As a result, the value of this indicator could range from 0 to 365. The fewer the number of days in which air quality is either unhealthy or unhealthy for sensitive groups, the greater the urban sustainability. Cities experiencing a greater number of unhealthy days may be insensitive to the contributing causes of human health care problems and inattentive to the need to increase mitigation efforts to improve air quality. The actual number of days with "good air quality" has been identified as an indicator of sustainability [23, 24, 27].†

Cooling degree days: This variable is a measure of the average total number of cooling degree days (CDD) experienced annually by each city when compared to a base of 65° F.‡ The cities in the sample experience a mean of 2,385 cooling degree days, ranging from a low of 679 cooling degree days for Los Angeles and a high of 4,361 cooling degree days for Miami. This variable is used as a measure of only residential energy usage (E_R) since more air conditioning is typically required for cities that experience greater number of cooling degree days (as cooling degree days increase, air conditioning typically systems use more energy).

Demographic indicators have also been selected for study. Variables measuring urban population density and the relative changes in population and urban density over a period of time (10 year relative change in population compared to change in density) are independent variables helpful in measuring changes along these dimensions. The values for

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*Data for the variable air quality index was found on the USEPA website: www.epa.gov/airnow/.

† Data for the variable days unhealthy and unhealthy for sensitive groups was found on the USEPA website: www.epa.gov/airnow/.

‡Data for the variable *cooling degree days* was found on a website sponsored by the National Oceanic and Atmospheric Administration (NOAA): lwf.ncdc.noaa.gov/oa/climate/online/ccd/nrmcdd.html.

these variables were compiled from data found in the 2000 U.S. Census.

Population density: This indicator is the average population density of the city per square kilometer for the year 2000. Higher population densities indicate less urban sprawl, greater centralization of population, more concentrated development and a greater degree of sustainability. Low urban population densities suggest greater sprawl, decentralized population, less concentrated development patterns and a lower degree of sustainability. As a point of reference, the average population density in the U.S. is just under 30 inhabitants per square kilometer. Increasing population densities has been suggested to be a direct measure of sustainability [26] and a goal and indicator of improved sustainability in cities [23].

10 year relative change in population compared to change in density: This indicator records the changes in population relative to changes in density over a specific ten year period. The indicator is calculated as the percentage change in population from 1990 to 2000 less the percentage change in population density from 1990 to 2000. If urban population growth is outstripping increases in density then the value is positive and land area (possibly due to sprawling development) is being added to the city. If urban population growth is not outstripping increases in density then the value is negative and the urban area is likely becoming more densely populated. Densification suggests relatively less suburban development. Population growth and density have been identified as demographic environmental indicators related to sustainability [1, 15, 24]. However, the use of this calculated quantity as a measure of energy use is novel and untested.

Identifying Values for Quantitative Variables

Data for each of the ten variables was obtained and tabulated for all of the 25 selected Sunbelt cities. There is no missing or omitted quantitative data for these variables. The values of the selected dependent variables are as follows:

Per capita energy costs (E_C): The values for this variable range from a low per capita annual cost during the year 2000 of $1,951 for cities in Florida (Miami and Jacksonville) to a high of $4,638 for cities in

Louisiana including New Orleans. Per capita energy costs are lowest in California, Arizona and Florida which are energy importers and highest in Texas and Louisiana which are energy exporters. The mean value for the 25 sampled Sunbelt cities is $2,661.

Cities located in states with lower per capita energy use (e.g., Los Angeles, Tucson, Miami) also expend fewer dollars per capita on energy. Cities located in states with higher per capita energy use (e.g., Houston, Dallas and New Orleans) expend more dollars per capita on energy. Los Angeles, Long Beach and Miami not only have the highest rates of homes heated by alternative or no fuels but also are located in states with comparatively lower rates of per capita energy usage and per capita energy costs.

Per capita energy usage (E): For data collected for the year 2000, this variable ranges from a low value of 250.0 million kilojoules for cites in Arizona (Phoenix and Tucson) to a high of 936.2 million kilojoules for cities in Louisiana (New Orleans). The mean value for the 25 sampled Sunbelt cities is 409.0 kilojoules. The U.S. national average in 2000 was 371.4 million kilojoules.* An interesting finding is that during 2000 residents in California consumed only half the energy per capita as residents of Texas. Residents of Louisiana consume than 3.7 times more energy per capita than residents of Florida.

Transportation sector per capita energy usage (E_T): For data collected for the year 2000, this variable ranges from a low value of 94.1 million kilojoules for cites in Florida (Jacksonville and Miami) to a high of 213.5 million kilojoules per year for cities in Louisiana (New Orleans). The mean value for the 25 sampled Sunbelt cities is 113.0 million kilojoules. This mean quantity (E_T) is a subset of p*er capita energy usage (E)* representing 27.9% of the mean of *E.*

Residential sector per capita energy usage (E_R): For data collected for the year 2000, this variable ranges from a low value of 41.1 million kilojoules for cites in California (e.g., Long Beach and Fresno) to

*Data from the Energy Information Administration: www.eia.doe.gov/emeu/aer/txt/ptb0105.html.

a high of 80.1 million kilojoules per year for cities in Oklahoma (Oklahoma City and Tulsa). The mean value for the 25 sampled Sunbelt cities is 64.3 million kilojoules. The mean quantity *(E_R)* is a subset of p*er capita energy usage (E)* representing 15.7% of the mean for *E.*

Table 2 provides the values of the dependent variables. This table has been compiled using data from the Energy information Administration (*State Energy Data 2000*) and the U.S. Census Bureau.

Table 2. Per capita energy cost and usage data (2000).

Sunbelt City	Per Capita Total Costs $ *E(C)*	Per Capita Total Million Kilojoules *E*	Transportation Sector Million Kilojoules *E(T)*	Residential Sector Million Kilojoules *E(R)*
Los Angeles	2,098	265.5	95.4	41.1
Houston	3,551	586.6	132.1	67.5
Phoenix	2,059	250.1	95.2	58.2
San Diego	2,098	265.5	95.4	41.1
Dallas	3,551	586.6	132.1	67.5
San Antonio	3,551	586.6	103.8	67.5
Jacksonville	1,951	260.5	94.1	65.3
Austin	3,551	586.6	132.1	67.5
Memphis	2,419	375.9	103.8	76.5
Nashville	2,419	375.9	103.8	76.5
El Paso	3,551	586.6	103.8	67.5
Charlotte	2,404	464.2	92.9	74.3
Fort Worth	3,551	586.6	132.1	67.5
Oklahoma City	2,706	428.2	131.2	80.1
Tucson	2,059	250.1	95.2	58.2
New Orleans	4,638	936.6	213.5	76.4
Las Vegas	2,413	334.3	108.8	66.0
Long Beach	2,098	265.5	95.4	41.1
Albuquerque	2,259	327.9	132.8	53.4
Fresno	2,098	265.5	95.4	41.1
Virginia Beach	2,372	343.5	103.4	74.1
Atlanta	2,416	357.2	112.0	75.9
Mesa	2,059	250.1	95.2	58.2
Tulsa	2,706	428.4	131.2	80.1
Miami	1,951	260.5	94.1	65.3

The two selected energy use variables are: 1) the number of homes heated by alternative fuels or no fuel; and 2) percentage of single occupant residences. The values of the energy usage indicators for the study are summarized below.

