Assessing the Electric Productivity Gap and the U.S. Efficiency Opportunity

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RMI | Rocky Mountain Institute

About RMI

Rocky Mountain Institute® (RMI) is an independent, entrepreneurial, nonprofit organization. We foster the efficient and restorative use of resources to make the world secure, just, prosperous, and life-sustaining.

Our staff shows businesses, communities, individuals, and governments how to create more wealth and employment, protect and enhance natural and human capital, increase profit and competitive advantage, and enjoy many other benefits — largely by doing what they do far more efficiently.

RMI brings a unique perspective to resource issues, guided by the following core principles:

- •Advance Resource Productivity Systems
- •Thinking Positive Action Market-Oriented Solutions
- •End-Use/Least-Cost Approach
- •Biological Insight
- •Corporate Transformation
- •The Pursuit of Interconnections
- •Natural Capitalism

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Series Overview:

Closing the Efficiency Gap Research

We need a new utility paradigm to significantly reduce global greenhouse gas emissions from electricity production and energy consumption. At RMI, we are envisioning how an electric utility that generates less than 20 percent of its electricity from fossil fuels and nuclear would operate. This electric utility would meet demand through energy efficiency, renewables, demand response, and distributed generation. The foundation of this model is energy efficiency; however, efforts to increase efficiency must be ramped up in order for this new utility paradigm to succeed.

Utilities, policy makers and business people are taking positive actions to overcome the barriers to energy efficiency on both the state and national level. However, few have compared states to each other to determine why some states have been much more effective at using efficiency as a resource. Such a comparison shows there is a real and large electric productivity gap ($GDP/kWh) between states.

This paper is the first in a series that will provide states with clear levers, that when pulled, will increase electric productivity through accelerated energy efficiency implementation. In this paper RMI shows that the gap between our top ten states and the national average is large and strongly suggests that the U.S. has the opportunity to rapidly reduce the carbon footprint of electricity while growing our economy.

The second paper will focus on solutions to close the electric productivity gap. First we will identify the efficiency opportunities open to states. Many of these have been well known for years but we prioritize them in order to keep focused on those most likely to generate near term impact. We also identify the key enabling levers such as building codes, utility cost recovery mechanisms, and performance incentives that are required to unleash and accelerate capture of the opportunity.

Our final paper in the series will focus on our implementation efforts. RMI believes that in order for energy efficiency to truly be regarded as a resource, we must conduct an in-depth analysis of one or two states. While performing this “deep dive” RMI will partner with regional and local energy efficiency stakeholders to ensure clear understanding and buy-in to achieve real traction is present.

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Executive Summary

The electric power industry is one of the most resource intensive industries in the world. In the United States alone, the electric power industry is responsible for emitting approximately one-third of all greenhouse gas emissions (GHG) in the country. Largely, these emissions come from the combustion of fossil fuels to create electricity. Any solution that seriously seeks to address concerns about climate change, energy security, and rising energy costs will need to make energy efficiency the first and foremost component in a portfolio of solutions.

It is commonly known that energy efficiency implementation has not achieved its technical or economically feasible potential in the United States, and many have attempted to quantify how much electricity the U.S. can save in the future. However, few have compared states to each other to determine why some states have been much more effective at using efficiency as a resource.

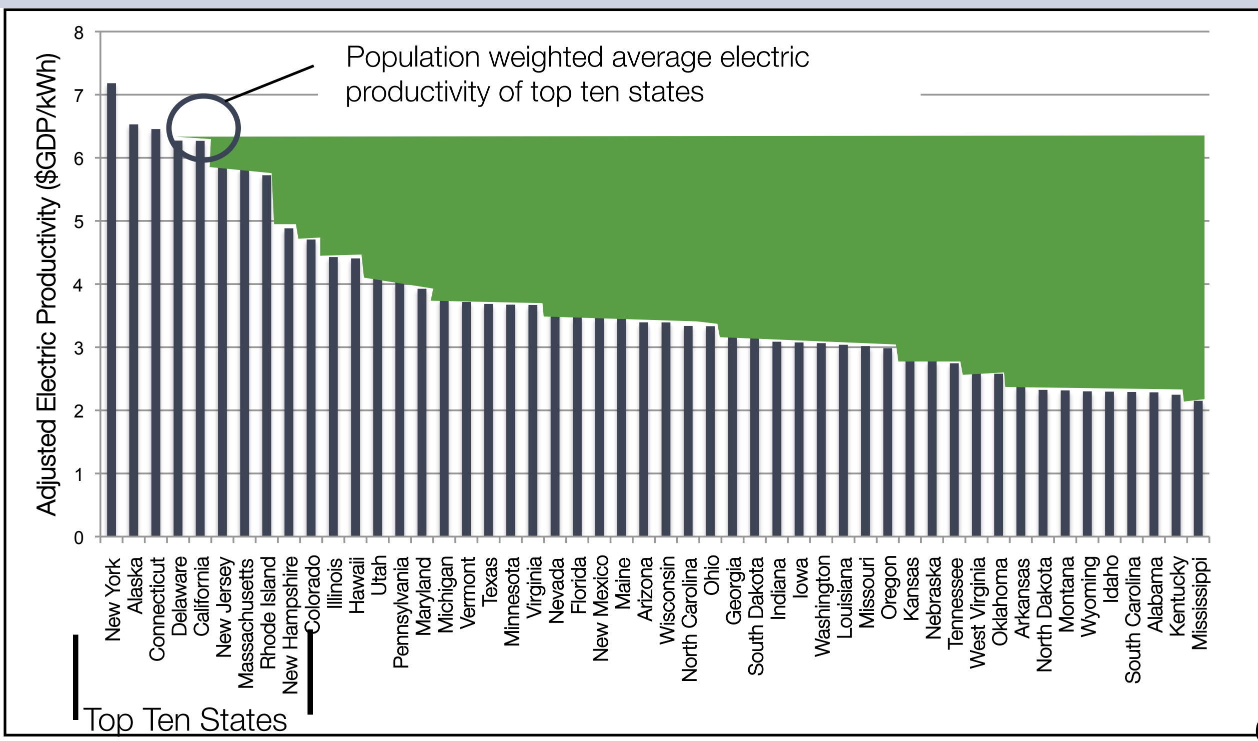
This paper explores one aspect of the energy efficiency solution: how effectively has the United States used its electricity? RMI conducted this analysis on state-level electric productivity (measured in dollars of gross domestic product divided by kilowatt-hours consumed, or $GDP/kWh) to determine what states are the most productive with their electricity.

