Unlocking the Potential of Behavioral Energy Efficiency: Methodology for Calculating Technical, Economic, and Achievable Savings Potential

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ABSTRACT

Utilities are on track to meet aggressive energy efficiency (EE) goals (Sciortino et al., 2011) but their work is about to get harder. Shocks to the efficiency landscape, including the phase-out of CFL programs and falling generation costs, mean that fewer programs can deliver scalable, cost-effective energy savings. Utilities are turning to Behavioral Energy Efficiency programs to bolster their EE portfolios. Using behavioral psychology, these programs have been proven to motivate customers to make smarter decisions and save energy.

As utilities scale up behavioral programs, potential studies provide a helpful barometer for achievable savings. So far, only a few studies assess the impact of behavioral programs. We calculate the industry's first, state-by-state assessment of the achievable potential of behavioral efficiency programs. Based on results from 218 large-scale behavioral feedback programs across more than 8 million households and 88 U.S. utilities, we find that utilities and states are currently underinvesting in behavioral savings. Behavioral programs are cost-effective for 79 million households, or 61% of the US population. Deployment of behavioral programs, at their full economic potential, could generate 19,000 GWh in annual electricity savings and $2.2 billion in end-consumer savings per year.

Introduction

Utilities across the country spend $8 billion annually to help customers lower their energy use (Forster, Wallace, and Dahlberg, 2013). Through these investments, utilities are on track to meet aggressive energy efficiency (EE) goals (Sciortino et al., 2011). But their work is about to get harder. Shocks to the efficiency landscape, including the saturation and phase-out of compact fluorescent lamp (CFL) programs and falling electricity generation costs, mean that there are fewer programs available to deliver large-scale and cost-effective energy savings.

In this new environment, utilities have increasingly turned to behavioral approaches to energy efficiency. One type of behavioral energy efficiency approach, first pioneered by Sacramento Utility District in 2008, are proactive, personalized reports to utility customers, termed home energy reports, that use behavioral psychology to motivate customers to save energy. Behavioral approaches are widespread[1] and widely evaluated.[2]

The Role of Potential Studies

Utility energy efficiency portfolios are commonly planned and administered in multi-year filing cycles. Prior to forming their plans, utilities or state regulating bodies often commission

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[1] Behavioral approaches are approved in 29 states, and programs are run by more than 4 companies on behalf of over 90 utilities in 8 countries. See Appendix for states where behavioral energy efficiency is an approved resource.
[2] Behavioral energy efficiency programs have been independently evaluated more than 30 times. For a full list, see http://www.opower.com/company/library/verification-reports

potential studies to survey energy efficiency options. Potential studies can include overviews of energy by end use, estimates of EnergyStar appliance penetration within a state or utility footprint, estimates of hours of lighting, and take into account existing penetration of appliance and other technologies, footprint latitude, and local climate characteristics.

As utilities across the country think about scaling up behavioral programs in their energy efficiency portfolios, these potential studies provide a helpful barometer for the level of savings that can be achieved. So far, a few organizations have released studies that assess the impact of behavioral programs. KEMA, now DNV GL, found that Behavioral Program potential could save up to 132 GWh per year in Xcel Colorado's territory (KEMA, 2013a). In New Jersey, EnerNOC found that behavioral program potential in the state could save up to 544 GWh and 25 million therms in a three-year period (EnerNOC, 2013). More broadly, McKinsey quantified the savings potential of all behavioral interventions at 16%-20% of total US residential energy use (Heck, 2013).

One reason the practice of incorporating behavioral approaches into potential studies is not more widespread is because the data and methodology to provide informed projections of behavioral potential are not widely available. Thus, a primary purpose of this study is to disseminate a scientifically-derived methodology to quantify potential for behavioral energy efficiency programs, as well as to provide the first comprehensive, state-by-state study of the electric savings potential of one type of behavioral program that uses home energy reports.