Homes heated by alternative fuels: The values of this variable indicate that few households in the selected Sunbelt cities use alternative fuels or no fuel for heating. The observed values found for this variable range from a low of 0.3 percent for the cities of Charlotte, Las Vegas and Tulsa, to a high value of 7.3 percent for Miami. Other cities with above average values include Los Angeles (4.4%) and Long Beach (3.3%). The mean value for the 25 sampled Sunbelt cities is 1.2%.

Single occupant residences: The values of this variable range from low of 19.2% for El Paso, Texas to a high of 38.5% for Atlanta, Georgia. The mean value for the 25 sampled Sunbelt cities is 28.9%.

Table 3 provides a summary of the energy use data for the cities in the sample identifying data for each variable and its corresponding city. The selected transportation variables are: 1) travel time to work; 2) alternative means of transport to place of employment; and 3) the percentage of households that have no or only one vehicle.

Travel time to work: The values for this variable range from a low of 18.6 minutes for Tulsa to a high for Los Angeles of 29.6 minutes. Other cities with low values include Tulsa (18.6 minutes), Albuquerque (20.4 minutes) and Oklahoma City (20.8 minutes). Cities with higher values include Long Beach (28.7 minutes) and Atlanta (28.3 minutes). The mean value for the 25 sampled Sunbelt cities is 24.5 minutes.

Alternative transportation: Values for this variable provide a range of 17% which varies among the cities from a low of 5.3 % for both Oklahoma City and Fort Worth to a high of 22.3% for Atlanta. In Virginia Beach, 5.5% of the residents either work at home or have alternative means of transportation to work. Other cities with higher percentages include New Orleans (21.6%) and Los Angeles (17.9%). The mean value for the 25 sampled Sunbelt cities is 9.9%.

Table 3. Summary of energy use variables (2000).
Source: U.S. Census 2000.

Sunbelt City	Alternate or no Fuels for Heating %	Single Occupant Households %
Los Angeles, California	4.4	28.5
Houston, Texas	0.9	29.6
Phoenix, Arizona	0.9	25.4
San Diego, California	0.5	28.0
Dallas, Texas	0.6	32.9
San Antonio, Texas	0.6	25.1
Jacksonville, Florida	1.2	26.2
Austin, Texas	0.5	32.8
Memphis, Tennessee	0.5	30.5
Nashville/Davidson, Tennessee	0.7	33.8
El Paso, Texas	0.4	19.2
Charlotte, North Carolina	0.3	29.5
Fort Worth, Texas	0.5	28.6
Oklahoma City, Oklahoma	0.6	30.7
Tucson, Arizona	0.9	32.3
New Orleans, Louisiana	0.7	33.2
Las Vegas, Nevada	0.3	25.0
Long Beach, California	3.3	29.6
Albuquerque, New Mexico	0.6	30.5
Fresno, California	1.1	23.3
Virginia Beach, Virginia	0.8	20.4
Atlanta, Georgia	0.6	38.5
Mesa, Arizona	0.5	24.2
Tulsa, Oklahoma	0.3	33.9
Miami, Florida	7.3	30.4

Household vehicles: The majority (greater than 50%) of households in 12 of the selected Sunbelt cities have no or only one vehicle. Cities with the largest percentage of households with no or only one vehicle include New Orleans (69.6%), Miami (68.8%) and Atlanta (66.0%). Interestingly, Virginia Beach has by far the lowest percentage of households with no or only one vehicle, approximately 35.7%. Other Sunbelt cities with low values for this variable include Nashville (41.8%) and Houston (44.5%). The mean value for the 25 sampled Sunbelt cities is 51.8%. In addition, the data indicates that the majority of households in 13 of the 25 cities have two or more vehicles.

Table 4 (from U.S. Census Bureau, *Census 2000*) provides a summary of the data relative to the transportation indicators for the sampled Sunbelt cities. Residents of Los Angeles, Atlanta and Miami experience longer than average travel times to work, are more likely to avail themselves of alternative transportation systems and have a higher than average percentage of households with no or only one vehicle.

Table 4. Transportation variables (2000).

Sunbelt City	Mean Travel Time to Work Minutes	Alternative Transport %	0 to 1 Vehicles per Household %
Los Angeles, California	29.6	17.9	56.8
Houston, Texas	27.4	10.5	44.5
Phoenix, Arizona	26.1	8.8	48.4
San Diego, California	23.2	11.8	47.2
Dallas, Texas	26.9	8.2	56.9
San Antonio, Texas	23.8	8.2	49.5
Jacksonville, Florida	25.2	6.8	47.5
Austin, Texas	22.4	10.4	50.3
Memphis, Tennessee	23.0	6.6	58.3
Nashville/Davidson, Tennessee	23.3	7.2	41.8
El Paso, Texas	22.4	6.5	46.1
Charlotte, North Carolina	25.1	7.9	47.0
Fort Worth, Texas	24.6	5.3	49.1
Oklahoma City, Oklahoma	20.8	5.3	48.3
Tucson, Arizona	21.6	9.8	56.0
New Orleans, Louisiana	25.7	21.6	69.6
Las Vegas, Nevada	25.4	9.4	51.0
Long Beach, California	28.7	10.0	57.6
Albuquerque, New Mexico	20.4	8.0	46.5
Fresno, California	21.7	7.5	53.0
Virginia Beach, Virginia	23.9	5.5	35.7
Atlanta, Georgia	28.3	22.3	66.0
Mesa, Arizona	25.9	6.6	47.0
Tulsa, Oklahoma	18.6	7.5	51.6
Miami, Florida	28.1	17.2	68.8

On the other hand, residents of Tucson, Tulsa, and Fresno have shorter commuting times, are less likely to use alternative transportation, and also have a higher than average percentage of households with no or only one vehicle. People in New Orleans experience average commuting times, tend to use alternative transportation to a greater extent and have the lowest percentage of households with two or more vehicles.

The environmental indicators are represented by two variables: 1) the air quality index (AQI); and 2) the number of days per year that the air quality is considered by a common standard to be either unhealthy or unhealthy for sensitive groups.

> *Air quality index (AQI)*: Within the group of selected Sunbelt cities, Jacksonville with its service economy and offshore breezes has an unusually low mean AQI of 0, by far the best air quality in the sampled Sunbelt cities. Cities with the next lowest mean air quality indexes are Miami (37) and San Antonio (38). The city of Fresno, located in the country's largest air basin and noted for notoriously poor air quality, has the highest mean value of 80. Cities with the next highest mean air quality indexes are Los Angeles (72) and Long Beach (72). The mean AQI value for the 25 sampled Sunbelt cities was 50.8 for the year 2000.

> *Days unhealthy and unhealthy for sensitive groups*: A number of cities have low scores for this variable: Virginia Beach (0), Tucson (0), Jacksonville (2), Miami (2), San Antonio (3) and Albuquerque (3). For residents of these cities, air quality is typically healthy for all groups of individuals and air quality (excluding point sources of pollution) is not normally of concern to human health. The city of Fresno experienced most days (132) in 2000 during which the air quality was either unhealthy or unhealthy for sensitive groups. Cities with the next highest values were Los Angeles (88) and Long Beach (88). The mean value for the sampled Sunbelt cities during the year 2000 was 28.4 days.

Jacksonville has the lowest score in both categories and holds the distinction using these measures of having the cleanest air in the sample of Sunbelt cities. Fresno has the highest scores in both categories, implying that Fresno experiences unhealthy ambient outdoor air conditions more often than any of the other sampled Sunbelt cities. Los Angeles and Long Beach, both part of the Los Angeles Metropolitan Statistical

Area (MSA), tie for second place as having the next most unhealthy air. Prolonged periods of poor air quality indicates significant urban air pollution, often caused by the inefficient burning of fossil fuels, vehicular urban transportation systems and possibly extended periods of stagnant air. Such conditions are often experienced in both the Fresno and Los Angles basins.