The primary findings of this paper are:

- The electric productivity gap between the top performing states and the rest of the nation is immense.
- There is a huge gap in the implementation of efficiency. If the rest of the country achieved the normalized electric productivity of the top performing states, with 100 percent adoption, the country would save a total of ~1.2 million gigawatt-hours annually.
- 1.2 million gigawatt-hours is the equivalent of 30 percent of our annual electricity use, or 62 percent of our nation's coal fired electrical power.
- In 2020, if the United States can, on average, achieve the electric productivity of the top performing states today, we can anticipate a 34 percent reduction in projected electricity demand, while maintaining 2.5 percent annual economic growth.
- For the purposes of this analysis, the top performing states that lead the nation and define the electric productivity gap are not shown as having gap. This does not mean that these states have exhausted all technical, economic or achievable efficiency. To the contrary, RMI believes that these states still have the opportunity to greatly enhance their electric efficiency, which this study does not consider.

National Adjusted Electric Productivity Gap

The normalized electric productivity gap between the top 10 states and the rest of the country is 1.2 million GWh.



Credit: mangpages

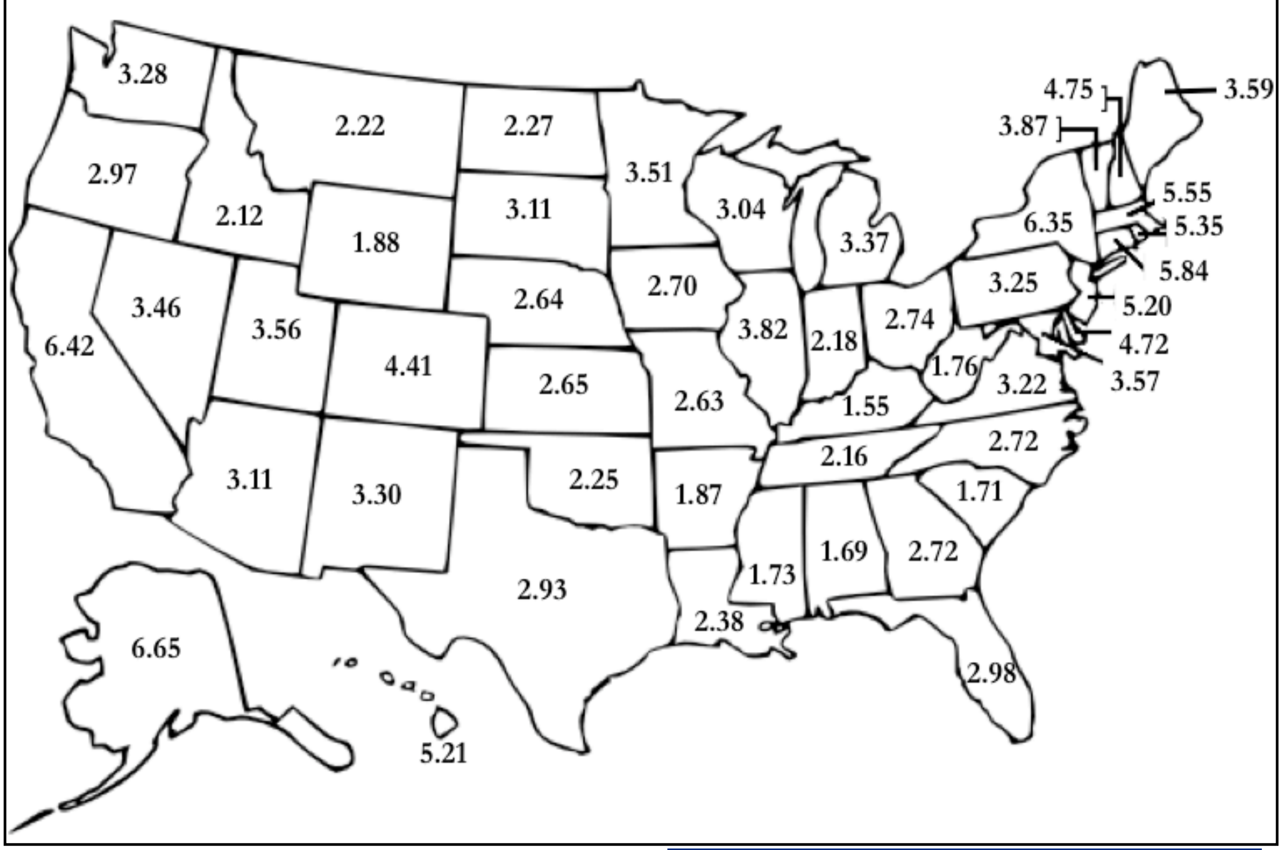
I. Introduction

The role that energy efficiency has historically played in the U.S. is generally under appreciated. If energy productivity had remained constant since 1970, the U.S. would have consumed 207.3 quadrillion BTUs in 2007 when it actually consumed only 101.6 quads. In other words, the U.S. consumed less than half of what was projected. While some of this increase in productivity can be attributed to changes in the economy, economists have estimated that improvements in energy efficiency have been responsible for a 65-75 percent increase in productivity since 1970.[1] If the U.S. had instead attempted to meet this demand through generation alone, costs would have been significantly higher (~ $1.65 trillion more) and severely hindered this economic progress.