Methodology for Quantifying Behavioral Program Potential

Potential studies typically categorize savings potential into the following categories, as defined by the EPA's "Guide for Conducting Energy Efficiency Potential Studies" (2007):[3]

- Technical potential—The theoretical maximum energy efficiency savings that can be achieved, disregarding non-engineering constraints such as economics or customer adoption patterns
- Economic potential—The sub-set of technical potential that is cost effective as compared to conventional supply-side energy resources and based on the applicable cost effectiveness calculation.
- Achievable potential—The sub-set of economic potential that is reasonable for the utility or state to achieve during the next filing cycle assuming the most aggressive program scenario possible, typically taking into account customer adoption patterns. This is also referred to as the maximum achievable potential.

This study uses publicly available data sets from the Energy Information Administration (EIA), monthly savings measurements from 218 behavioral feedback programs at 88 utilities, regression modeling for predicting energy savings, as well as third-party cost effectiveness calculators for avoided costs to determine technical, economic, and achievable potential by utility.[4] Those values are aggregate at the state and national levels to produce the tables in the Findings and Recommendations section.

[3] Program potential, which accounts for program-specific constraints such as budgets or program design, can also be included in potential studies but is not addressed here given the broader scope of this research.
[4] Utility-level potential is aggregated to the state level in this study. For utility-level information, please contact rachel.kane@opower.com

Unlike most technology-adoption efficiency programs, best-practice home energy report programs auto-enroll participants and provide an opportunity to opt-out. For other programs, utility customers opt-in to receive a home audit, or to claim an appliance rebate, and therefore will typically only include hundreds or thousands of participants in a given utility footprint. One consequence of opt-out design is wider and immediate adoption. Due to opt-out design, the economic and achievable potential for home energy report programs are equivalent because the economic potential is not degraded by opt-in rates.

Data Acquisition

This study requires two data points on each utility—total residential households and average usage. The most comprehensive source of this data is the EIA Form 861 which provides self-reported data from electric utilities.

Technical Potential

There are two technical limitations to deploying home energy report programs —sample size and program limitations. This study is limited to utilities with a residential footprint of at least 50,000 households to ensure adequate sample sizes for measurement and verification.[5]

This means that of the 3,477 electric utility entities, 291 are included in the study as having enough residential households. However, because most households in the U.S. are customers of these larger utilities, this restriction does not limit the study by much—it still includes 84% of all households receiving electricity from utilities in the United States.

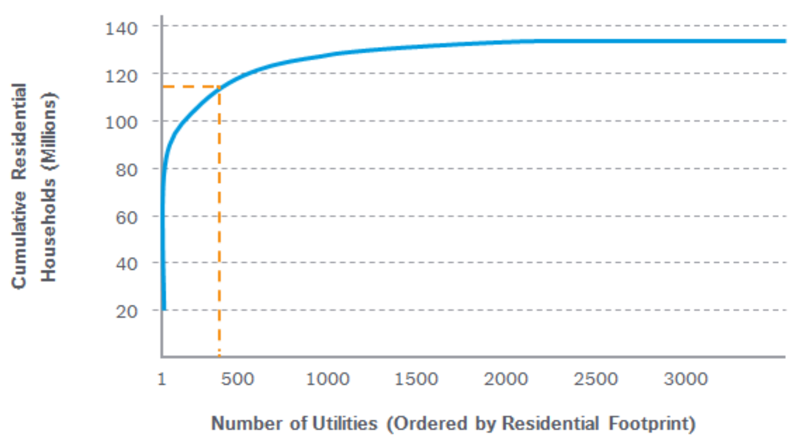

Figure 1. Cumulative residential households by utility size.

Home energy report programs often face eligibility limitations that reduce technical potential. These limitations are concentrated around outlier data, and include the following:

- Multiple service points per fuel—home energy report programs may not be able to accommodate households with multiple electric or gas meters at a single premise

[5] This is not to say that the sample size required for a home energy report program is 50,000 households. Strictly speaking, to measure savings from a behavioral energy efficiency deployment requires a minimum of 10,000 treatment and 10,000 control households. The 50,000 household minimum is a conservative assumption to account for those sample sizes and allow for issues of eligibility and attrition.