Relevant demographic indicators are population density for the year 2000 and the relative change in population compared to changes in population density (1990-2000).

Population density: Oklahoma City (282 per km^2 or 730 per $mile^2$), Jacksonville (323 per km^2 or 837 per $mile^2$) and Nashville (398 per km^2 or 1,031 per $mile^2$) have the lowest population densities among the Sunbelt cities in this study. Miami (3,889 per km^2 or 10,072 per $mile^2$), Long Beach (3,316 per km^2 or 8,588 per $mile^2$) and Los Angeles (2,868 per km^2 or 7,428 per $mile^2$) have the greatest population densities. The mean population density for the sampled Sunbelt cities is 1,203 persons per km^2 or 3,166 per $mile^2$.

10 year relative change in population compared to density: All of the sampled Sunbelt cities with the single exception of New Orleans, experienced increases in population growth between 1990 and 2000. Six of the cities experienced negative changes in density while the remaining 19 cities experienced positive changes in density during the period. Albuquerque had the largest negative percentage change in population density (-14.7%) while Las Vegas experienced the largest positive change in density (36.2%). There are five cities among the selected Sunbelt cities that have slightly negative values: Tulsa (-0.5%), Jacksonville (-0.2%), Oklahoma City (-0.2%), Nashville (-0.1%) and Los Angeles (-0.1%). In Dallas, New Orleans, Virginia Beach and Atlanta, the change in population equaled the change in density, meaning that changes in population are moving in tandem with changes in density. While this indicator is less than or equal to 0 for nine of the selected Sunbelt cities, it is positive for 16 of the cities. In a number of Sunbelt cities, population growth is substantially exceeding changes in population density: Las Vegas (49.0%), Charlotte (38.3%), Albuquerque (31.3%), Tucson (23.7%), San Antonio (22.4%) and Austin (18.9%). The mean percentage change in population less the mean percentage change in population density of the sampled cities is roughly 9%, indicating that population growth is generally outstripping changes in density.

There are interesting relationships which result from a comparison of the data for population density and the data indicating percentage change in population less percentage change in population density. For example, the three Sunbelt cities in the sample with the greatest population density in 2000, Miami (3,889 per km^2), Long Beach (3,316 per km^2) and Los Angeles (2,868 per km^2), saw only negligible changes in the percentage change in population less percentage change in population density, ranging from a value of -0.1 to a value 0.9.

Likewise, the three cities with the lowest population density in 2000, Oklahoma City (282 per km^2), Jacksonville (323 per km^2) and Nashville (398 per km^2), saw only negligible changes in the percentage change in population less percentage change in population density, ranging from a value of -0.2 to a value -0.1. This indicates that these cities are either inelastic or due to large municipal areas, they did not need to expand their land area to accommodate demands due to population growth. As a result, population growth is being accommodated by increases in population density as vacant land within the cities is being developed. Table 5 data was compiled using data retrieved from the U.S. Census Bureau (Census 1990 and Census 2000 data) and summarizes the findings concerning the demographic indicators relevant to changes in population and changes in population density.

Equally interesting is that five Sunbelt cities (San Antonio, Charlotte, Tucson, Las Vegas, and Albuquerque) with the largest difference between percentage population change and percentage change in population density (ranging from 22.4% to 49.0%) fell into a relatively narrow range of population density (877 to 1,197 persons per km^2). Population growth is being accommodated by increases in land area suggesting that these cities are more elastic. The population density range from 877 to 1,197 persons per km^2 is less than the mean population density for the sampled Sunbelt cities of 1,203 persons per km^2. This suggests that new land developments are less densely populated than existing developments in these cities. As a result, Sunbelt cities with faster growing populations tend to consume more land. While population density is declining in San Antonio, Charlotte, Tucson, and Albuquerque, population density is increasing in Las Vegas.

Table 5. Demographic indicators.

Sunbelt City	2000 Population Density Per Sq KM	1990-2000 Population Change %	1990-2000 Change in Population Density %	1990-2000 Population Change - Pop. Density %
Los Angeles, California	2,868	6.0	6.1	-0.1
Houston, Texas	1,166	19.8	11.6	8.2
Phoenix, Arizona	904	34.3	18.8	15.5
San Diego, California	1,323	10.2	10.0	0.2
Dallas, Texas	1,135	18.0	18.0	0.0
San Antonio, Texas	1,085	22.3	-0.1	22.4
Jacksonville, Florida	323	15.8	16.0	-0.2
Austin, Texas	825	41.0	22.1	18.9
Memphis, Tennessee	921	6.5	-2.4	8.9
Nashville/Davidson, Tennessee	398	11.6	11.7	-0.1
El Paso, Texas	811	9.4	7.8	1.6
Charlotte, North Carolina	877	36.6	-1.7	38.3
Fort Worth, Texas	615	19.5	14.8	4.7
Oklahoma City, Oklahoma	282	13.8	14.0	-0.2
Tucson, Arizona	1,001	20.1	-3.6	23.7
New Orleans, Louisiana	1,062	-2.5	-2.5	0.0
Las Vegas, Nevada	1,197	85.2	36.2	49.0
Long Beach, California	3,316	7.5	6.6	0.9
Albuquerque, New Mexico	1,124	16.6	-14.7	31.3
Fresno, California	1,380	20.7	14.6	6.1
Virginia Beach, Virginia	611	8.2	8.2	0.0
Atlanta, Georgia	1,154	5.7	5.7	0.0
Mesa, Arizona	1,024	37.6	19.5	18.1
Tulsa, Oklahoma	773	7.0	7.5	-0.5
Miami, Florida	3,889	1.1	0.8	0.3

The data indicate that rapid population growth in cities such as Phoenix, Austin, Fort Worth, Fresno, Las Vegas and Mesa is requiring both the expansion of land area and coincidental increases in population density in order to accommodate new residents.

ENERGY COSTS AND SECTOR ENERGY USE

If policies are to succeed, to what ends do they need to be directed? One-way Analysis of Variance Analysis (ANOVA) regression is revealing. The relationships between the dependent variables *per capita energy* *costs* (E_C) and the selected independent variables are not significant.

The first regression considered uses the aggregate measure of energy costs as the dependent variable and local measures of energy usage as the independent variables. A regression can be performed using the dependent variable *per capita energy costs* (E_C) across the selected Sunbelt cities (N=25). The independent variables used for this regression are: *alternative or no fuels for heating, single occupancy households, travel time to work, population density, household vehicles, days unhealthy and unhealthy for sensitive groups, population density, air quality index*, and *10 year relative change in population compared to density.* The results of this regression provide a coefficient of determination (R^2) of 34.2%. This is proved to be insignificant ($p >.1$) and all independent variables are found to be insignificant.

The analysis indicates that urban policies designed to influence changes in these variables are likely an ineffective means of achieving a goal of impacting energy costs. If cities are motivated to implement their policies by the notion that aggregate energy costs can be influenced, then this analysis proves this belief to be flawed. As market logic would suggest, aggregate costs are not in the long term influenced by these kinds of local or regional policies. Market economists believe that energy costs are more likely subject to the forces of supply and demand for energy products and influenced by external conditions on the national and international scene, rather than by local conditions.