Over that same time period, some states have been much better than others at employing energy efficiency as a resource to meet total energy demand. The disparity between the top states and the rest of the country is not an issue that many utilities, policy-makers, and business leaders are aware of. In this paper, RMI highlight the enormity of the gap between top performing states and the rest of the country.

[1] Metcalf 2004.

Figure 1: Electric Productivity by State, 2005. Units expressed in $GDP/kWh.



II. State Electric Productivity

What is Electric Productivity?

Electric productivity is measured as dollars of gross domestic product (GDP) per kilowatt-hours (kWh) consumed.

For more than 30 years, the benefits of energy efficiency have been espoused, yet, as a nation, achievement rates fall far short of the economically feasible potential. In an effort to better understand the efficiency opportunity, RMI conducted analysis on electric productivity (measured in dollars of gross domestic product divided by kilowatt-hours consumed, or $GDP/kWh).

RMI chose to use electric productivity for several reasons. First, though the metric is not a perfect indicator, electric productivity helps gauge which states are using electricity most efficiently. Second, it is a metric that allows business people and policy makers to understand the positive economic impact of holding constant, or reducing, electricity consumption. Third, it provides states with a measurable goal that they can move towards, and also compare how similar states are progressing. Finally, we can use electric productivity as a metric to measure progress, and to reinforce the actions of high performing states at the Federal level.

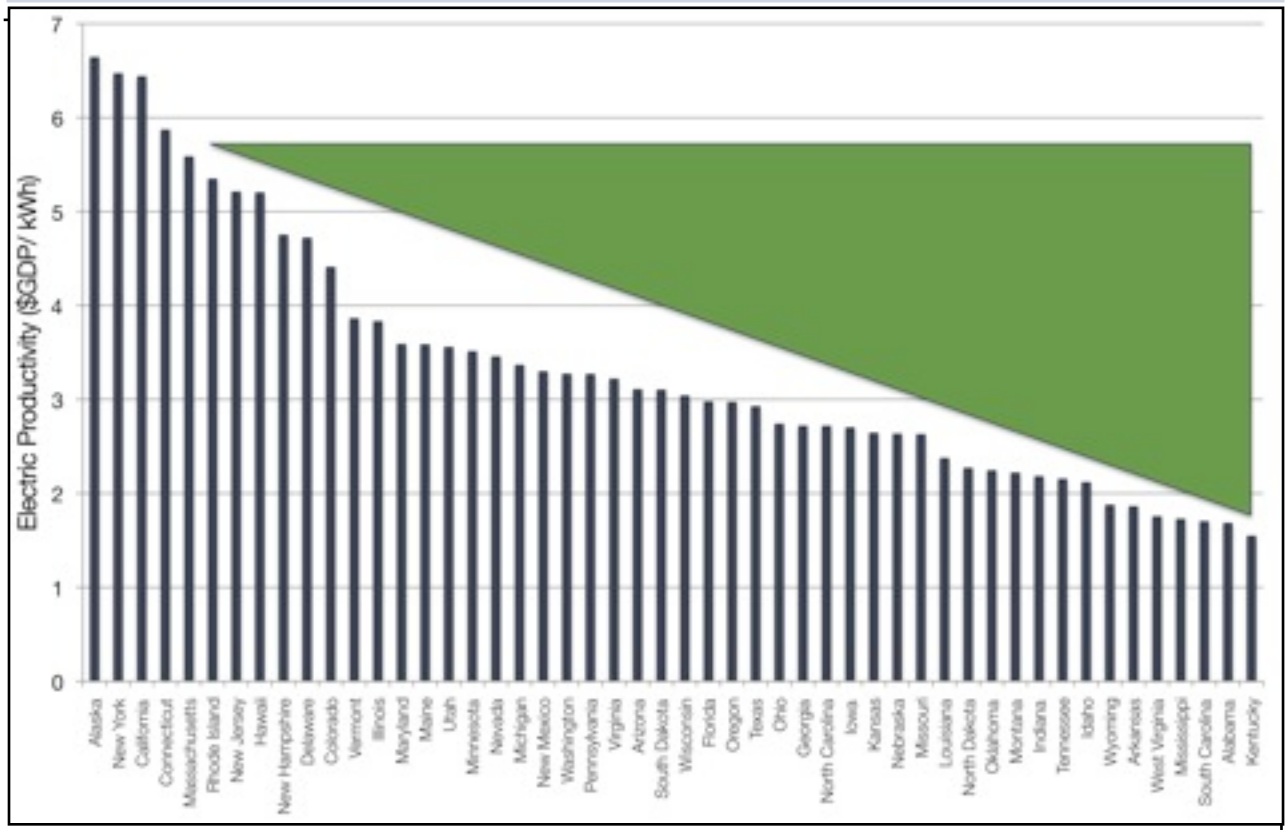
Using 2005 electricity consumption and gross domestic product data, RMI compiled each state's electric productivity, as shown in Figure 1. In 2005, the national average, population-weighted, electric productivity was $3.76 of GDP per kilowatt-hour consumed. For the same period, the average, population-weighted, electric productivity of the leading ten states was $6.10 of GDP per kilowatt-hour (kWh) consumed.

