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Modeling the Effects of Appliance Standards through Geographic Analysis

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ABSTRACT

The U.S. federal government sets minimum energy efficiency standards for many commonly used household appliances. GIS has served as the ideal tool for aiding in the analysis and visualization of geographic patterns related to energy use in the United States. By overlaying climate, energy consumption, appliance use, economic and demographic data in ArcView, researchers at Lawrence Berkeley National Laboratory have been able to model the effects of proposed national appliance standards on the population. The creation of standards is a closely scrutinized process with many stakeholders, so the ability to analyze and present predictions for subpopulations geographically provides useful intermediate results to process participants.

OVERVIEW

U.S. homeowners spend over $110 billion annually to power home appliances, including refrigerators, freezers, water heaters, furnaces, air conditioners and lights (NREL 1995). Such appliances account for nearly 70% of all the primary energy consumed in homes (NREL 1995). Although many consumers do not consider energy efficiency when making these purchases, operating costs may exceed the initial purchase prices several times over. Manufacturers, however, have little incentive to invest in efficient technology that may be slow to be adopted in a highly competitive market.

To encourage energy savings and standardize state-level regulations, the federal government sets minimum energy efficiency standards for many commonly used household appliances. The Energy Analysis Department at Lawrence Berkeley National Laboratory assists the U.S. Department of Energy in conducting engineering, economic and environmental analyses in the development of these standards. These activities include environmental and economic cost-benefit assessments for consumers, manufacturers, utility companies and the nation. GIS serves a valuable role in the standards-setting process, aiding in the visualization of both geographic patterns related to energy use in the United States and the predicted effects of standards on regional populations.

BACKGROUND

The Department was first authorized by Congress in 1978 to set mandatory energy efficiency standards for 13 household appliances and products under the National Energy Policy and Conservation Act (NEPCA). The standards were to achieve the maximum improvement in energy efficiency that is "technologically feasible and economically justified." The NEPCA was amended in 1987 by the National Appliance Energy Conservation Act (NAECA), which set the first national efficiency standards for home appliances, as well as created a schedule for regular updates. The Energy Policy Act of 1992 (EPAct) expanded the coverage of these efficiency standards to certain commercial and industrial equipment. EPAct also established maximum water flow-rate requirements for specific plumbing products.

Table 1 shows the appliances with legislated energy-efficiency standards (by EPCA and subsequent legislation). These standards are expected to save about 24 EJ of source energy from 1993 to 2015 (NREL 1995). Already consumers have saved $1.9 billion in energy costs, and over the lifetimes of the products (installed between 1990 and 2015) consumer savings will reach $58 billion (NREL 1995). In addition, environmental benefits result from reduced atmospheric emissions of carbon, NOx and other pollutants associated with energy production.

Table 1. Energy-efficiency Standards Promulgated by Law

Refrigerators, refrigerator-freezers, freezers	Water heaters
Room air-conditions	Furnaces
Central air-conditioners and heat pumps	Dishwashers
Direct heating equipment	Clothes washers
Fluorescent lamp ballasts	Clothes Dryers
Kitchen ranges and ovens	Pool heaters

Currently under revision are the standards for fluorescent lamp ballasts, clothes washers, water heaters, and central air conditioners and heat pumps. These rulemakings are following a more informal, consensus-based approach designed to expedite the standard-setting process. Representatives from manufacturers, trade associations, utilities, state energy offices and environmental organizations meet voluntarily to negotiate and review proposed energy-efficiency standards.

GEOGRAPHIC ANALYSIS

As a tool for this consensus-driven approach, GIS is used to model the effects of proposed standards on subpopulations in the U.S. Berkeley Lab has compiled detailed information about key factors affecting energy consumption, such as appliance type and ownership, demographic variables, climate (Figure 1), energy consumption, fuel mix and energy prices, from a variety of sources and with various resolutions and geographic boundaries, as described in Table 2. These data are overlaid and maps are developed that display the regional patterns of household life-cycle cost and energy savings for different demographic segments. In this way researchers are able to assess the effect of standards on various groups, differentiated by such factors as income, age and location.

