**Transportation Behavior and Energy use Across Settlement and Population Groups   
– a Typology (Draft for internal use)**

*Patricia Romero-Lankao*

1. **Rationale and goal**

A solid body of literature has examined energy use and associated emissions in urban areas []. However, many of the studies are based on one or a handful of case studies and on the use of different inventory approaches (Table 1 Annex). Scholars are faced with lack of consistent and comprehensive data to measure, in particular, the increasing importance of emerging technologies. Here, we suggest a typology to identify clusters of features and drivers of emergent behavior in transportation and associated energy use and emissions across settlement types and socioeconomic status groups.

1. **Attributes and drivers**

Multiple and interacting attributes and drivers have been found to explain differences in energy and GHG emissions within and across populations and settlement types from core to rural areas [refs]. Here we present a summary of these, while section 3 and Table 2 provide detail on selected indicators.

*Sociodemographic:* Age has key implications for energy use and associated GHG emissions [J E Cohen, 2010]. Household activity levels vary over a person’s lifetime, and mobility patterns and energy consumption adjust to changing household needs, time use, and expectations. Household composition and size also have a signiﬁcant inﬂuence. Generally speaking, larger households have relatively lower energy use because of efficiency and economy of scale benefits [Brantley Liddle, 2004; Pachauri, 2004]. More persons, in particular more children per household, relate to lower per capita consumption, even under comparable per capita incomes (Lenzen, 1998a; Wier et al., 2001; Lenzen et al., 2006). Studies also find that at similar income levels, education, and ethnicity/race also play a role explaining energy consumption (Marcotullio et al 2014).

*Economic:* The majority of research has found that wealth and income lead to increased energy use [Kahn, 2009; Romero-Lankao et al 2009; Weisz and Steinberger, 2010]. However, diverse and inconclusive findings exist on the potential for non-linear relationships and interaction effects. For instance, differences in income have a weak influence on direct energy requirements, while indirect energy requirements increase strongly with income (Reinders et al., 2003; Lenzen et al., 2004; Moll et al., 2005).

*Techno-infrastructural or urban form* are the settlement type factors directly connected to mobility and energy use; they include indicators such as density, land use, and the layout of transportation infrastructure and technologies (road, rail, EV). The “physical infrastructure of a particular neighborhood could be one key determinant of lifestyle-related emissions that could also act as a barrier to lifestyle change” (Baiocchi et al., 2010).

It has been found that suburban and rural households are about 10% more energy intense than urban ones, mostly because they spend more on residential energy use and mobility requirements (Lenzen, 1998a, Munksgaard et al., 2005). At the same time, core urban households tend to have relatively higher levels of total energy requirements, largely due to their overall higher incomes (Lenzen, 1998a; Wier et al., 2001; Lenzen et al., 2004). Shammin et al 2010 found for instance that, as expenditure increases, the contribution of direct energy to total energy requirements decreases, and for the highest income decile more than 50% of total energy is attributable to indirect energy categories.

*Environmental* factors such as climatic conditions and carbon content of energy sources are equally important. For instance, close relationship between climatic inﬂuences and residential energy requirements for thermal comfort has been documented (Kennedy et al., 2009; Wang et al., 2010). (Develop)

*Governance*: Zoning regulations, land use plans, investments and policies, lead to a heterogeneous distribution of access to energy, land and transportation infrastructure both across settlements and populations [Stone Jr. 2009; Bulkeley 2013]. For instance, the percentage of public transportation, an indicator of governance, is significant and negatively inelastic for energy use by the sector (for example, a 1% increase in public transportation use would lead to a decrease in CO emissions by 0.48%, with other factors held constant). For transportation to command a dominant share of traveling it needs to reliable, comfortable, and safe, thus a proof of good governance. Still, notwithstanding being unreliable, uncomfortable, or unsafe, transportation can be the only option for poor populations.

1. **Methods and data**

Data: Besides data on energy use, we will gather data assess the influence of five of factors: socio-demographic, economic, techno-infrastructural, *e*nvironmental and governance (SET*E*G)[]. Information on sociodemographic and economic indicators such as gender, education, ethnicity, income and house tenure are from the U.S. Census and American Community Survey (IPUMS-NHGIS). Urban form and governance indicators are from both IPUMS-NHGIS and the Center for Neighborhood Technology’s Housing and + Transportation Affordability Index (CNTH+T Index). Impact indicators are from CNTH+T and from the Low-Income Energy Affordability Data (LEAD) Tool. Index Heating and cooling degree days were obtained from NOAA as a proxy for weather and climate conditions for 2016 (See Table 2).

Our goal is for most variables to be in natural logarithmic form. Variables that cannot be interpreted in logarithmic form will be coded as dummy variables.

Methods: We will:

1. Build on existing literature and our prior work [], to create indicators describing the multidimensional SET*E*G factors associated with differences in transportation behaviors, and energy use.
2. Conduct a standard multiple regression approach with log-transformed variables as described in standard applied regression literature.
3. Conduct either threshold regression or hierarchical cluster analyses. We might start with a focus on transportation and then move to buildings and resilience in FY2020.
4. Group settlements and populations into high, medium and low energy use clusters. We will run tests for spatial autocorrelation to measure the geographic clustering of each of the input indicators.

**Table 1: comparison between the top-down regional approach and the bottom-up IO analysis methods in relation to urban energy assessment**

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| --- | --- | --- | --- | --- |
| Starting point | Items covered | Items not covered | What does the result reveal? | Suitable for |
| *Top-down regional, production approach* | Residential operational energy  Ground transportation energy (sometimes also air and maritime)  Direct energy consumption by industries within boundary | Embodied energy in service and goods  Upstream energy consumed for the extraction  Conversion and transportation of energy to region. | Per capita direct energy requirements for sustaining households, public administration and industry | Quantifying ongoing direct energy demand of the city  Policy and management of economic structure and energy efﬁciency of the city |
| *Bottom-up  Input–Output, consumption approach* | Household residential operational  energy  Household ground transportation, including public transit  Energy embodied in household consumption goods | Industrial and administrative energy use within the city, other than that covered by the goods and services consumed by households. | Per capita total direct and embodied energy requirements for sustaining the lifestyle of urban households | Understanding total energy demand, including those embodied in goods, of household consumption  Quantifying the total energy footprint and impact of households  Policy and measures for behavioral and macro- economic change for sustainability |

Bainez et al. 2013

Table 2: Indicators