Cities, even a set of large cities such as our 25 Sunbelt cities, are unlikely to influence aggregate energy costs by implementing local policies. For example, a city might increase the number of homes that use alternative heating systems, reduce the number of household vehicles or provide alternative transport but such actions will not influence aggregate energy costs. According to Self [28] such "evidence suggests that the pursuit of micro-efficiency does not add up to macro-welfare and prosperity" and that the problem may lie "not so much in any disjunction between the two levels of the economy as in errors in micro-economic theory itself." The analysis renders additional evidence that the conservative view in the model of a "spontaneous self-regulating system" can be "strongly challenged" [28]. Taking all of the variables into account, it is clear that local and regional efforts are likely ineffective in regard to aggregate measures without some other influence, such as a broadly based, world scale, concerted initiative.

Dispensing with energy costs, the analysis now considers energy usage variables. An analysis of variables representing the economic sectors that are most likely to be affected by disaggregated measures of energy use is in order. It is known that the variable *per capita energy use* (*E*) includes transportation sector, residential sector, industrial sector and commercial sector energy usage components. Cities attempting to create incentives for economic development can be viewed as being supportive of business development interests and are less likely to pursue policies that regulate industrial and commercial sector activities. As a result, they may be reluctant to implement policies that focus on energy usage in these sectors. Alternatively, certain variables used in this analysis are logically related to the transportation and residential sectors. Energy use by these sectors may have a stronger relationship with selected variables. The variables considered are *transportation sector per capita energy usage* (E_T) and *residential sector per capita energy usage* (E_R). Both variables are subsets of *per capita energy usage* (*E*).

To further probe for the potential of a relationship between sector energy use and their indicators of measures of energy use, variables are selected that would logically be related to the energy usage of the transportation sector. A selected dependent variable measuring total transportation sector energy use is tested against selected independent variables that are measures of transportation usage by means of an ANOVA regression. The independent measures are those that are often the focus of local transportation policies. To this end, the dependent variable *transportation sector per capita energy usage* (E_T) is tested against the independent variables *alternative transportation, travel time to work, population density* and *household vehicles*, again using regression and analysis of variance.

The results indicate a coefficient of determination (R^2) of 38.2% which is significant ($p<.05$). This suggests that the energy usage by the transportation sector (E_T) can be explained in part by these four variables. Using the data, the equation for E_T for all cities (N=25) becomes:

$$E_T = 88.7877 + (2.2041 \text{ X } \textit{alternative transportation}) - (1.5846 \text{ X } \textit{travel time to work}) - (0.0159 \text{ X } \textit{population density}) + (1.1666 \text{ X } \textit{household vehicles})$$

Next, the dependent variable *residential sector per capita energy usage* (E_R) is tested against the selected independent variables that are measures of residential energy usage using an ANOVA regression. The selected variables are *alternative or no fuels for heating, single occupancy households,* and *cooling degree days.* For this case, the independent variable *cooling degree days* is introduced since residential sector energy usage in Sunbelt cities is accepted to be a function of changes in demand for indoor space cooling due to the varying local conditions.

While the regression analysis does not control for other variables, the results for the residential sector variables provide a R^2 of 32.6% which is significant ($p<.05$). This regression suggests that the energy usage by the residential sector (E_R) can be explained in part by these three variables. Using the data, the equation for E_R for all cities (N=25) becomes:

$E_R =$ 29.2799 - (3.1149 X *alternative or no fuels for heating or no fuels for heating*) + (0.9801 X *single occupancy households*) + (.0043 X *cooling degree days*)

These findings are important as they support the notion that focused local policies that are directed toward influencing these variables can be an effective means of influencing both transportation and residential sector energy usage. However, policies directed toward other measures are likely to be less effective. For example, increases in residential energy use are associated with increases in the number of single occupancy residences, increases in cooling degree days and declines in the number of alternatively heated residences. These findings offer evidence that local policy efforts can be productive when they are focused and targeted toward very specific ends.

THE RELATIONSHIPS OF POLICIES WITH VARIABLES

Ranking systems often use both qualitative and quantitative variables in assessing sustainability. The next challenge is to compare and interpret the information gained from the qualitative investigation of policies to the analysis of the selected quantitative data. An analysis will be developed that provides insight into the relationships of policy adoption in Sunbelt cities. From this information, an index is devised to rank cities based on energy related indicators of sustainability by using both qualitative and quantitative data. Sunbelt cities are divided into two distinctive groups based on rates of policy adoption and selected variables. Commonalities and differences between groups are discussed.

The ten selected qualitative policies discussed earlier provide evidence that many of the sampled cities have policies in place to manage energy use and sustainability. Recall that the selected qualitative policies included utility rebate programs, city operated energy efficiency programs, utility and government program support, sustainable development policies, use of high occupancy vehicle lanes, ICLEI membership, Clean Cities designation, Energy Star^{TM} partnership, curbside recycling programs and brownfield redevelopment programs. It is possible to rank the cities by the number of categories of policies that cities choose to employ. Recall that the cities in our sample of 25 Sunbelt cities have adopted 1 to all 10 of these policies. Las Vegas utilizes seven of these policies. The number of policies employed by each city can be called its rate of policy adoption.

While the literature reviewed identified aspects of sustainable cities not directly related to energy or environmental factors, for the purposes of this study, cities with policies in place to respond to all categories of policies can be considered to be promoting a goal of improved urban sustainability. On the other hand, cities with no or few policies in place either lack a sustainability agenda or may not be earnest in their quest to become "sustainable."

Quantitative rankings are similarly achieved. The variables for each of the 25 cities were rank ordered using the raw values obtained during the research. An index was devised to provide a possible range of scores for each variable from .0 to 1.0. The city with the lowest quantitative ranking for each variable was assigned an index score of 0.0 for that variable and the city with highest score for the variable was assigned an index score of 1.0. Index scores for the other intervening cities were proportionately assigned based on the values of their variables. With a total of nine variables, the lowest index total theoretically achievable was a 0.0 and the maximum index total that was potentially achievable was a 9.0.* All variables are equally weighted in this index. The total score provides a newly created composite variable.

Calculated index values for each of the selected variables includ-

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*To derive an index for the year 2000 which is uninfluenced by 1990 data, the variable *10 year relative change in population* compared to *density*. The variable *cooling degree days* is also not used for this index as it is accepted that while cities can establish policies for designs of structures which respond to varying climatic conditions, they have no direct policy control over weather.

ing energy costs can be determined. All variables in the index are equally weighted. An index value combining all remaining variables yields the variable *index scores* which is comprised of the sum of the index values for the following nine variables: *per capita energy use (E), homes heated by alternative fuels, single occupant households, travel time to work, alternative transportation, household vehicles, air quality index (AQI), days unhealthy and unhealthy for sensitive groups* and *population density.* Using this procedure, the summed values indicate that Miami has the highest index total of 6.74 and that Nashville has the lowest index total of 3.17. The mean index value of the 25 selected cities is 4.0.

Using the rate of policy adoption or total *number of policies* (from 1-10) as the independent variable and the computed *index scores* to serve as the composite dependent variable measuring energy use, a regression without controlling for other influences provides an R^2 of 14.9%. The regression also indicates that the relationship between the *number of policies* employed and the composite total values of the indexed variables is significant ($p < .1$) with $p = .057$.

This provides evidence that policies developed to implement energy reductions and enhance sustainability are associated with higher total index measures. The analysis supports the notion that the composite measure along the selected dimensions has a weak but statistically significant relationship to the number of policies selected by Sunbelt cities. In addition, this model provides empirical evidence that there are various means of reducing energy usage and achieving the sustainability goals of cities.

