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Energy efficiency: The bird's-eye view☆

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ABSTRACT

If energy efficiency policy works, it should be possible to detect its effect on aggregate demand. The article integrates ideas from conventional methods for forecasting electricity demand to build a model to investigate the relationship between per person electricity use and energy efficiency policies. The model is then estimated with historical data on 50 states and the District of Columbia to evaluate the effect of publicly funded energy efficiency.

1. Introduction

In what has come to be known as the "Rosenfeld effect"—in deference to Arthur Rosenfeld, the University of California, Berkeley's physicist and influential member of the California Energy Commission – California's per-person electricity use has remained relatively steady since the mid-1970s, despite the proliferation of electricity-using devices. Meanwhile, the rest of the nation's electricity usage has risen. Today, California consumes nearly 40% less electricity per person than the national average.

Arthur (Art) Rosenfeld is widely known as a founding father of the energy efficiency movement. He earned that title for his many scientific contributions, especially in developing the now widespread energy efficiency performance standards for appliances and buildings. He also helped advance energy efficiency by conceiving a logical policy framework, built on economic and engineering principles, thus pioneering the "Art" of Energy Efficiency—the title of his 1999 autobiography.[1]

Arthur Rosenfeld died last year, aged 91. In his memory, this article searches for a possible Rosenfeld effect beyond California. The article integrates ideas from econometric methods for forecasting electricity demand to build an analytic model that explains the relationship between retail electricity sales and investment in energy efficiency. It begins with a review of national trends in electricity intensity (measured as annual per-capita retail electricity sales) during the decade ending in 2016, and uses the analytic model with data on 50 states and the District of Columbia to estimate the effect of publicly funded energy efficiency on these trends.

2. California: Special but not unique

For four decades, efficiency has been a priority in California's energy policy and planning —a history quite visibly marked by continuous attempts at paving the way for greater efficiency. Curling is the closest sports analogy that comes to mind.

California launched its first generation of utility electricity-efficiency programs and adopted the first electricity-efficiency building codes and appliance standards in the mid-1970s. Following the hiatus caused by restructuring of wholesale electricity markets in the 1990s, the energy crisis of 2001 and a growing awareness of climate change dangers reinvigorated interest in energy efficiency. In 2005, California designated efficiency as the resource-of-choice for meeting the state's future electric load growth. Two years later, the state established an incentive mechanism (the Risk-Reward Incentive Mechanism) to encourage the state's utilities to achieve higher savings. In 2008, the state adopted the California Long Term Energy Efficiency Strategic Plan, which established a roadmap for energy efficiency investments through 2020.

California's praised policy accomplishments have established the state as an example to follow in a national mission to control energy use and greenhouse gas emissions. The state also has been hailed as a model

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[1] Arthur Rosenfeld. "The Art of Energy Efficiency: Protecting the Environmment with Better Technology." Annual Review of Energy and Environment. 24:33–82. 1999.

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for other countries.[2]

Several attempts have been made to invalidate the causal link between stable trends in California's electricity use and the state's energy efficiency policies by offering alternative hypotheses to explain the divergence in California's per capita electricity use from the national average.

California, the skeptics have argued, is an exceptional state with distinctive characteristics: non-energy-intensive industry, high electricity prices, smaller households, higher proportions of multifamily units in housing, a conservation ethic, and the natural advantage of a mild climate. Upon factoring in these structural and natural attributes, the critics have argued, differences between California's per-capita electricity use and that of other states disappear.[3] Others have suggested that California's flat per-capita electricity use has more to do with coincidental factors such as urbanization, the size of dwelling units, and the residential fuel mix, than with the effects of the state's energy efficiency policies.[4]

Such reasoning has led critics to raise broader concerns about the effectiveness of California's policies, as other states—and countries—attempt to emulate them.[5] One critic has gone so far as charging that California's model is unrealistic not only for the nation, but following California's example would prove detrimental to the national interest by putting domestic firms at a global competitive disadvantage by increasing the cost of doing business.[6]

Amid these criticisms, California is doubling down on its energy efficiency policy. In the decade ending in 2016, California IOUs spent about $10.3 billion on electric energy efficiency and reported savings of about 3.4 billion kilowatt-hours. New legislation passed in 2015 calls for a doubling of savings by 2030.

Understanding California's experience is important. The state has served as a pioneer in energy efficiency and today provides a well-known case study, both within the United States and abroad. As other states and countries continue to adopt policies and programs similar to California, the need increases to effectively evaluate efficiency policies.

However, it appears that California may not be the only state experiencing declining electricity use. Data from the Energy Information Administration (EIA) shows that national, annual, per-capita retail electricity sales dropped from 12,300 kW h in 2006 to 11,650 kW h in 2016—a 5.3% at drop at an average annual rate of about 0.5%, as shown in Fig. 1. Between 2006 and 2016, consumption declined in 41 states, including the District of Columbia, by just under 8% on average.