Much of RMI's analysis focuses on the average electric productivity of the top ten states, which are referred to as the "top performing states" throughout the analysis. The purpose of this analysis is to estimate how much electricity would be saved if all states achieved the electric productivity of the top performing states through energy efficiency. RMI believes that the productivity of the top performing states serves as solid benchmark for what other states can achieve. However, it is important to say that these top ten states still have large efficiency opportunities themselves-—no state has come close to capturing all cost-effective efficiencies.

The electric productivity gap that exists is quite apparent, as shown in Figure 2, where states are ranked based on their electric productivity, ordered from left to right, without any adjustments. California and New York, for example, both earned greater than one and a half times more GDP per kWh consumed than the national average. If the national average electric productivity improved to the level of the top performing states, the country would have saved over 1.6 million GWh in 2005. This is the equivalent to the output of over 75 percent of coal-fired generation in the United States in 2007.

Simplistic conclusions drawn from the raw data on electrical productivity are rightly open to criticisms. Factors such as a hot and humid climate that increases cooling demand or an economy heavily reliant on electric-intensive manufacturing could drastically affect a state's productivity. To understand which states are actually the best performing, RMI normalized the exogenous factors that skew electric productivity.

Figure 2: 2005 National Electric Productivity Gap
The electric productivity gap between the top 10 states and the rest of the country is 1.6 million GWh.



III. Normalizing Productivity

For the first phase of our analysis, RMI investigated whether the electric productivity gap is real or can be explained away by factors beyond the control of individual states. There are numerous factors that can increase electric productivity including:

- Mild climates
- Service based economy
- Electricity rates
- Culture
- Split incentives
- Information/cost barriers
- Regulation bias for supply-side resources
- Long-term state policy support for electric efficiency

Of the many possible factors, most are within the control of states and their inhabitants. That said, a few skew electric productivity such that they must be accounted for before drawing conclusions. Notably, the two factors that are outside the near-term control of the state are climate and state economic composition.

RMI chose to look at the impact that climate has on electric productivity because geographic location will inevitably affect the amount of energy consumed. Milder climates, such as parts of California, do not need to operate heating and air conditioning systems as often as more extreme climates, such as Alabama. Therefore, it is critical to examine the real impact that climate has on electric productivity. The results of the analysis and adjustments are described below in Section A. More information on the climate adjustment and methodology is available in Appendix B.

Secondly, RMI choose to look at economic mix, for a few reasons. First, it is a common perception in the energy world that states with heavy industry use more energy, and therefore will have a lower electric productivity. To address this concern, RMI analyzed the make up of each state's economic mix to determine if industry or commercial heavy economies unfairly increase or decrease state electric productivity. The results of the analysis and adjustments are described below in Section B. More information on the economic composition adjustment and methodology is available in Appendix B.

In this paper, RMI used energy modeling alongside statistical analysis to determine how much these variables skewed productivity. RMI believes that using energy modeling and statistical analysis together provides insightful information about which states have "busted barriers" to increase the level of efficiency implementation.


Credit: chascar

A. Assessing Climate

Buildings, industry and infrastructure dominate electricity consumption, and the majority of the end uses are climate independent (Figure 3). However, climate is perhaps the most cited reason different regions in the country consume more electricity, or cannot achieve higher levels of electric productivity and energy efficiency.

There are volumes of studies attempting to explain quantify how climate affects energy consumption.[2] Most studies have normalized for weather, essentially removing it from the energy equation, to better understand how a region consumes energy over a period of time. In this study, RMI estimated how regional heating and cooling load affect electricity consumption. For example, if you had two similar buildings; one located in California, and another located in Alabama, what impact would the climate in Alabama actually have on the electricity end-use consumption?

The first variable that this analysis sought to address was whether climate has a significant impact on the ability of states to achieve higher levels of electric productivity; and, if it would eliminate some or all of the 1.6 million GWh gap that exists between high and low electric productivity states.

State Electric Productivity Climate Adjustment

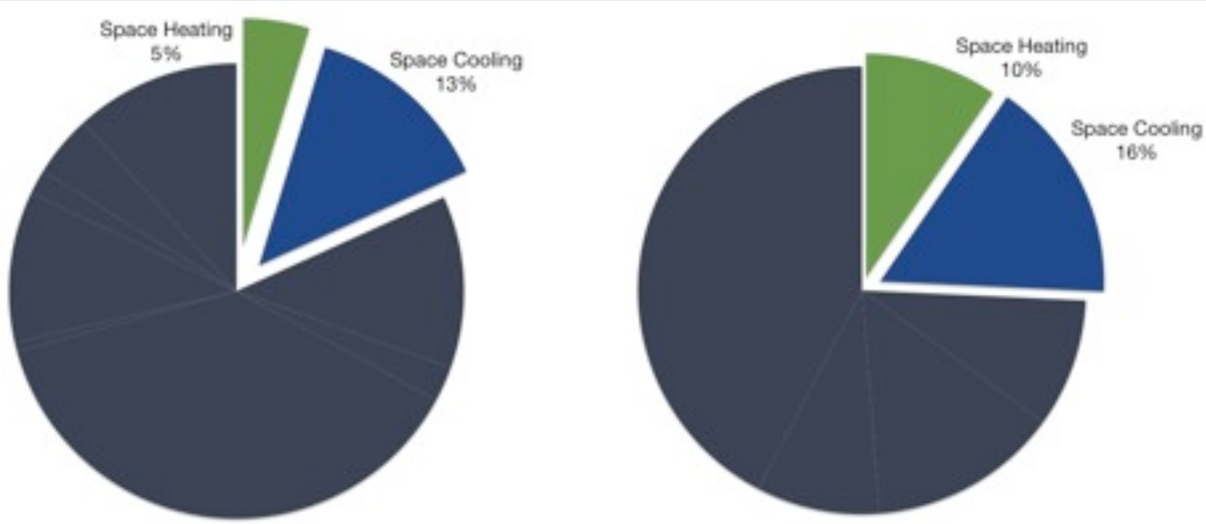
Goal: Determine how electricity consumption is affected by differences in heating and cooling load in each state:

- Divide the U.S. into five climate regions
- Choose climate representative city
- Analyze differences in electricity consumption between regions
- Identify end uses that change with climate regions
- Scale electric space cooling and heating consumption to temperate region
- Apply space cooling and heating numbers to electricity consumption

Making the Climate Adjustment

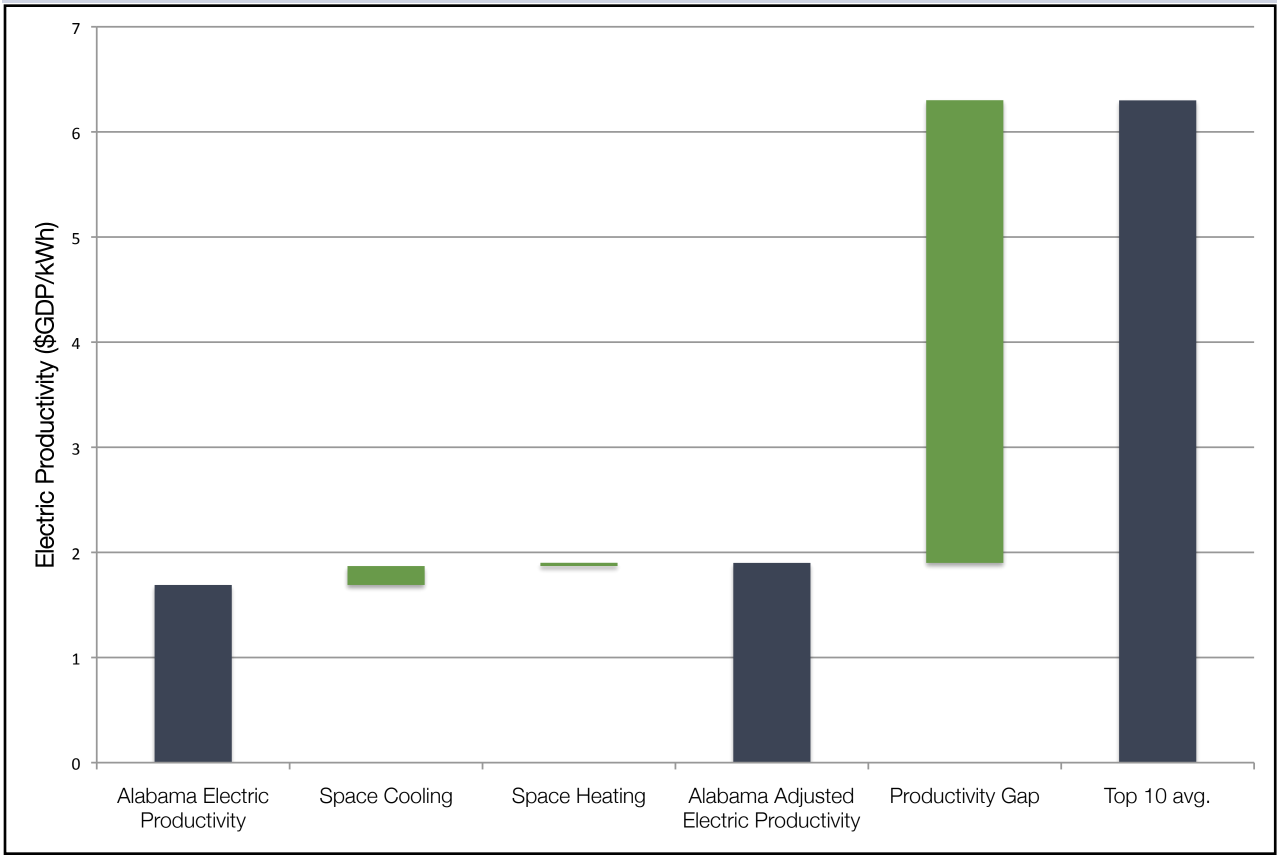
For this analysis, RMI determined the typical climate for each region and then used building energy models to quantify the impact climate has on a modern building's electricity consumption. Adjustments for consumption were only made to climate-dependent end-uses because an end-use like lighting does not vary much due to variations in

Figure 3: End-uses affected by Climate
Residential (left), commercial (right) from EIA's RECS 2001 and CBECS 2003



[2] Train et. al, 1984, Ramanthan et al. 1985, Engle et al. 1986, Hor et al. 2005

Figure 4: Climate-Adjusted Electric Productivity for Alabama
After adjusting for climate, Alabama's productivity gap is 58.6 thousand gigawatt-hours



climate.[3] Table 1 in Appendix B illustrates how climate impacts the electricity consumption in the residential, commercial, and industrial sectors for each region.

As an example Figure 4 represents how much more electricity buildings in Alabama use due to their hot, humid climate as compared to a milder, temperate climate. Moving from left to right, the first bar displays Alabama's 2005 electric productivity without any adjustments. The next two bars display how many more megawatt-hours Alabama uses in due to its hot and humid climates.

The fourth bar shows Alabama's electric productivity, with its climate adjustment. Alabama receives a 15 percent increase in electric productivity due to its climate. The fifth bar shows the electric productivity gap that still exists between Alabama, with its climate adjustment, and the electric productivity of the top performing states. Finally, the last bar shows the average, population weighted electric productivity of top performing states.