Table 2. Data Types, Sources and Geographic Resolution

Data Type	Source	Resolution
Fuel prices	NEMS	National
Technology cost/efficiency	LBNL analysis	National
Household characteristics	RECS	Census division
Appliance equipment/ownership	RECS	Census division
Building construction/retirement	RECS	Census division
Energy load data	MAISY	State
Climate characteristics	NOAA	PEAR
Population demographics	Census Bureau	County
Business Pattern Data	Census Bureau	County
Public Use Microdata Sample	Census Bureau	City/Place
Consumer energy prices	LBNL survey	Utility service territory
Gas and electric service areas	OnTarget, Inc.	Utility service territory

The household data used for this analysis is primarily from the Residential Energy Consumption Survey (RECS) conducted by the Energy Information Administration (EIA) of the U.S. Department of Energy. This survey provides detailed information on characteristics related to household energy use, including number of people, age, income, appliances, building age and types of fuel used. The location of these households is only specified by census division; however, RECS does provide average annual heating degree days (HDD) and cooling degree days (CDD) for each survey point. Berkeley Lab used the climate data in the RECS database to assign each of the households a more precise physical location. The country was divided into 42 climate zones, each typified by a single city's HDD/CDD ratio (Figure 1). The climate data for these cities were collected from weather stations by the National Oceanic and Atmospheric Administration (NOAA). Households were then assigned to a climate zone based on HDD and CDD relative to 65˚F for the year 1993. Patterns in energy consumption and the life-cycle cost of the standards are then aggregated and mapped based on these climate zones.

Figures 2 and 3 show examples of RECS data that were used in the analysis. These maps illustrate patterns for daily hot water usage per capita as well as the average setpoint for water heaters at residences. As is evident from these maps, water usage is higher in the warmer, southern regions, while the average temperature to which water is heated for household use is higher in cooler, northern regions. Consumer characteristics from RECS such as these are combined with engineering analysis to determine the life-cycle cost of a baseline water heater (Figure 4). This baseline is then compared to the life cycle-cost of a water heater under several proposed energy-efficiency standards. GIS

Figure 1. Climate Zones and Their Representative Cities

helps illustrate the effect of these proposed efficiency standards based on regional variation as well as demographic and other relevant factors (Figure 5). In the example in Figure 5, the difference in life-cycle cost (from the baseline) for proposed standards 2 and 3 is shown in the two maps on the left. In this instance, proposed standard 2 results in more significant savings over the life of the appliance and the savings are more evenly distributed regionally, as compared to proposed standard 3. In the maps on the right in Figure 5, the effect of these same two proposed standards is shown for low-income households. Once again, proposed standard 2 is expected to yield greater, more uniform savings than proposed standard 3, as well as greater savings for low-income as compared to average households.

Similar analyses are conducted for other proposed water heater standards, other demographic categories, and other appliances. GIS has enabled researchers at Berkeley Lab to examine the effects of proposed standards on subgroups and by region, and serves as a valuable tool for presenting intermediate results to stakeholders and policy-makers during the standards-setting process.

