Grading the 2014 Commercial Sector Energy Efficiency Performance by State

Based on the State Energy Data System data of the Energy Information Administration

Previously EPMI has developed exploratory methods for "grading" the entire building sectors of states in the United States for the years 2004 and 2009. Recently EPMI presented residential sector building energy efficiency "grades" for states (http://epminst.us/states/stres12grade.htm) for the year 2012, based on extractions from the book, *Shaping Residential Sector Energy Performance* (http://epminst.us/states/shapingres.htm). This report covers consideration of grading the energy efficiency performance of state commercial sectors for the year 2014. (http://epminst.us/states/Grading the 2014 Commercial Sector Energy Performance by State.pdf)

SEDS Data

The State Energy Data System (SEDS) is the EIA's comprehensive repository of US state-level energy statistics (http://www.eia.gov/state/seds/). SEDS provides a historical time series of prices, energy production, consumption, and expenditures for the whole country and by state that are defined as consistently as possible over time and across sectors for analysis and forecasting purposes. SEDS also has gross domestic product data.

Some SEDS data are obtained directly from surveys conducted by EIA, but many data are estimated using other available information. The estimations are necessary for the compilation of "total energy" estimates, which is challenging given the wide array of energy sources and means of distribution.

For the commercial sector, SEDS tracks fuel types as: coal, natural gas, five types of petroleum products, biomass, geothermal energy, and electricity. Hydroelectric power is a tabulated category, but direct use is estimated to be so small as to be almost negligible nationally.

Sectoral Modeling

Modeling sectoral energy performance requires a different mindset than modeling the energy performance of individual buildings. Instead of finding ways to combine results of many individual buildings, the energy use of states is modeled. The geographic analysis domain has been raised from the level of individual building sites to entire states, where a reasonably complete picture of overall sectoral energy use is available.

The previous work on modeling entire building sectors to develop energy performance scoring for states has shown that building sector energy performance based on normalization of energy use for both population and weather factors can be achieved reasonably using multiple-parameter linear regression, a statistical method. There are other methods that could be used, but experience has shown that multiple linear regression best meets the need, especially for populations of buildings.[1]

The Energy Star® performance rating system (Portfolio Manager performance scoring under energystar.gov) is typically based on multiple linear regression results for several discrete specific populations of buildings.

Weather affects heating and cooling energy use, but the energy used for heating is different than the energy used for cooling, and both of these are subsets of the energy used per person. To analyze multiple factors together requires a multidimensional approach that determines the average for a sector of the contributions of each factor.

State population totals allow normalization on a per-person (per-capita) basis, and degree-days allow some ability to include weather normalization. Additional weather complexity is possible, but introducing both heating and cooling degree-days into the analysis is probably as complicated as should be attempted at this stage of knowledge.

Population-weighted heating and cooling degree-days by state are available from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA):

ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/

Reliable degree-day data from this URL are available from 1999 onward. The degree-days from the NCDC are the population-weighted degree-days (DD) for each state, both heating and cooling, with a base temperature of 65ºF. Additional complexity occurs in that the degree-day effects must also be per person, so the actual analysis factors used for the normalizations are:

1. Population of each state (# of people)
2. Population-weighted heating degree-days (HDD) of each state times the number of people in the state (person-degree-days)
3. Population-weighted cooling degree-days (CDD) of each state times the number of people in the state (person-degree-days)

Simplistically, the regression analysis returns the average energy use of 50 states plus the District of Columbia (central trend for all combined) calculated for each factor, separating the aggregate weather-dependent effects for HDD and CDD from the non-weather-dependent aggregate per-capita use.

In order to use regression analysis on sectors that use multiple fuels, source (primary) energy is typically required instead of delivered (site) energy. In the United States, there are statistically significant differences between populations of buildings that are all-electric and those that are not IF delivered energy is used for the calculations. If primary

[1] Readers can consult the report *Investigation of Metered Data Analysis Methods*, 1989, Section 2.1. http://epminst.us/ORNLproducts/CON-279.htm

energy is used, the statistical difference is not significant. For performance measurement based on statistical methods, unacceptable biases can be introduced if there are statistically different groups pooled together in the analysis. Other means could be tried to overcome the difficulties of using delivered energy to develop more complex sectoral energy performance measurements, but the use of primary energy is simpler at this time.