- Energy usage gap—Because some home energy report programs show trends in usage over time, gaps in meter reads may render the premise ineligible
- Multiple read cycles—If a premise is associated with multiple read cycles, the premise may be ineligible for data-driven programs
- Negative usage—If any reads have a negative usage value, the premise may be ineligible for data-driven programs
- Low / high electric history—Programs often set a daily minimum and maximum usage threshold to ensure data-driven programs are sent to occupied households and avoid outlier households

On average, these criteria only exclude a small percentage of households from participating in home energy report programs. For the purposes of this study, this percentage is assumed to be 10% of the residential footprint.

Usage By Percentile

EIA data provides average usage for the utility footprint. However, efficacy and cost effectiveness of Behavior Programs is linked to usage, with higher usage households saving more energy. To accurately determine impact, this study needs more granular inputs. Using a data set that included 88 US utility clients allowed the study to include approximately 40% of US residential usage. Examining this data allows for precise extrapolation of the distribution of energy usage around the mean.

Figure 2 below show average usage by percentile for 22 electric utilities. Note that the slope of the curve is similar across utilities, although the magnitudes change.

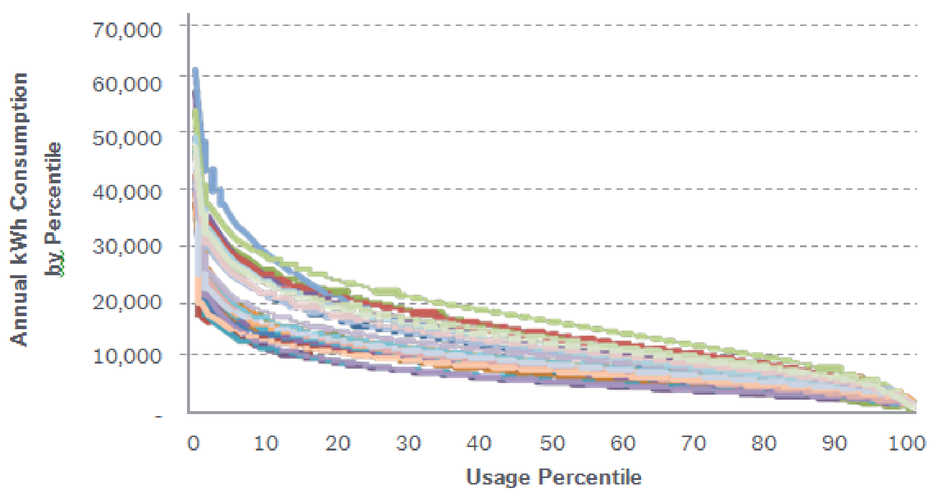

Figure 2. Cross-utility normalized energy consumption by percentile.

Knowing both the average usage within a footprint, as well as the consistent distribution around the mean, allows calculation for average usage for each percentile (Figure 3).

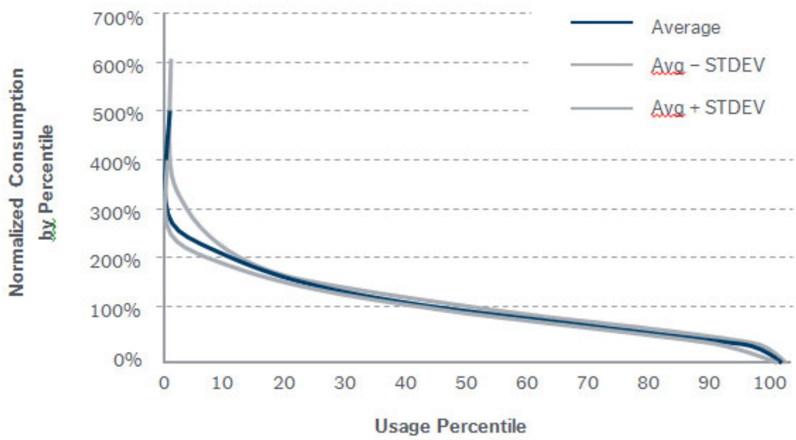

Figure 3. Mean energy usage by percentile.