In an effort to create a more functional and credible model, various combinations of the variables available were probed. The five dependent variables *alternative transportation, population density, homes heated by alternative fuels, days unhealthy and unhealthy for sensitive groups* and *household vehicles* resulted in the highest coefficient of determination that yielded a significant result. These five variables are used to provide a new, less cumbersome index score. This revised index provides a possible range of scores for each variable from 0.0 to 1.0 with a total possible range from a low score 0.0 to a high score of 5.0. All variables are equally weighted in this index to avoid any dominating influence by one or a set of variables. Using the total *number of policies* (ranging from 1-10) as the independent variable measuring policy adoption with the individual indexed values for the five variables (*alternative transportation, population density, homes heated by alternative fuels, days unhealthy and unhealthy for* *sensitive groups* and *household vehicles*) as variables that are indicators of energy use, this regression results in an R^2 of 40.3%. This suggests that the relationship between the independent variable and the values of the five remaining indexed variables is stronger than in the model offered in previous models due to the higher coefficient of determination. The result is also significant ($p < .1$) resulting in $p = .062$.

The strength of the statistical relationship among these variables has value. These quantitative variables can now be used as a tool from which to devise a sustainability index. The formula for *number of policies* that results is provided below:

number of policies = 3.5596 + (4.2471 X *alternative transportation*) + (8.6678 X *population density)* - (3.6771 X *homes heated by alternative fuels*) + (1.399 X *days unhealthy and unhealthy for sensitive groups*) – (3.6265 X *household vehicles*)

Ranking Sunbelt Cities

The major cities of the Sunbelt are growing both in size and population. They are individual and dynamic yet are experimenting with various policy agendas. This study provides an assessment using a focused set of policies that are being employed by Sunbelt cities. A few of the cities (e.g., Miami, San Diego and Los Angeles) are seriously concerned about energy and sustainability and are aggressively pursuing many policy solutions.

The majority of the selected Sunbelt cities are less concerned about energy and sustainability issues. As a result, their rates of policy adoption are more variable. In these cases, a city might direct its policies more toward transportation solutions than changes in residential designs. Many cities work closely with their local utilities while other cities have a less cordial or even adversarial relationship with their local utilities. Some cities pursue memberships in organizations with common goals while others are less participatory. There are also Sunbelt cities that have only recently adopted energy and sustainability policies. As a result, additional time may be required to yield more measurable results. For others cities (e.g., Virginia Beach, Oklahoma City and Charlotte), concerns about energy and sustainability do not appear to have become part of the public policy agenda. It is also possible that other effective policy agendas are being pursued that respond to the issues of energy and sustainability yet are not considered by this study.

Earlier a functional typology was proposed in which various types of policies could be categorized as energy management programs, transportation system policies, organizational memberships or those directly affecting the urban environment. These categories offer a definable set of functional indicators that are readily identifiable. This led to a clearer comprehension of how the selected policies focused on certain sustainability and energy concerns. The utility of the variables selected can be further demonstrated.

By reviewing the qualitative data, it is clear that programs are available to policies and that they are being used in Sunbelt cities to manage and reduce urban energy usage. Cities indeed have choices. While a variety of policies and programs are being implemented, some are more widely adopted than others. Many of these policies are intended to manage or reduce energy use in addition to meeting other related objectives. Table 6 summarizes the extent of application of the policies used by the select Sunbelt cities.

As Table 6 indicates, curbside recycling programs are nearly ubiquitous while membership is the ICLEI is comparatively rare. In Sunbelt cities, programs such as those that provide alternative energy options, expand high occupancy vehicle lanes and promote brownfield redevelopment are expanding, while utility sponsored rebate programs are in decline. Some policies, including city operated energy efficiency

Table 6. Rates of policy adoption.

Types of Policies N = 25	Cities with Policy	Cities Lacking Policy
Local government and utility policies		
Utility rebate programs	44%	56%
City operated energy efficiency programs	76%	24%
Local energy conservation programs	52%	48%
Local policy		
Sustainable development as a policy goal	56%	44%
High occupancy vehicle lanes	48%	52%
Participation in membership based organizations		
International Council for Local Environmental Initiatives	24%	76%
Clean Cities Program	76%	24%
Energy Star Partner	40%	60%
Environmental policies		
Curbside recycling program	96%	4%
Brownfield redevelopment program	76%	24%

programs, Energy Star partnerships and utility rebate programs were found to be more common in cities with larger populations than in the smaller cities. It is likely that more populous cities have larger staffs, expertise and resources to implement and support policies of these types.

It can be hypothesized that sustainable practices such as energy efficiency, energy conservation and alternative energy are likely to lead to greater urban sustainability. To assess this possibility a set of dependent variables was considered in relation to selected sets of independent variables. The results were determined to be mixed. There was no significant direct relationship discovered between the values of the dependent variables that measured the total per capita costs of energy. The analysis implies that the local policies of the largest Sunbelt cities are having no discernable or measurable impact on per capita aggregate measures of energy use and energy costs. For these two measures of energy use, this hypothesis is proved false when considered in regard to the selected set of independent variables and all sampled Sunbelt cities.

However, variables measuring disaggregated energy use for the transportation and residential sectors were each tested against subsets of the selected independent variables. Transportation energy usage was determined to be in part a function of the availability and use of alternative means of transportation to work, the amount of travel time to work, population density and the number of household vehicles. Residential energy use was found to be related to the percentage of homes that used alternative fuels for heating or did not require heating, the number of single occupancy households and the annual average number of cooling degree days. These relationships between the disaggregated dependent variables and the selected independent variables were determined to be statistically significant. For the two disaggregated measures of energy use, the hypothesis is proved true when considered in relationship with all sampled Sunbelt cities using the selected independent variables.

DEVELOPING A SUSTAINABILITY INDEX

A combined index can be devised from the qualitative policy scores and the composite index score using the five quantitative variables *alternative transportation, population density, homes heated by alternative fuels, days unhealthy and unhealthy for sensitive groups* and *household vehicles.* This new index has a possible range of 0.0 to 10.0 and will be referred to as the sustainability score. This is accomplished by multiplying the policy score by 50% (or dividing by 2) and adding the score to the combined index value of the five selected variables. The resulting sustainability score provides equal weight to both the policies in place and the results of the indexed variables. The following formula defines how a sustainability score for each city can be calculated using this methodology.

Sustainability Score = (*number of polices* X .5) + index value of *alternative transportation* + index value of *population density* + index value of *homes heated by alternative fuels* + index value of *days unhealthy and unhealthy for sensitive groups* + index value of *household vehicles*

As shown in the formula, sustainability score values represent the sum of the weighted policy score and the total of the index scores of the significant variables. Using this formula, cities can be ranked in order based on their calculated sustainability scores.

The sustainability score for the selected Sunbelt cities has a range from high of 9.16 for Miami to a low of 1.91 for Charlotte. Other cities that accompany Miami in the upper tier include Los Angeles, San Diego, Atlanta and Tucson. The mean sustainability score for the 25 cities is 4.9. Phoenix, with a score of 5.11, can be considered a typical Sunbelt city based on the sustainability score. Las Vegas has a sustainability score of 5.4 which is slightly higher than the mean of the sample. The values of index range for the 25 cities spans 72.5% of the available range. The mean weighted policy score of the 25 cities is 3.0 while the mean index score (using significant variables) is 1.9. This indicates that rates of policy adoption exceed the indexed values.