Basic Model Results for 2014

For 2014 the total primary energy use of the US commercial sector is 18.15 quads. A “quad” is a quadrillion Btu/yr. A quadrillion (10^{15}) is a million billions or a thousand trillions. A British thermal unit (Btu) is the amount of heat energy needed to raise a pound of water (about a half-quart or half-liter) one degree Fahrenheit.

The scoring model is based on a linear, ordinary least squares regression of the population and DD-based normalization parameters against the dependent parameter of total annual primary energy use in 2014 for the commercial sector of each state and DC, N = 51.

In the initial regression all parameters are highly significant, with $p < 0.0001$, but the intercept is highly nonsignificant ($p = 0.31$). With a highly nonsignificant intercept (likely zero), the regression is run again without an intercept. The coefficients for the other parameters remain mostly the same when there is no intercept. This approach can be preferable, since some unacceptable effects will be introduced for smaller states if there is an intercept.

In the revised regression with no intercept, the overall model is much the same, with a little higher effect going to degree days. R-square and the F-statistic are technically not defined, but they can be estimated. Statistical results are summarized in the next table.

Regression Model Statistics

1	Dependent Parameter		Total primary energy use in 2014	
2	# of observations Model adjusted R-square Model F Statistic		51 ~ 0.98 ~ 768	
	Model Significance		< 0.0001	
3	**Parameter**	**Model Coefficients**	**T value**	**Significance**
	Intercept	(forced to 0)		
	Population	14.70 MBtu/ capita	5.01	< 0.0001
	HDD effect	6.12 kBtu/ capita-DD	13.77	< 0.0001
	CDD effect	10.57 kBtu/ capita-DD	9.95	< 0.0001

Model R-square of 98% indicates the linear model is appropriate and estimation of the combined effects of population and weather should be good.

Total commercial sector primary energy use for 2014 is 57 MBtu/capita (direct SEDS data), so the non-DD effect energy (14.7 MBtu/capita) is about one-quarter of the total (see table below). Multiplying the model coefficients times population and degree-days leads to the total energy use breakout in the table below. The HDD-effect energy use is about half of the total, and CDD-effect energy use is also about one-quarter.

HDD-dependent, CDD-dependent, and Other Energy Use

Year	Other energy use, quads	HDD-effect energy use, quads	CDD-effect energy use, quads	Total energy use, quads
2014	4.74	9.00	4.40	18.15
2014%	26.1%	49.6%	24.3%	100%

Readers who have a concern about these percentages should read a separate analysis of commercial sector energy use, especially the material on end uses of energy.[2]

Additional Potential Normalizations

Examination of the model results for individual states suggests that there are additional effects related to GDP per capita and energy prices. The District of Columbia is mainly a city, with no suburban, ex-urban, or country population to balance off the higher intensity of energy use in the commercial parts of the city. DC uses a lot of commercial sector energy per capita and receives a failing grade using this scoring model. DC also has GDP per capita that is over double any other state. Adding GDP per capita to the regression does not change the results much though (DC still receives an 'F'), and makes the overall distribution of "grades" less "normal."

Hawaii always scores very high using scoring models such as presented above, due to high energy prices, mild climate, and climatic adaptations by the population. Adding energy pricing as an additional normalizing factor also changes the final scoring some, but the decision here is that results are desired that do not hide (normalize out) the effects of energy prices on sectoral energy use.