Forecasting Energy Savings

It is necessary to apply observed home energy report program results to understand the potential savings impact by utility by percentile. This paper relies on the data set resulting from 218 live programs at 88 utilities. In addition to 24 independent evaluations, the program implementer also measures savings from these deployments on a monthly basis. The resulting data set includes more than 6,000 program-month observations of savings. The program implementer uses this data to build a forecasting regression model, which correlates the characteristics of each program with resulting savings to accurately predict energy savings. A subset of these data points is from smart meter deployments and enables the calculation of peak demand coincidence and forecast of demand savings. During peak hours, saving rates are 1.5 times the average savings for a given program over the course of a month.

The main predictors of per household energy savings are baseline energy usage and the number and timing of home energy reports sent. Important but less predictive variables include state level indicators (e.g. ACEEE state scorecard rank), utility level indicators (e.g. Is the utility investor-owned?), and program level indicators (e.g. number of touch-points customer receives).

Fitting the forecasting regression model with usage by percentile, as well as the state, utility, and program level indicators, provides expected kWh savings and kW savings per household per year. Forecasts are run for 36 months to account for the common 3-year filing cycles for efficiency programs. Annual achieved savings for participants in Behavior Programs are demonstrated to increase year over year, which is why Year 2 and 3 savings forecasts are higher than Year 1 savings forecasts (Dougherty, 2013; KEMA, 2013b; Wu, 2012).

Figure 4 shows the distribution of forecast savings per household by year against actual measured savings per household by year. Note that the distributions of the forecast and measured values nearly overlap, suggesting that the forecast model is predicting future results to be similar to measured results. The forecast values skew slightly higher than measured values. This is largely due to behavior program underrepresentation and the subsequent lack of data points at high usage utilities in the South East. While the program implementer’s forecasting model predicts the average program savings very well, improvements are underway to better predict outlier situations as availability increases.

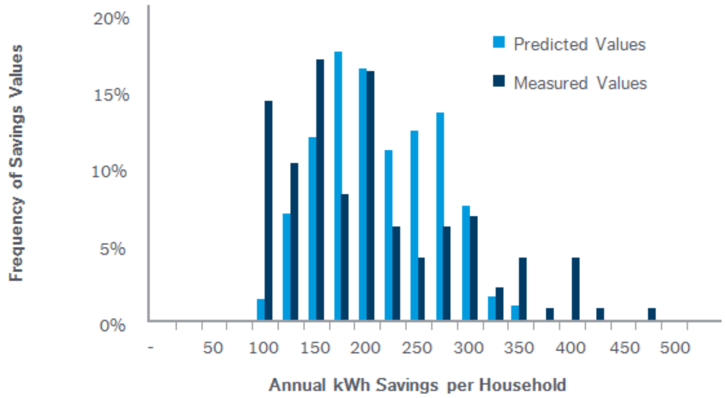

Figure 4. Predicted and measured savings values per household.

Costs Per Household

Home energy report costs vary by deployment and provider. In general, electric program costs can vary between $10.00 and $14.00 per household, depending on additional products and services accompanying each deployment.

Calculating Cost Effectiveness

This study uses the Total Resource Cost (TRC) test as the primary means for determining cost effectiveness. Because the home energy report programs typically do not include any customer incentives, the resulting TRC is equal to the Utility Cost Test (UCT). Despite the prevalence of TRC as the main cost test (EPA, 2009), states vary in the calculation of the TRC and the primacy of that cost test. Calculations differ on whether they include avoided capacity costs, avoided GHG emissions costs, line loss, social benefits, or other factors. This study does not vary the calculation of the TRC at the utility level. Instead, TRC is calculated generally as (CPUC, 2002):

$$TRC = \frac{NPV[avoided\ cost_{generation} \times kWh \times (1 + line\ loss) + avoided\ cost_{capacity} \times kW]}{NPV[Behavior\ Program\ cost + Utility\ administration\ costs]}$$

The standardized use of TRC allows this study to comprehensively examine economic potential at every operating company in the US. However, one implication of the study is that as cost test calculations vary by state or utility, the resulting economic potential could change as well.

The avoided costs used for these calculations are derived from three external sources.