There are anomalies within the rankings. Miami and New Orleans are examples of Sunbelt cities with index scores that are higher than their corresponding policy adoption rates. This suggests that their policies have been relatively effective. Miami has the highest population density of the sampled cities, has fairly high rates of public transport use and the highest percentage of homes that are alternatively heated or require no heat. New Orleans has a low rate of policy adoption and the second highest index score among the selected Sunbelt cities. The high index score for New Orleans is due to high rates of alternative transport use and a low number of days with unhealthy air. In addition, New Orleans has the highest rate of households with no or only one vehicle among the selected Sunbelt cities.

On the other hand, San Diego is an example of a Sunbelt city with a high rate of policy adoption but a correspondingly low index score. This is due in part to low rates of alternatively heated homes (resulting in part from the warm climate). San Diego is a commuter city and has comparatively low rates of households with one or fewer vehicles.

Table 7 provides a summary of the policy scores, the summed index of significant variables scores for the five selected variables and the sustainability scores.

Despite the anomalies noted earlier, there are consistencies as well. Cities that have utility rebate programs, city operated energy

Table 7. Sustainability ranking of Sunbelt cities.

Sunbelt City	Policy Adoption Rate (A)	Weighted Policy Score (A*.5)	Selected Index Measures* (B)	Sustainability Score (A*.5)+B
Miami, Florida	9	4.5	4.66	9.16
Los Angeles, California	10	5.0	3.00	8.00
San Diego, California	10	5.0	1.77	6.77
Atlanta, Georgia	8	4.0	2.72	6.72
Tucson, Arizona	8	4.0	2.15	6.15
Long Beach, California	7	3.5	2.53	6.03
Austin, Texas	8	4.0	1.82	5.82
Houston Texas	8	4.0	1.51	5.51
Las Vegas, Nevada	7	3.5	1.90	5.40
San Antonio, Texas	7	3.5	1.82	5.32
Dallas, Texas	7	3.5	1.81	5.31
Albuquerque, New Mexico	7	3.5	1.73	5.23
Phoenix, Arizona	7	3.5	1.61	5.11
New Orleans, Louisiana	3	1.5	3.09	4.59
Tulsa, Oklahoma	5	2.5	1.66	4.16
Jacksonville, Florida	5	2.5	1.56	4.06
Fort Worth, Texas	5	2.5	1.37	3.87
Memphis, Tennessee	4	2.0	1.75	3.75
Mesa, Arizona	4	2.0	1.55	3.55
Nashville, Tennessee	4	2.0	1.21	3.21
Fresno, California	4	2.0	1.05	3.05
El Paso, Texas	3	1.5	1.46	2.96
Virginia Beach, Virginia	3	1.5	1.17	2.67
Oklahoma City, Oklahoma	2	1.0	1.36	2.36
Charlotte, North Carolina	1	0.5	1.41	1.91

efficiency programs and local programs to support energy conservation (Los Angeles, San Diego, Austin, Las Vegas and Houston) have an average sustainability score of 7.3, outpacing the average of the other twenty whose average sustainability score was 4.8. The four cities (New Orleans, Virginia Beach, Charlotte and Oklahoma City) that lack such programs have a much lower average sustainability score (2.9).

Cities that participate in related organizational activities are more successful at achieving measurable results than those that do not when measured against the selected indexed variables. Recall that the organizational activities selected were ICLEI membership, Clean Cities designation and engagement of the Energy Star^{TM} program. Those cities participating in all three organizations (Los Angeles, San Diego, Miami, Atlanta and Tucson) scored higher on both the average sustainability score (7.4) and the average index score (2.9). Cities that did not participate in any of these organizations (Jacksonville, Memphis, Nashville, New Orleans, Mesa and Charlotte) had lower average sustainability scores (3.4) and lower average index scores (1.8). It can be concluded that greater participation in organizational membership programs appears to be somehow associated with greater success at implementing these policies.

Comparing Characteristics of Groups of Cities

To further understand the differences between cities, the sampling of 25 Sunbelt cities are grouped into two exclusive categories based on their sustainability score. Group A includes thirteen (13) cities with a sustainability score > 5.0. This group includes Miami, Los Angeles, San Diego, Atlanta, Tucson, Long Beach, Austin, Houston, Las Vegas, San Antonio, Dallas, Albuquerque and Phoenix. Group B includes the twelve (12) remaining cities with a sustainability score < 5.0. Group B includes New Orleans, Tulsa, Fort Worth, Memphis, Jacksonville, Mesa, Nashville, Fresno, El Paso, Virginia Beach, Oklahoma City and Charlotte.

Cities in Group A are designated as Type A cities while cities in Group B are designated as Type B cities. Table 8 provides a compiled set of average values for the data comparing Type A cities to Type B cities. Type A cities are characterized as having higher sustainability scores that Type B cities which have characteristically lower sustainability scores.

Table 8. Data for groups of cities ranked by the Sustainability Index.

Indicator or variable	Unit of measure	Type A	Type B
Number of cities	Each	13	12
Policies adopted	range = 0-10	7.9	3.6
Index score	range = 0-5	2.2	1.6
Sustainability score	range = 0-10	6.2	3.3
Population	Each	1,064,376	518,994
Population density	per square Km	1,614	756
1990-2000 population	percent change	22.3	15.5
1990-2000 population density	percent change	9.0	9.0
Pop. change - pop. density	percent	13.1	6.4
Energy costs	$s per capita	2,589	2,740
Total energy use	Kj per capita	378.7	441.8
Residential energy use	Kj per capita	59.3	69.2
Transportation energy use	Kj per capita	111.8	119.2
Alternative heating fuels	percent	1.6	0.6
Single occupant households	percent	29.9	27.7
Cooling degree days	base = 65	2,488	2,273
Solar radiation in January	Langley	280	235
Travel time to work	Minutes	25.5	23.4
Use of alternative transportation	percent	11.7	7.9
Vehicles per household (0-1)	percent	53.8	49.6
Air quality	Index value	54.1	47.3
Days with unhealthy air	range = 0-365	31.9	24.7

Sources: United States Census Bureau (1999, 2000); Energy Information Administration (2000); United States Environmental Protection Agency http://www.epa.gov/airnow/index.html (2004); Mazria, E. (1979) *The passive solar energy book*; National Oceanic and Atmospheric Administration http://www.cpc.noaa.gov/products/analysis_monitoring/cdus/degree_days/.

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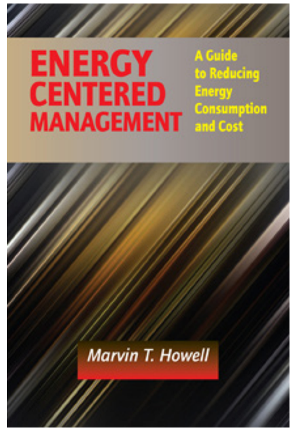

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Both Type A and Type B cities have similar rates of change in population density. However, this is where the commonalities seem to end. The data indicate that when the groups are compared to each other, Type A Sunbelt cities have a set of characteristics that are fundamentally different than Type B cities. Both the climate and geography differ. The summer climate of a typical Type A city is more severe (meaning hotter) and the winters are sunnier than Type B cities. Cities in California are more likely to be Type A cities while those in Oklahoma and Tennessee are more likely to be Type B cities.

Considering demographic measures, Type A cities are more than twice as large as Type B cities in average population. As a result, Type A cities are more likely to be regional centers of commerce and politically more powerful. Type A cities are more than twice as likely to be their state capitals as Type B cities. Rates of population growth for Type A cities are roughly 50% higher than Type B cities. The population density of a typical Type A city is 2.1 times as great as a Type B city. Suburban development is outpacing increases in population density in both types of cities but suburbanization is occurring at a faster rate in Type A cities than in Type B cities.