Alabama is not a special state. With the exception of a few of the top performing states, each state continued to have a large electric productivity gap after its climate adjustment. States with less temperate climates do consume more electricity but climate does not account for the disparity between the top states and the rest of the country. If all states had a climate

Why Alabama?
RMI uses Alabama as an example to illustrate how adjustments were made to productivity in a state with a hot and humid climate and high amounts of energy-intensive industry. Even with these adjustments, Alabama still has a large productivity gap.

[3] To see how climate-dependent end-uses vary by region, see Table 1 Appendix B.

similar to the temperate region, RMI estimates that national electricity demand would be approximately 10 percent lower.

B. Assessing Economic Composition

The second variable commonly mentioned as a barrier to achieving higher electric productivity is state economic composition. For example, California's service-based economy is commonly attributed for falsely inflating its electric productivity. The goal of our economic composition analysis was to determine the electric consumption impact of different economic compositions. RMI's analysis suggests that, for many states, strong commercial sectors increase a state's electric productivity. However, some of the best performing states have a high proportion of electric-intensive industries, and many poor-performing states have a low proportion of electric-intensive industries.

Making the Economic Composition Adjustment

To address the impact that economic composition has on state electric productivity, RMI assessed how much state electricity consumption would change if all states had the economic composition of top performing states.[4]

States where industry accounts for a large proportion of GDP generally have lower electric productivity because the commercial sector generally has much higher electric productivity.[5] Thus, states with high industrial compositions generally received an upward boost to electric productivity.

Service-based Economy

Due to their large commercial sectors, some states have a high productivity due to the state economic composition rather than using their electricity efficiently. For instance, a state which has had a strong real-estate sector will have an advantage over a state with a heavy industrial base because less electricity is required to produce one dollar in GDP in real estate compared to an aluminum smelter. As a result, RMI adjusted states' electric productivity based on the proportion of GDP that comes from the commercial sector.

In order to make this adjustment, RMI looked at the percentage of GDP that comes from each state's commercial and industrial sectors[6] and adjusted the electric productivity as if each state had the same economic composition of the top performing states. This adjustment was our largest and there is little doubt that states service-based economies had an advantage before this adjustment was made.

State Electric Productivity Economic Composition Adjustment

Goal: Determine how electricity consumption changes if all states have the same economic composition, including energy-intensive sub-sectors.

- Examine states' industrial and commercial makeup
- Estimate electricity consumption by NAICS 3-digit code for industrial sub-sectors
- Scale electricity consumption by energy-intensive industries to that of the top performing states
- Adjust commercial/industrial GDP makeup to that of the top performing states

Electric-Intensive Industry

RMI decided to look one level deeper, into the details of the industrial sub-sector data. Industrial sub-sector data provides one more level of granularity in economic composition data. The notion that the sub-sectors are what skew electric productivity seems intuitive. States with high amounts of electric-intensive industries, such as aluminum smelters or concrete manufacturing, should have a lower productivity than states with an industrial makeup consisting of agriculture and construction, which require much less electricity per unit of GDP.

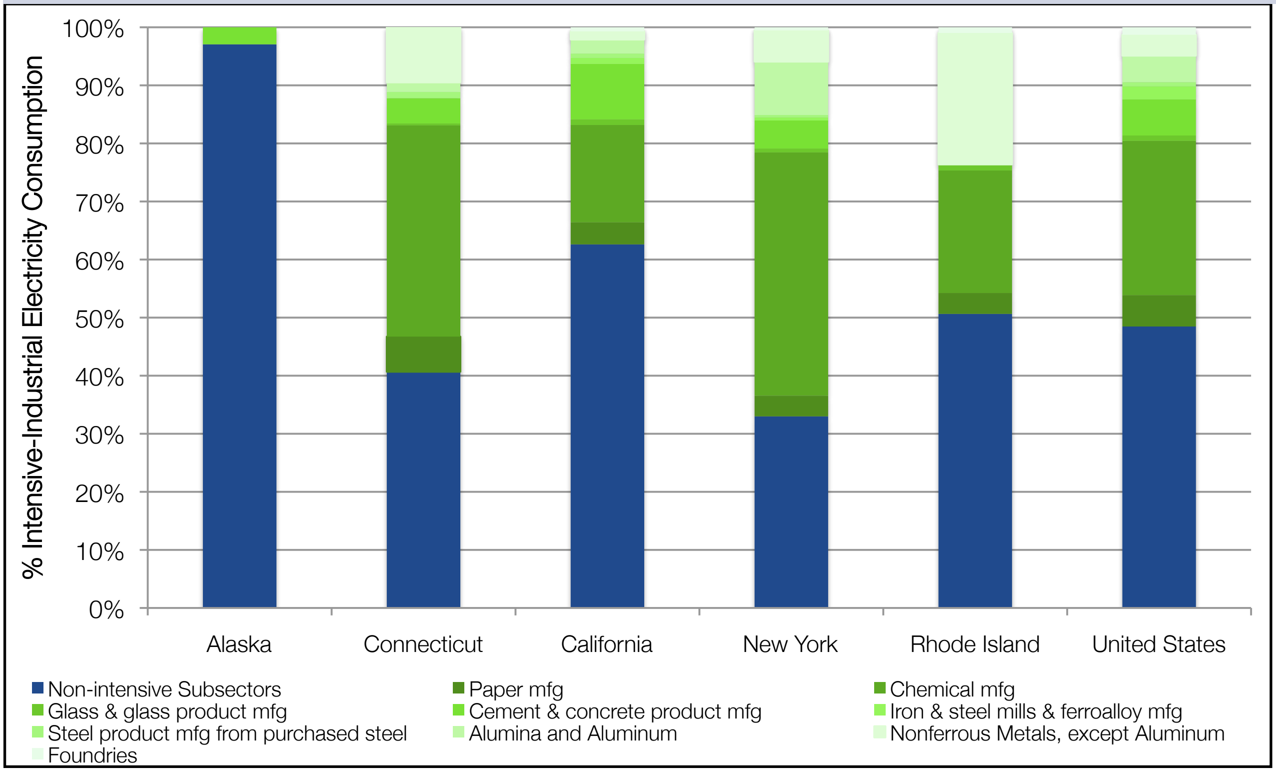
[4] According to Bureau of Economic Analysis, the top ten electric productivity states have an economic mix of approximately 84 percent commercial and 16 percent industrial, while the national average economic mix in comparison is 78 percent commercial and 22 percent industrial.