Eight states showed a drop greater than California's, with Hawaii experiencing the largest drop at nearly 20%—almost twice that of California. Electricity consumption rose in 10 states by an average of 7%, ranging from almost 36% to less than 1%. North Dakota's per-capita electricity use climbed by 35.6%, the highest rate in the country, followed by South Dakota (9.0%), Louisiana (8.6%), and Iowa (6.4%). Electricity consumption also increased, though at more modest rates, in Mississippi (2.0%), Nebraska (3.2%), New Mexico (1.5%), New York (0.8%), and West Virginia (0.3%).

3. The megawatt in a negawatt

Since 2006, the American Council for an Energy Efficient Economy, ACEEE (which, incidentally, Arthur Rosenfeld founded), has published annual reports that benchmark state progress on policies that promote energy efficiency. The *State Energy Efficiency Scorecard* uses officially sanctioned data to rank states in six areas: utility-funded programs, transportation, building energy codes, combined heat and power, state policy initiatives, and appliance standards. The report's latest edition, published in September 2017,[7] identified Massachusetts, California, Rhode Island, Vermont, and Oregon as the top performers and cited Idaho, Florida, and Virginia as the most-improved states.

According to the Scorecard, utilities across the country spent $6.3 billion in 2016 on electric efficiency programs, a steady, four-fold increase from the $1.6 billion spent in 2006. As shown in Fig. 3, these expenditures equaled 0.55% of utility retail revenues in 2006 and 1.7% in 2016. Reported savings also rose proportionately, from 7.8 million MWh in 2006 to 25.4 million MWh in 2016. From 2006 to 2016, these savings represent more than a three-fold increase from 0.21% to 0.68% of retail electricity sales, averaging at about 0.5% per year.

Existence of an energy efficiency resource standard is a clear demarcation among states. In 2016, states with an EERS spent significantly more and produced higher savings, investing the equivalent of 2.6% of retail electric revenues and lowering retail sales by 1.2%. States without EERS obligations spent 0.8% of retail revenues and achieved proportionately lower savings of 0.3% of retail sales. Among states with an EERS, Texas ranked lowest in expenditures (0.6% of retail revenues) and savings (0.2% of retail revenues), on average, while Vermont counted as the most aggressive, with expenditures of 6.8% of retail revenues and savings at 2.5% of retail sales.

The correlation between expenditures and savings shows a slightly downward trend, suggesting declining returns on efficiency expenditures. The average cost of acquiring savings rose modestly between 2006 and 2016, perhaps reflective of depleting savings opportunities from low-cost measures, such as residential lighting.

4. The trouble with negawatts

Because energy savings cannot be observed directly, they must be estimated using engineering calculations or statistical inferences. Savings are typically first calculated for individual measures or projects, then aggregated to program or portfolio levels, awarding the scheme its moniker, the "bottom-up" approach. Bottom-up is not a unified methodology (although this has started to change); it is inconvenient to use and can be expensive. It also can misstate savings for failing to account for three issues that have vexed analysis and policy makers.

The first problem is the technical interaction effect, which arises when installing multiple efficiency measures together. Electricity end uses tend to function interdependently—higher efficiency in one end use affects electric loads in another end use. By simply adding savings from individual measures, the bottom-up approach can overstate or understate savings, sometimes by a wide margin.[8]

This approach also fails to address two issues that complicate public policy in more areas than energy efficiency. The first is attribution: separating the direct effects of an energy efficiency policy or program from observed (gross) changes in consumption by accounting for the influence of coincidental factors unrelated to the program, such as price change. The resulting net-to-gross ratio has become a singularly charged topic in energy efficiency policy, especially in states where utilities face strict savings targets. Further clouding the issue, non-programmatic effects are extremely difficult to define, and there are no

[2] The World Bank once praised California's utility demand-side management and efficiency standards for the stale's stable per-capita electricity demand. The World Bank, Development and Climate Change, Technology Report, The World Bank, Washington, DC, 2010, p. 215.

[3] Mitchel, Cynthia. "Stabilizing California's Demand: The Real Reasons Behind the State's Energy Savings." Public Utilities Fortnightly. March 2009.

[4] Sudarshan, Anant and James Sweeney. *Deconstructing the Rosenfeld Curve: Understanding California's Low Per Capita Electricity Consumption*. Stanford University. Sept. 30, 2008.

[5] Levinson, Arik. *California Energy Efficiency: Lessons for the Rest of the World, or Not?* Georgetown Economics Department, Elsevier. 2014. http://faculty.georgetown.edu/aml6/pdfs&zips/CaliforniaEnergy.pdf.

[6] Clement, Jude. "Is California's Electricity Policy Really a Model for the United States?" Innovative Energy Policies. Ashdin Publishing. 2011.

[7] ACEEE. 2017 State Energy Efficiency Scorecard, Report U1710. September 2017.

[8] Haeri, Hossein. "Energy Efficiency: The Art of Measurement." Public Utilities Fortnightly. January 2018.