Type A cities not only have larger populations and faster population growth rates, they also have higher rates of policy adoption. While levels of commitment to sustainability vary, these cities are not moving from crisis to crisis in their approaches, but instead they appear to be developing and implementing broadly based and flexible policy strategies.

Type A cities have the administrative infrastructure in place which provides them the opportunity to implement a broader range of policies than deployed by Type B cities. In regard to the ten policies considered in this study, the larger cities have a greater propensity to adopt polices. In fact, Type A cities have adopted an average of 7.9 policies while Type B cities have adopted an average of only 3.3 policies.

Type A cities are more likely to have locally sponsored energy saving programs, have their utilities engaged and be pursuing energy conservation programs in city owned buildings. By a wide margin, Type A cities are more likely to have established sustainability goals and be Energy Star™ partners. Interestingly, all cities in the sample that are ICLEI members are Type A cities. All cities in the sample that have not adopted Clean Cities plans or brownfield redevelopment programs are Type B cities. Type B cities are more selective in the policies they choose and are more likely to implement those that require fewer resources to implement. The only city that has not implemented curbside recycling (El Paso) is a Type B city. Charlotte, Virginia Beach and Oklahoma City are Type B cities and none have documented utility sponsored rebate programs, established policies for city buildings or locally supported energy conservation programs.

Though overall rates are low for all Sunbelt cities, homes in Type A cities are 2.5 times more likely to be heated by alternative fuels. They have slightly higher percentage of single occupancy households. Residents of Type A cities are 48% more likely to use alternative forms of transportation to get to work or work at home than their Type B city counterparts. Type A cities have fewer households with two or more vehicles. Type A cities, such as Las Vegas, San Diego and Atlanta are more likely than Type B cities to have light rail or monorail services. However, residents of Type A cities spend a couple of minutes longer on the daily commute to work. Despite their higher use of public transport, Type A cities have more problems maintaining air quality. They experience an average of seven additional days annually when the air quality can be categorized as unhealthy or unhealthy for sensitive groups than Type B cities.

Residents of Type B cities spend almost 6% more dollars annually on energy than residents of Type A cities. Germane to this study are the rates of actual energy consumption. Type A cities are simply more energy efficient. When measured on a per capita basis, Type B cities consume 17% more total energy, 17% more transportation sector energy and almost 7% more residential sector energy than Type A cities.

In regard to rates of policy adoption only four cities, Miami (Type A), Oklahoma City (Type B), Charlotte (Type B) and New Orleans (Type B), have policy adoption rates that are less than their index scores. The rest of the cities have policy scores that are greater than total index scores. Recall that New Orleans is pursuing an aggressive strategy to reduce energy use in city government facilities as a means of implementing an urban policy agenda focused on reducing the impact of global warming.

Type A cities Miami and Los Angeles are leading the pack based on their sustainability scores. Their high rates of policy adoption are coupled with high index scores. These two cities are "talking the talk" and "walking the walk." These cities are investing money, time and administrative equity in an effort to bridge the gap between policies and their results. These cities are arguably focused not simply on the policies themselves but also on how policies can be successfully implemented to achieve the broadest impact.

Other Type A cities, like Austin, Houston and San Diego have high rates of policy adoption with correspondingly low index of significant variables scores. It is unlikely that the policies of these cities are succeeding in decreasing energy usage and improving sustainability. One interpretation is that these cities may indeed have policies in place but are "talking the talk" and not "walking the walk." Some of the policies in these cities appear to be nominal, possibly inadequately funded but certainly not providing acceptable results. In fairness, it is also possible that the adopted policies for these cities have not yet had adequate time to make a noticeable impact when measured by the narrowly selected policies and indicators used in this study. The Type B version of this approach is offered by cities like Jacksonville and Fort Worth who publicly "talk the talk" and whose rates of policy adoption within their group are above average, yet have correspondingly below average index scores. Perhaps there are other measures against which their efforts can be measured. For cities such as Tulsa and Mesa, it will be shown that they are actually decreasing actual aggregate energy use.

Type B cities such as Virginia Beach, Oklahoma City and Charlotte have low rates of policy adoption and correspondingly low index scores. These cities are neither "talking the talk" nor "walking the walk." They are out of step with the crowd, heading in another direction, pursuing other agendas, or perhaps focused on policies and solutions beyond the scope of this study.

THEORY OF DIVERGENCE

It is also possible to hypothesize that for some of the sampled cities, policies supporting sustainability and measures of urban energy consumption are on divergent paths. A divergence would be indicated by high rates of policy adoption with the intent of reducing energy consumption combined with observable increases in aggregate energy consumption. If a divergence exists, are the policies and programs sufficient to find empirical evidence of reductions in aggregate measures of energy use?

Considering the two types of cities, one with high policy adoption rates (Type A) and the other with much lower policy adoption rates (Type B), does the data further support a divergence theory? The estimates for per capita city energy use can be calculated by using the data that included city population, state population and per capita energy use for the years 1990 and 2000. The formulas used for estimating values for per capita city energy use and total city energy use are as follows:

Per capita city energy use = Total city population + Total population of state X per capita state energy use

Total city energy use = Per capita city energy use X Total city population

From these, detailed estimates of per capita energy usage for all cities in the years 1990 and 2000 can be tabulated. The tabular results based on this formula indicate:

- In 2000, the average estimated energy use of a typical Type A city (N=13) is 432,400 billion kilojoules per year while the Type B cities (N=12) use an average of 224,500 billion kilojoules per year.

- From 1990 to 2000, per capita energy usage declined in 92% of the Type A cities and in 75% of the Type B cities. For this period, per capita energy usage has declined by an average of 2.4% in Type A cities and by an average of 4.3% in Type B cities.

- From 1990 to 2000, total city energy usage increased by an average of 53,000 billion kilojoules for Type A cities and increased by almost 20,000 billion kilojoules for Type B cities. From 1990 to 2000, total city energy use has increased by 20.4% in Type A cities and by 10.0% in Type B cities.

Cities adopt more policies and the policies are having an impact as evidenced by the declines in per capita energy consumption. Less energy is being used on a prorated per capita basis by city residents. It can be asserted that due to improvements in equipment, processes and infrastructure, energy efficiency based on per capita measures has improved in 21 of the 25 (84%). The reductions in energy use are of a magnitude that impact sustainability by decreasing energy use. While other factors are not being controlled, the evidence is incontrovertible. The broader policies that cities employ in their sum are having an impact. If policies were not in place, energy use on a per capita basis would continue to be increasing. Cities can impact sustainability based on per capita measures. They are likely most successful when employing policies that have a direct impact on disaggregated measures of energy use while only indirectly impacting aggregate measures.

Both Type A and Type B cities decreased energy use by fractional annual rates from 1990 to 2000 with Type B cities decreasing energy use more rapidly. Of the 25 cities, all but four cities experienced declines in per capita energy usage from 1990 to 2000. Of the four with increasing per capita energy usage (Tucson, New Orleans, Virginia Beach and Charlotte), Tucson is the only Type A city among these.

However, despite the broader deployment of policies designed to impact energy use, total energy use continues to increase substantially. These data firmly support our hypothesis that proposed that there is a divergence between policies and aggregate measures of energy use. In fact, Type A cities, the group with the highest rates of policy adoption, have greater average increases in energy usage than the Type B cities which tend to have lower rates of policy adoption. There are examples within the groups that are illustrative. Tucson, a Type A city with a high rate of policy adoption, has the largest rate of increase in estimated per capita energy usage from 1990 to 2000 and the second highest increase in total energy use among the 25 selected cities. It might be inferred that Tucson is among those cities that has perceived a set of problems and is rapidly putting programs into place in an effort to resolve them.