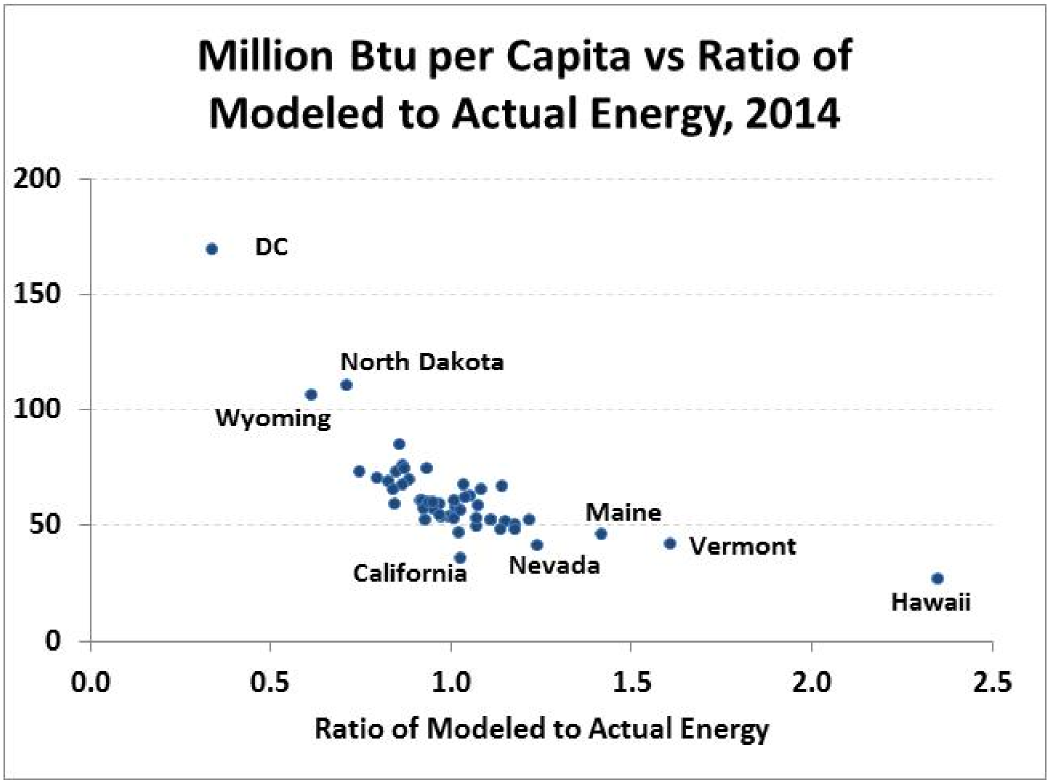
Normalizing for GDP or energy pricing is not done here.

Setting the Grading 'Curve'

In previous efforts aimed at grading the combined residential and commercial sectors, the state scores were set to a grading curve to allow letter grades to be assigned. Since Hawaii energy use is anomalous, Hawaii has always been dropped from determination of the curve, and Hawaii receives an A+. In this first effort to grade the commercial sector by itself, the scores for Maine and Vermont are also very high, and a more reasonable

[2] EPMI 2016. *Understanding Commercial and Service Sector Energy Use*, http://epminst.us/commercial/commercial.htm

curve can be obtained by also dropping Maine and Vermont. The figure below displays commercial sector energy use per capita vs model scoring ratio using the scoring model here.



Whatever the cause, commercial sector energy use per capita in Maine and Vermont is on the lower end of the scale, and their score — where the score is the ratio of modeled to actual sectoral energy use — is fairly high. Hawaii scores so high due to the factors mentioned previously, and Maine and Vermont have some type of influence that is also impacting their scores. Possibly a primary factor is highly effective energy conservation efforts in the commercial sector in those states.

Additional effects related to weather, such as wind effects, which are not treated using degree-days, may be in play to some extent. Wind effects are difficult to model, and population-weighting of wind effects would make obtaining readily usable data even more challenging.

With the understanding that only degree-day and basic population effects are handled by this scoring approach, and that an overall reasonable distribution of grades is desired, the grading curve is set using Nevada as the point of '100' on the grading scale. Nevada is something of an exception also, in that extensive dedicated federal funding to develop expertise in building energy management and run building energy efficiency efforts has been received in-state.