[5] 2005 national commercial productivity (dollars of commercial GDP/ commercial electric sales) was 7.57 compared to 2.63 for industrial productivity (dollars of industrial GDP/industrial electric sales).

[6] GDP derived from government spending was excluded from this adjustment.

Figure 5: Industrial Electricity Composition for Top Performing States and National Average

The amount of electric-intensive industries in top states varies little compared to the national average

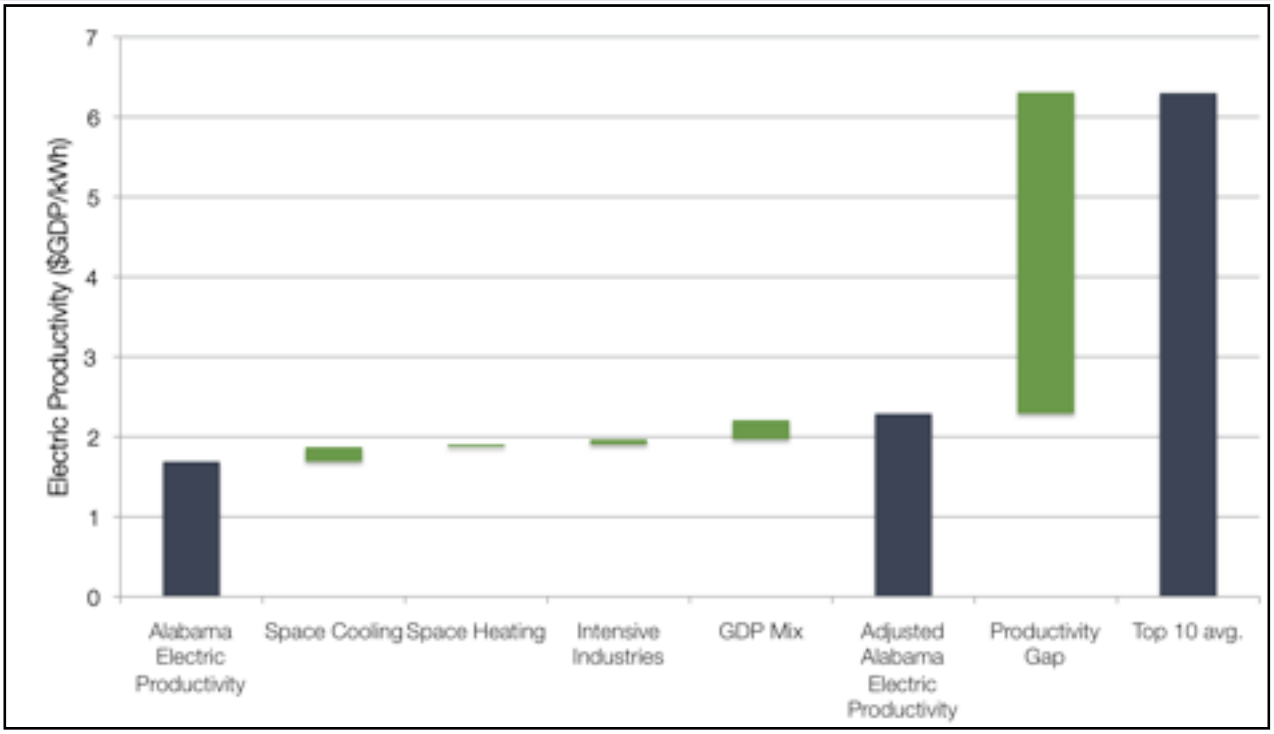


However, the analysis indicates that some of the best performing states have a high proportion of electric-intensive industries, as shown in Figure 5.

That said, RMI adjusted state electricity consumption as if all states had the same proportion of industrial electricity consumption from high electric-intensive sectors. Overall, this adjustment increased the size of the gap because the top performing states have a higher proportion of electricity consumption from intensive industries than the national average. Top performing states, RMI believes, have used efficiency in their industries and increased productivity while other states still have tremendous opportunities to increase their efficiency.