Among the 25 cities only two appear to have declining actual energy use. Both are Type B cities. Mesa has an average rate of policy adoption among Type B cities yet achieves the largest percentage decline in per capita energy use of the sampled cities. Tulsa has an above average rate of policy adoption among Type B cities and achieves a slight percentage decline in per capita energy use

If average per capita energy use is declining and population densification is occurring among the selected Sunbelt cities, then why does total energy use continue to increase? Are there any additional relationships and results that can be gleaned from the data? Development subsidies to provide incentives for suburbanization are a set of policies that have been touted as one of the solutions to population growth for cities. Populations are accommodated by development on the urban periphery. How are these policies related to the resulting energy use of cities? First, one must accept the notion that most all Sunbelt cities in this study have experienced new suburban development in some form between

1990 and 2000. Increases in population density, can be assumed to rely primarily on existing infrastructure. When suburbanization occurs, new construction at the perimeter of the city is typically at lower population densities. While suburbs vary in density, let's assume that on the average, the patterns of population densities in new developments across the sample of Sunbelt cities are likely to be relatively constant. This notion is supported by Newman and Kenworthy [23] who believe that "These identical, mechanical suburbs are becoming universal" and become a sprawling "monotonous megalopolis." If suburbs are nearly identical across cities, the resulting total energy usage due to suburbanization is likely to be of a similar magnitude.

Considering the varying influences of climate on energy, buildings in some cities may require more energy for heating and less for cooling while others may require less energy for heating and more for cooling. As a result, energy usage not accounted for by changes in density will result from factors that are related to new development. For ease of discussion, these changes will be called suburbanization. If true, average changes in suburban energy use will be relatively constant across cities regardless of whether or not a city is a Type A city or a Type B city. Recall that the grouping of these cities into types resulted from rates of policy adoption and indexed values of selected variables and not from unexplored variables such as lot size, size of new residences or measures of infrastructure improvements. The following formula tests this relationship for the period from 1990 to 2000.

α = change in Type A city energy use due to suburbanization as a proportion of total change in energy use from 1990 to 2000

ϕ = change in Type B city energy use due to suburbanization as a proportion of total change in energy use from 1990 to 2000

n_α = 13, sample size for Type A cities

n_ϕ =12, sample size for Type B cities

$$\alpha = \frac{[(\sum \%\triangle\text{Type A population} \div n_\alpha) - (\sum \%\triangle\text{Type A population density} \div n_\alpha)]}{\sum \%\triangle\text{Type A Energy Use} \div n_\alpha}$$

$$\alpha = (22.29\% - 9.04\%) \div 20.40\% = .6495$$

$$\phi = \frac{[(\sum \%\triangle\text{Type B population} \div n_\phi) - (\sum \%\triangle\text{Type B population density} \div n_\phi)]}{\sum \%\triangle\text{Type B Energy Use} \div n_\phi}$$

$$\phi = (15.52\% - 8.96\%) \div 10.03\% = .6540$$

$$\therefore \alpha \cong \phi$$

The fact that the calculated ratios for both groups of cities are nearly equal is of importance. The findings support suburbanization as a form of development that has a similar impact on urban energy use regardless of policies, measures of energy use or city type. These equations estimate the relative contribution of suburbanization to increases in the total energy usage of Sunbelt cities. As indicated from the formulas, suburban development is responsible for a substantial portion of the increasing energy use in cities, more than offsetting the declines in energy use resulting from energy savings practices, policies and programs that in sum have tended to reduce energy usage.

The analysis not only finds a divergence between policy adoption rates and increases in energy use but also identifies suburbanization as a probable cause of the divergence. The increases in energy use, likely due to suburbanization, are having a dampening effect on sustainability in cities by contributing to increases in urban energy use.

SUMMARY AND CONCLUSIONS

In this article, the dependent variable that measures aggregate energy costs (E_C) was considered against an array of variables across a selection of 25 Sunbelt cities. Each of the measures of energy use were defined and described at length. The values of these variables were provided in tabulated formats. A series of analyses were performed using ordinary least squares regression and analysis of variance. Raw values for variables were used in each regression. The results of the regressions on per capita energy costs (E_C) indicated that no statistically significant relationships were identified between this aggregate measure and the selected independent variables. The results were interpreted as an indication that local policies directed toward influencing aggregate energy costs are likely to be ineffective.

The regressions for the dependent variables transportation sector energy use (E_T) and residential sector energy use (E_R) are more enlightening. The measures of transportation sector energy use was determined to have a significant relationship to variables such as the number of vehicles per household, the percentage of those using alternative transportation to get to work, travel time to work and population density. The analysis suggests that ways of reducing energy usage include reducing the number of vehicles per household, supporting programs that provide alternative means of getting to and from work, impacting travel time to work and increasing population density. These types of solutions may be feasible if local planning and transportation system policies are modified.

The measures of residential sector energy usage were found to have a stronger and significant relationship to the variables alternative or no fuels for heating, percentage of single occupant households, and cooling degree days. The analysis suggests that ways to reduce residential energy use include increasing the number of homes using alternative fuels for heat and decreasing the number of single occupant households. This analysis supports the concept of decreasing the impact of extreme climates on residences. Possibilities include locating residences in areas with less severe climates or providing improved residential design to control for temperature extremes (e.g., providing controls or building envelope improvements such as insulation) thus reducing residential energy usage. This means that cities need to be more selective in selecting site locations for their facilities and more creative in how their buildings are planned and designed.

The results of the analysis were interpreted as an indication that local policies directed toward influencing transportation or residential sector energy usage are likely to be effective and yield fruitful results if the policies are directed toward selected measures.

This article compared the information gained from the qualitative investigation of policies to the analysis of the quantitative data. An analysis was presented providing insight into the relationships of policy adoption in Sunbelt cities. For example, it was found that there exists a statistically significant relationship between rates of policy adoption and indexed measures of energy use. A statistical analysis was used to select five quantitative variables that were used in the sustainability index. Derived from the analysis, a sustainability index was devised to rank cities based on energy related indicators of sustainability by using both qualitative and quantitative data.

Sunbelt cities were divided into two distinctive groups based on rates of policy adoption and selected variables. Commonalities and differences between groups were discussed. Cities were designated as either Type A or Type B cities. The groups of cities were determined to have fundamental differences. Type A cities have larger populations, greater population densities and higher rates of policy adoption than Type B cities. Both Type A and Type B cities are reducing their per capita rates of energy consumption. Per capita rates of energy use are declining more rapidly in Type B cities despite the fact that Type B cities have lower rates of policy adoption. Regardless, total urban energy consumption continues to increase in both Type A and Type B cities. Energy use is increasing more rapidly in Type A cities than in Type B cities.

An analysis of the data comparing Type A cities to Type B cities revealed that there is a common value that represents the increase in energy use due to new development, which was labeled suburbanization. Policies that promote suburban development were found to be offsetting energy reductions achieved by policies that cities have deployed to reduce urban energy use. The analysis discovered a divergence between policy adoption rates and increases in energy use but also identifies suburbanization as a probable cause of the divergence. The increases in energy use, likely due to suburbanization, are having a dampening effect on sustainability in cities by contributing to increases in urban energy use.

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