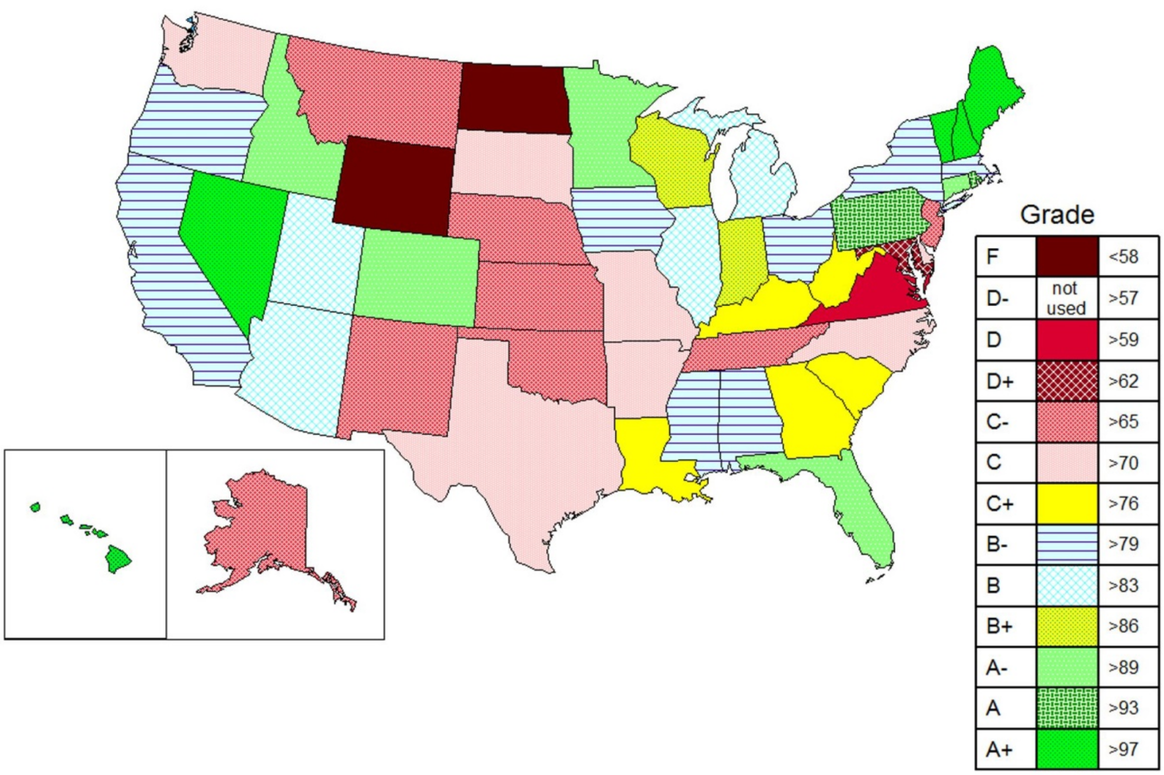
State Commercial Sector Energy Performance Grades

Based on using Nevada as '100' on the grading scale, the numerical and equivalent letter 'grades' for state commercial sector energy performance are shown in the following table. A map follows the table that shows the state grades and includes a table indicating the letter grade numerical cutoffs.

State	Performance Grade	
	Numerical	Letter
Alabama	80	B-
Alaska	69	C-
Arizona	86	B
Arkansas	74	C
California	83	B-
Colorado	93	A-
Connecticut	90	A-
Delaware	74	C
District of Columbia	27	F
Florida	92	A-
Georgia	79	C+
Hawaii	100	A+
Idaho	90	A-
Illinois	85	B
Indiana	87	B+
Iowa	83	B-
Kansas	68	C-
Kentucky	78	C+
Louisiana	77	C+
Maine	100	A+
Maryland	64	D+
Massachusetts	82	B-
Michigan	84	B
Minnesota	92	A-
Mississippi	81	B-
Missouri	71	C
Montana	70	C-
Nebraska	70	C-
Nevada	100	A+
New Hampshire	98	A+
New Jersey	66	C-
New Mexico	68	C-
New York	83	B-
North Carolina	74	C
North Dakota	57	F
Ohio	81	B-
Oklahoma	70	C-
Oregon	82	B-
Pennsylvania	95	A
Rhode Island	95	A

State	Performance Grade	
	Numerical	Letter
South Carolina	78	C+
South Dakota	75	C
Tennessee	68	C-
Texas	75	C
Utah	86	B
Vermont	100	A+
Virginia	60	D
Washington	75	C
West Virginia	77	C+
Wisconsin	87	B+
Wyoming	49	F

Map of State Grades



The District of Columbia has a grade of ‘F’. Delaware has a ‘C’ and Rhode Island has an ‘A’.