1. E3 Calculator —The E3 Calculator, funded by the California Public Utility Commission, is the cost effectiveness calculator of record for each of the California Investor Owned Utilities. This study uses the E3 calculator to calculate TRCs for all California utilities.[6]

[6] The E3 calculator can be found at www.Energy+EnvironmentalEconomics.Ethree.com/public_projects/cpuc4.php

2. Synapse Energy11—Synapse is commissioned to provide avoided costs for New England every two years. This document uses the 2013 Synapse avoided cost report (Horby, 2013).
3. DSMore—Integral Analytics' Demand Side Management and Risk Optimization Evaluator is the most widely used cost effectiveness calculator in the US. For the states not mentioned above, DSMore is used to calculate TRCs.

Economic and Achievable Potential

Once savings, program costs and TRCs for each percentile of users at every electric and gas utility in the US have been ascertained, determining economic potential is as simple as calculating the running TRC as the program expands from the highest users to the lowest users. The point at which the TRC equals 1 is the economic potential. Because of the opt-out program design of home energy report programs, the economic potential is not limited by slower market transformation. Achievable potential and economic potential are equivalent.

To translate kWh savings into customer bill savings, average electric retail prices for each utility are sourced from the EIA.Form 861 To translate savings into CO_2 emission reductions, state level carbon intensity estimates were drawn from the Carbon Monitoring in Action database, comprised of plant-level emissions data from the EPA & EIA.

Findings and Recommendations

Utilities and states are currently underinvesting in behavioral energy efficiency. Home energy report programs are cost-effective for 79 million households, or 61% of the US population. Deployment of behavioral programs, at their full economic potential, could generate 18,679 GWh in annual electricity savings, 10 million metric tons of CO_2 abated, and $2.2 billion in end-consumer savings per year. This represents 1.6% of current residential use, and is enough energy to take the entire state of Arkansas off the grid or 2.1 million cars off the road.[7]

However, today, fewer than 10 million US households are participating in such programs – with a potential of 79 million households, the scale of behavior programs could increase eightfold without sacrificing cost effectiveness.

Table 1. Overview of electric behavioral potential

Total Households	Technical Potential Households	Economic / Achievable Potential Households	Annual Generation Savings (GWh)	Annual Capacity Savings (MW)	Annual CO_2 Abated (Metric Tons)	Annual Customer Bill Savings
110 MM	96 MM	79 MM	18,679	3,198	10,200,007	$2.2B

[7] EIA-861 Survey for 2012 puts Arkansas residential sales at 17,909 GWh. EPA estimates 4.8 metric tons of CO2E / vehicle / year. Source: http://www.epa.gov/cleanenergy/energy-resources/refs.html

State by State Potential[8]

Figure 5 shows the relative electric potential by state, while Table 2 lists state details.

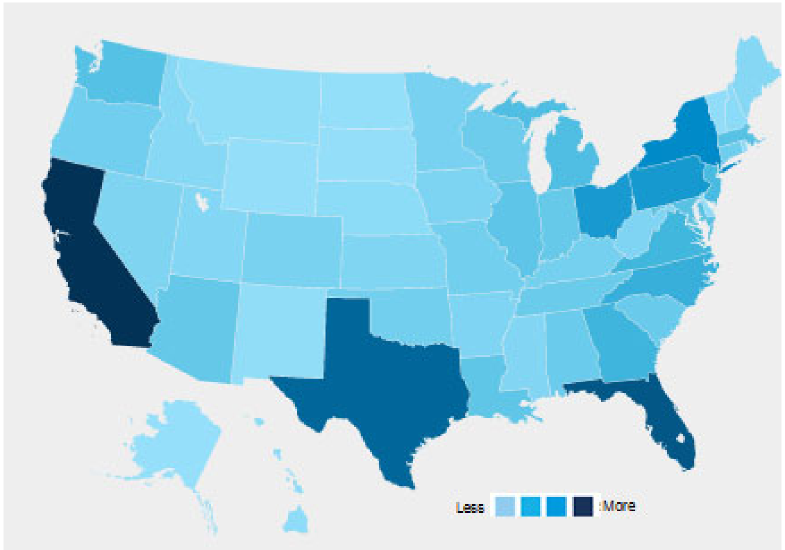

Figure 5. Relative electric potential by state.

