The Role Of VGI In Modeling Future Energy Demand

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1. Introduction

Modeling changes in future urban energy demand requires data on how and where energy is consumed. Urban energy consumption is strongly dependant on (1) urban form [Ewing, R. and Rong F., 2008][1], (2) consumer behaviour and economic activity [Diamond, R. (2003)][2] and (3) response to external environment [Hadley, S. et. al (2006)][3]. Data on (1) and (2) is usually collected using survey data while environmental factors are observations recorded at weather stations, of which there are ~3500 across the country, or modeled using numerical models. Over the next century, climate change is projected to affect urban energy demand in two ways: A) an average warming across the country will reduce heating requirements and increase cooling loads and B) increase in extreme weather events like heat waves and very high precipitation will put a strain on the energy infrastructure [*US Climate Change Science Program, Synthesis and Assessment Product 4.5, Feb 2008*]. Thus, it might seem that decreases in heating requirements cancel out the increases in electricity use for the energy system as a whole but the effects are not yet completely clear due to modeling deficiencies and uncertainty. A good summary of the underlying science can be found in M. Isaac (2008)[4]. Moreover, due to the high frequency forcing resulting out of an increase in extreme events like heat waves, analyses must be carried out at high spatial and temporal resolution. Therefore, there is a need for an integrated risk assessment of the energy supply infrastructure, an approach taking into account changes in urban form and composition and its response to the changing climate. Such an approach requires integrating the fields of social science, economics and climate science and we propose that a geoinformatics centered workflow is the best way to integrate such vastly different fields of study.

2. Methodology

Urban areas are composed mainly of three sectors - residential, commercial and industrial, of which residential and commercial sectors will be the ones affected by climate change since a major part of their energy consumption is for space conditioning and lighting. A large amount of spatial heterogeneity is seen in the energy consumption for space heating and lighting across the US, of which the Residential Energy Consumption Survey (RECS) and Commercial Building Energy Consumption Survey (CBECS) prepared by the DOE are good, albeit fairly coarse, indicators. Most of the studies done on the evolution of climate change induced energy demand in the United States have been performed either at the building level or for the nine US Census Regions a summary of which can be found in the US Synthesis and Assessment Product 4.5. The study by J. Huang (2006)[5] is by far the most comprehensive study on

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[1] Ewing, R. (n.d.). The Impact of Urban Form on U . S . Residential Energy Use. *Housing Policy Debate*, *19*(1), 1-30.

[2] Diamond, R. (2003). A lifestyle-based scenario for US buildings: implications for energy use. *Energy Policy*, *31*(12), 1205-1211.

[3] Hadley, S. W., Iii, D. J., Hernandez, J. L., Broniak, C. T., & Blasing, T. J. (2006). Responses of energy use to climate change : A climate modeling study. *Geophysical Research Letters*, *33*, 1-4.

[4] Isaac, M., & Vanvuuren, D. (2009). Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. *Energy Policy*, *37*(2), 507-521.

[5] Huang, J. (2006). The impact of climate change on the energy use of the US residential and commercial building sectors. LBNL-60754

this topic, which uses a prototypical building stock created for each of the nine US Census Regions, based on which building energy simulations are run for each climate location. What can be concluded from these studies - and what we identify as an opportunity for VGI to come in - is the lack of sufficiently disaggregated, high resolution data on building characteristics, householder demographics and urban form in the public domain. The former is required to effectively run building energy models (EnergyPlus Documentation, DOE, 2008) while the latter is necessary to inform future urbanization scenarios. Results from a regional climate model can then be coupled with this data to create a holistic framework for an integrated assessment model.

We propose a Web 2.0 based system where citizens are incentivized to provide their energy consumption habits through an intuitively designed web interface that will dynamically put together their hourly energy use as it evolves over the entire year. They will also provide information on their dwelling characteristics and its immediate surroundings. Thus an aggregate picture of the urban form can be assembled. All of this information can be further fed to a GIS (using OGC standards and open GIS technologies to ensure interoperability) to create an urban form map based on citizen input. Thus prototypical buildings as in Huang (2006) will be "built" in the form of a gridded urban form map, which will drive the building energy model at a high spatial and temporal resolution. Thus, data needed to run the building model will now be available at a much higher detail than current data sources mentioned in the previous section. We plan to use data generated from the Vulcan (www.purdue.edu/eas/carbon/vulcan/) and Hestia (www.purdue.edu/climate/hestia/) projects as one form of quality control on the data coming in from the VGI framework and that generated from the building simulations, in addition to the actual energy consumption data obtained from the citizens. Our approach therefore melds two quite different methodologies A) a bottom up engineering model and B) a top down econometric approach via a geoinformatics based system.

3. Conclusion

The framework that we propose is one which sets the stage for a new, integrative research direction drawing on collaboration from the fields of climate science, GIS/geoinformatics and socio-economics. It raises the following important and exciting research questions:

(1) the need for a geospatial data structure/data standard for compiling integrated climate/weather and energy use data (2) the need to develop a geoinformatics framework to couple climate/weather models (or their data) to land use simulation models and engineering building models (3) design of a web based data collection, mapping and authentication system (4) creating an effective incentive generation scheme to ensure large scale citizen participation and (5) design of an uncertainty analysis methodology for incoming data.

Answering these questions would require a collaborative effort from scientists and thinkers from these diverse fields and would benefit from the platform that the workshop will provide.