Scoring Data

In addition to providing a "grade" on sectoral energy performance, the raw scoring results also allow calculations of reductions in total primary energy use needed to achieve improved scores. The table below lists the calculated "average" primary energy use expected to be used in the commercial sector for each state (Modeled Primary) based on the scoring model. The Scoring Ratio is the Modeled Primary energy divided by the SEDS sectoral "total" (primary) energy for 2014. The 'grade' for Nevada was set to 100, so if a state wanted to have a 'grade' of 100, the modeled primary energy would need to be 1.237 times the actual energy used. Similarly, since the grade for Arizona was 86, the scoring ratio would need to be about 1.069 to achieve a grade of 86. [1.069 divided by 1.237 is 0.864 or 0.86 — alternatively, 0.86 times 1.237 = 1.064]

State	Grade	Modeled Primary Energy, Trillion Btu	2014 Primary Energy, Trillion Btu	Scoring Ratio
Alabama	80	260,292	262,362	0.992
Alaska	69	54,079	63,207	0.856
Arizona	86	360,752	337,511	1.069
Arkansas	74	166,116	182,540	0.910
California	83	1,450,339	1,418,499	1.022
Colorado	93	322,910	281,985	1.145
Connecticut	90	211,540	190,873	1.108
Delaware	74	52,493	57,258	0.917
District of Columbia	27	37,653	112,332	0.335
Florida	92	1,105,680	974,148	1.135
Georgia	79	533,201	548,785	0.972
Hawaii	100	91,169	38,836	2.348
Idaho	90	96,397	87,019	1.108
Illinois	85	859,333	820,066	1.048
Indiana	87	418,395	390,446	1.072
Iowa	83	219,836	213,305	1.031
Kansas	68	181,513	214,717	0.845
Kentucky	78	254,311	263,941	0.964
Louisiana	77	254,401	268,214	0.948
Maine	100	88,819	62,754	1.415
Maryland	64	336,369	423,946	0.793
Massachusetts	82	398,280	394,185	1.010
Michigan	84	646,314	624,750	1.035
Minnesota	92	420,736	368,950	1.140
Mississippi	81	162,803	162,001	1.005
Missouri	71	376,360	427,849	0.880
Montana	70	67,516	78,166	0.864
Nebraska	70	122,707	141,432	0.868
Nevada	100	148,662	120,160	1.237
New Hampshire	98	85,572	70,615	1.212
New Jersey	66	510,883	621,644	0.822
New Mexico	68	105,223	125,185	0.841
New York	83	1,160,887	1,134,798	1.023

State	Grade	Modeled Primary Energy, Trillion Btu	2014 Primary Energy, Trillion Btu	Scoring Ratio
North Carolina	74	530,065	576,712	0.919
North Dakota	57	58,193	82,447	0.706
Ohio	81	713,116	709,409	1.005
Oklahoma	70	229,632	265,802	0.864
Oregon	82	192,670	189,301	1.018
Pennsylvania	95	765,773	652,743	1.173
Rhode Island	95	60,590	51,528	1.176
South Carolina	78	258,728	267,955	0.966
South Dakota	75	59,735	64,260	0.930
Tennessee	68	364,373	434,474	0.839
Texas	75	1,528,987	1,638,786	0.933
Utah	86	167,884	157,372	1.067
Vermont	100	42,693	26,597	1.605
Virginia	60	458,844	615,607	0.745
Washington	75	348,505	376,493	0.926
West Virginia	77	106,345	112,290	0.947
Wisconsin	87	412,026	380,847	1.082
Wyoming	49	37,973	62,402	0.609

Usage

If performance comparisons among states are desired, modeling of performance in order to obtain a measured performance score can offer some benefits:

1. Energy performance of states can be compared with increased confidence, although there are likely to always be complaints about scores and methods
2. Improvements in performance scores can be used as goals
3. Relative performance of states might be used to determine levels of incentives or types of incentives that are offered
4. If the credibility of the performance scores is reasonably good, the scores can provide some political motivation for action

The performance measurement methods here are intended to allow readily understandable large-scale measurement of the energy performance of the US commercial sector. Use of these methods allows initial development of a program foundation for achieving large-scale energy use reductions in the commercial sector. Or at least to begin to speak more definitively about energy performance on a wider scale.