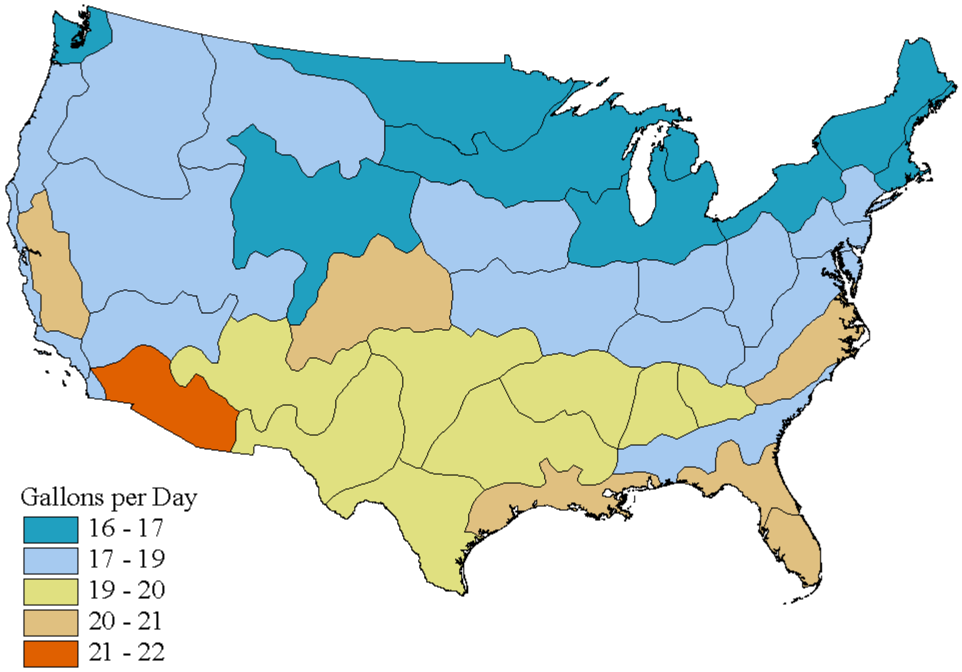

Figure 2. Daily Hot Water Draw per Capita

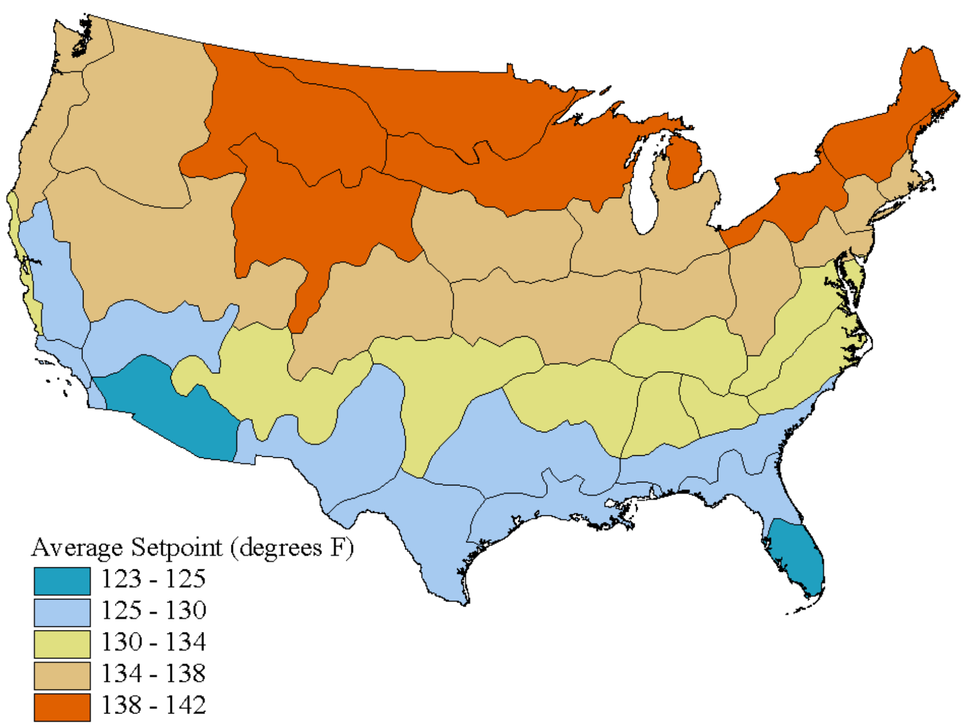

Figure 3. Average Water Heater Setpoint

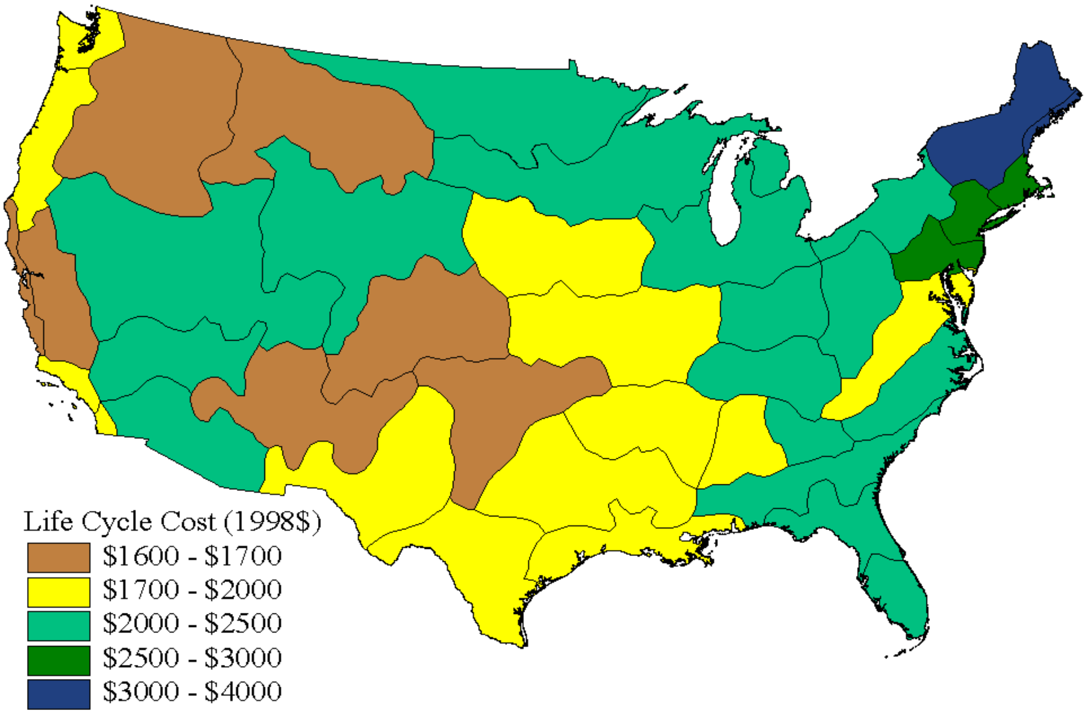