- California King: With the largest population and high electricity generation costs, California presents the largest savings opportunity given 89% of its households are cost effective for behavioral energy savings. 11.1 million cost effective households have the potential to save 2 TWh. New York, Florida, Texas, and Pennsylvania round out the top five for both cost effective households and potential savings.
- Southeast Energy Efficiency: Behavior potential is highest in states with high usage and high costs of electricity generation. This leads to some interesting implications for the Southeast, where high air conditioning loads lead to states with the highest average electricity usage in the country. Of the 22 million households in the Southeast states (Alabama, Arkansas, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee), 16 million are cost effective and could save 4,400 GWh each year.
- Replacing CFLs: Total annual residential savings amount to 22,900 GWh annually, as estimated by ACEEE (Downs, 2013). Behavior Potential of 18,679 GWh means that behavior programs can more than make up for the drop in savings coming as CFL programs phase-out (NEEP, 2013).

[8] The findings of this study are available in interactive map form (# of cost effective households, kWh, kW, CO2 and bill savings) at www.beepotential.com

Table 1. Electric behavioral potential by state

State	Residential Households	Technical Potential Households	Economic / Achievable Potential Households	Eligible Households as Percent of Total	Annual Electric Savings (GWh)	Annual Capacity Savings (MW)
United States	**110,291,156**	**96,352,040**	**78,562,059**	**71%**	**18,679**	**3,198**
Alabama	1,440,881	1,266,793	1,008,546	70%	312	53.4
Alaska	122,968	90,671	30,762	25%	7	1.3
Arizona	2,311,786	2,040,607	1,016,945	44%	353	60.4
Arkansas	938,728	784,855	554,277	59%	171	29.3
California	12,505,871	11,135,284	11,135,284	89%	1,998	342.1
Colorado	1,679,808	1,451,827	898,852	54%	204	34.9
Connecticut	1,639,779	1,415,801	1,415,801	86%	277	47.4
Delaware	334,136	280,722	280,722	84%	59	10.1
D.C.	217,299	185,569	180,002	83%	32,835	5.6
Florida	8,003,814	7,063,433	5,955,525	74%	1,623	278
Georgia	3,131,047	2,707,942	2,284,634	73%	626	107.1
Hawaii	389,521	320,569	320,569	82%	50	8.6
Idaho	559,453	473,508	573,508	103%	118,214	20.2
Illinois	4,679,718	4,161,746	1,257,527	27%	392	67.2
Indiana	2,019,698	1,767,728	1,194,967	59%	333	57
Iowa	957,861	842,075	817,105	85%	177	30.4
Kansas	868,029	741,226	706,399	81%	160	27.5
Kentucky	1,199,286	1,009,357	864,974	72%	237	40.5
Louisiana	1,724,590	1,472,131	1,230,878	71%	383	65.6
Maine	1,195,125	1,045,613	705,569	59%	124	21.2
Maryland	2,210,830	1,929,747	1,929,747	87%	445	76.2
Massachusetts	2,573,173	2,265,856	2,265,856	88%	441	75.5
Michigan	3,799,281	3,369,353	2,303,994	61%	502	85.9
Minnesota	1,423,236	1,240,912	939,482	66%	218	37.4
Mississippi	713,333	592,000	467,003	65%	145	24.9
Missouri	1,872,481	1,615,233	694,578	37%	251	43
Montana	323,786	271,407	180,886	56%	43	7.4
Nebraska	490,344	411,310	291,584	59%	71	12.2
Nevada	1,013,329	891,996	645,207	64%	167	28.7

New Hampshire	552,190	466,971	456,180	83%	77	13.2
New Jersey	3,337,769	2,963,992	2,863,483	86%	546	93.4
New Mexico	620,193	528,174	129,668	21%	40	6.9
New York	7,562,388	6,666,149	6,004,397	79%	1,109	190
North Carolina	3,391,226	2,932,103	2,524,590	74%	689	118
North Dakota	140,802	106,722	77,813	55%	19	3.2
Ohio	5,763,139	5,076,825	3,745,591	65%	928	158.9
Oklahoma	1,077,317	949,585	949,585	88%	249	42.7
Oregon	1,268,571	1,111,714	1,111,714	88%	262	44.9
Pennsylvania	5,525,739	4,833,165	4,398,591	80%	944	162
Rhode Island	424,116	371,704	371,704	88%	69	11.74
South Carolina	1,542,817	1,308,535	1,158,146	75%	319	54.6
South Dakota	127,076	94,368	63,997	50%	15	2.6
Tennessee	1,504,491	1,254,042	1,116,680	74%	313	53.6
Texas	8,015,902	6,904,312	4,595,658	57%	1,464	250.8
Utah	707,371	626,634	589,036	83%	132	22.6
Vermont	218,025	176,223	176,223	81%	36	6.1
Virginia	2,917,315	2,565,584	2,217,390	76%	608	104.1
Washington	2,244,754	1,950,279	1,844,589	82%	463	79.2
West Virginia	819,658	707,692	707,692	86%	169	29
Wisconsin	2,081,717	1,823,545	1,340,924	64%	291	49.8
Wyoming	109,389	88,450	67,222	61%	15	2.6

Recommendations

With 19,000 GWh of cost effective, achievable energy savings potential on the table right now, there are several calls to action for the utility-led energy efficiency community:

1. *Take advantage of the achievable potential today:* Unlike other efficiency programs that seek to hasten market transformation over a period of years or decades, Behavioral Energy Efficiency is available and cost effective for 79 million households today.
2. *Include behavioral interventions in all potential studies*: All potential studies should include a survey of behavioral interventions.
3. *Include behavioral interventions in all residential portfolios*: The logical next step is to include behavioral interventions as part of the portfolio such that utilities and their ratepayers begin to realize the benefits of these programs.

4. *Emphasize appropriate measurement and verification rigor*: While behavioral opt-out programs require different types of evaluation, the appropriate measurement and verification methodologies are not difficult to implement and have been comprehensively categorized. The aptly-named SEE Action study on "Evaluation, Measurement, and Verification of Residential Behavior-Based Energy Efficiency Programs" is the most complete guide and should be referenced for evaluation planning.

Appendix

Figure 7 shows the 31 states where behavioral energy efficiency is an approved energy efficiency resource. In states like Oregon and Texas, behavioral energy efficiency programs are approved but with no formal filing requirements.

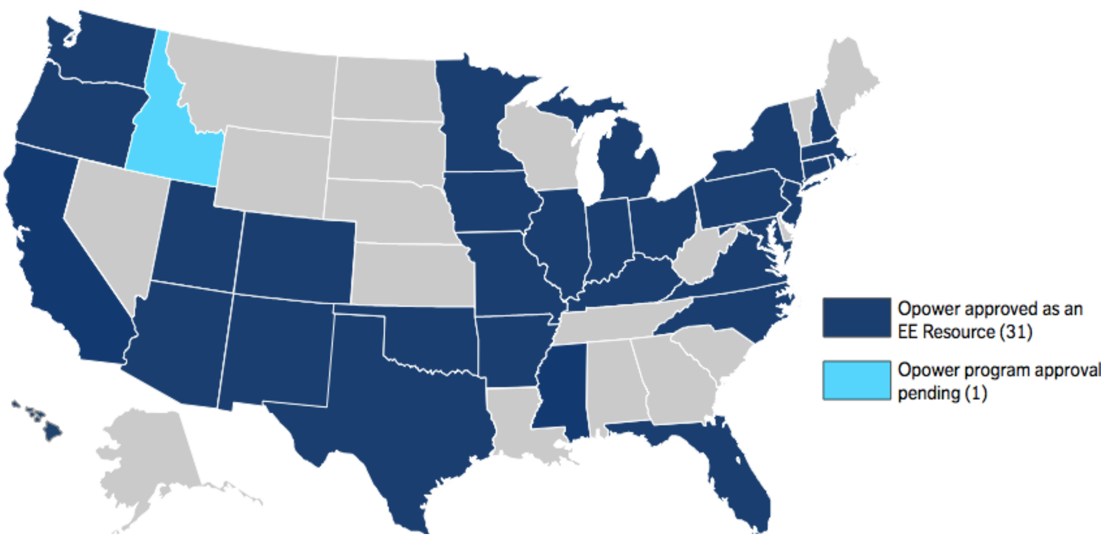

Figure 7. Cross-utility normalized energy consumption by percentile

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