Figure 4. Average Appliance Life-cycle Cost

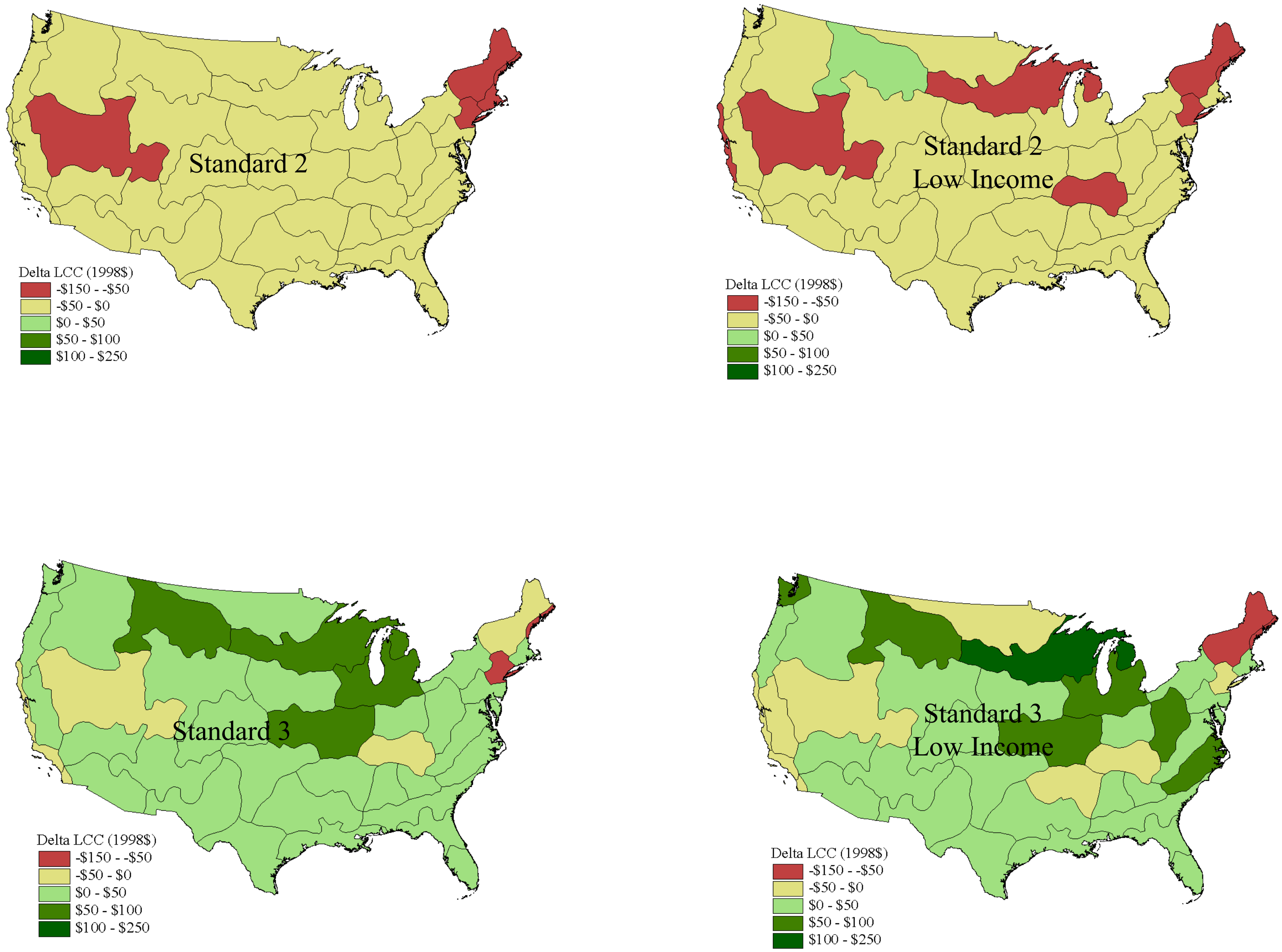

Figure 5. Proposed Standards Life-cycle Cost (Difference from Reference)

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