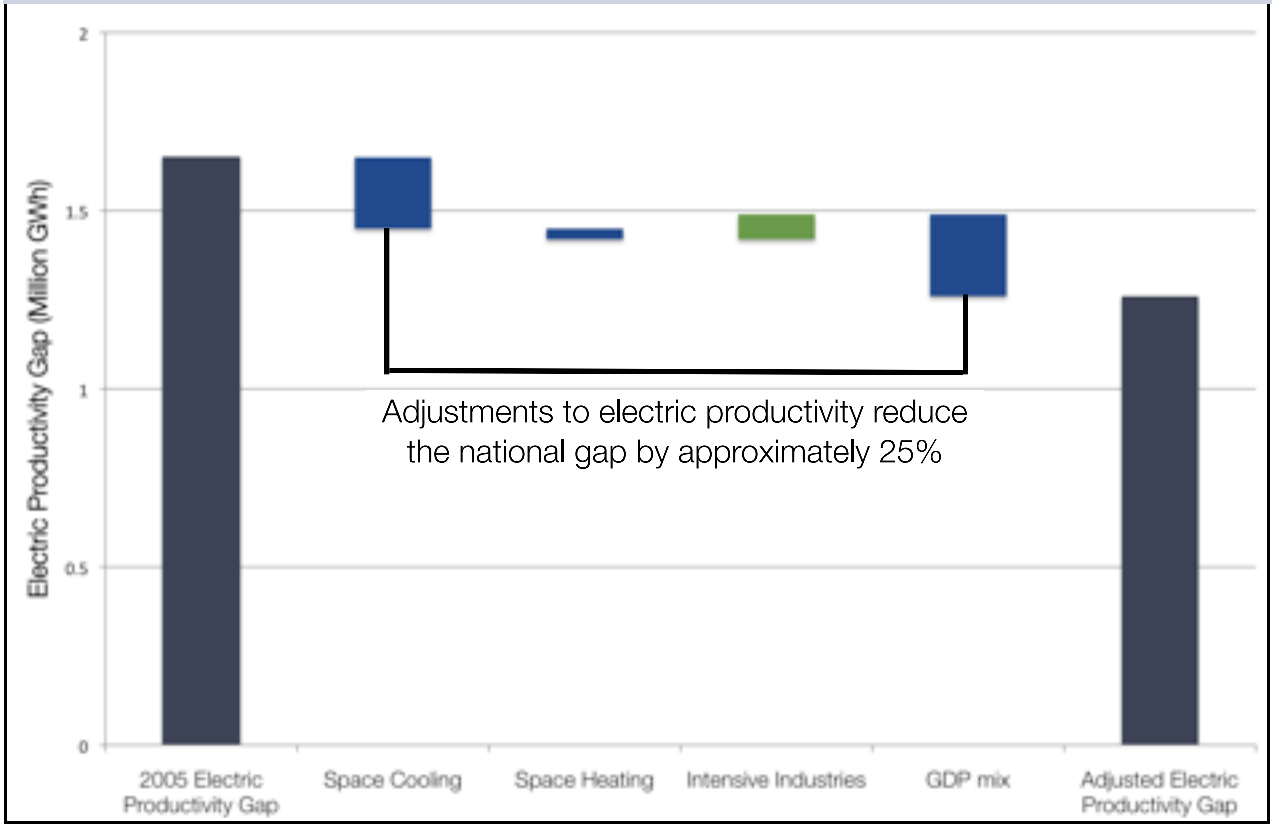
Continuing with the Alabama example, Figure 6 displays the incremental changes in electric productivity from the industrial and commercial economic composition adjustments. Moving from left to right, the first bar displays Alabama's 2005 electric productivity without any adjustments. The next two bars display how many more megawatt-hours Alabama uses in residential, commercial and industrial sector than a temperate climate due to its hot, humid weather, as discussed above.

Figure 6: Electric Productivity for Alabama Adjusted for Climate and Economic Composition
After adjusting for climate and economic composition, Alabama's productivity gap is 38.6 thousand gigawatt-hours



The fourth and fifth bars from the left are the economic adjustments. The fourth bar indicates how many fewer megawatt-hours Alabama would consume if the size of electric-intensive industries were reduced to the same size as the top performing states. The fifth bar represents how Alabama's electricity consumption would improve if its commercial and industrial GDP makeup was the same as the top performing states. The sixth and seventh bars represent Alabama's adjusted electric productivity and the productivity gap. Finally, the last bar shows the average, population weighted, electric productivity of top performing states.

Figure 7: Estimated National Efficiency Gap
National Efficiency Gap after all Adjustments is 1.2 million GWh



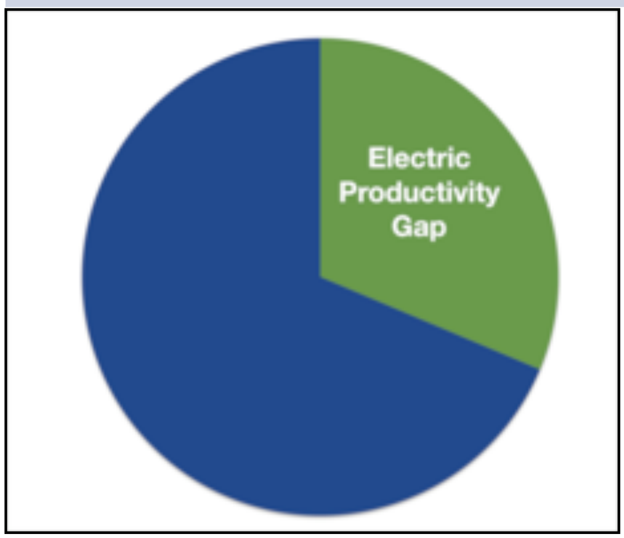
IV. Conclusion

On a national level, the productivity gap, after adjustments, is 1.2 million GWh. RMI's analysis indicates that while climate and economic mix adjustments to electric productivity account for approximately 25 percent of the gap (Figure 7), there is a real gap in state electric productivity that cannot be explained by factors outside the near-term control of the states.

Even with a quarter of the electric productivity gap removed, increasing state electric productivity through energy efficiency is probably the largest near term opportunity to reduce both electricity use and greenhouse gases. Simply put, the productivity gap is equivalent to approximately 31 percent of 2005 electricity sales (Figure 8) and the equivalent of 62 percent of coal generation. (Figure 9).

The electric productivity gap is large enough that utilities, business leaders, NGOs and governments should take note of it, and focus on closing the gap as opposed to refining the size of the gap to the next level of granularity. Even if another 15 percent of the electric productivity gap was eliminated through

Figure 8: National Electric Productivity Gap as a Proportion of 2005 Retail Sales
The electric productivity gap is 31% of 2005 Retail Sales



additional normalizations, the gap would still be over 1 million GWh.

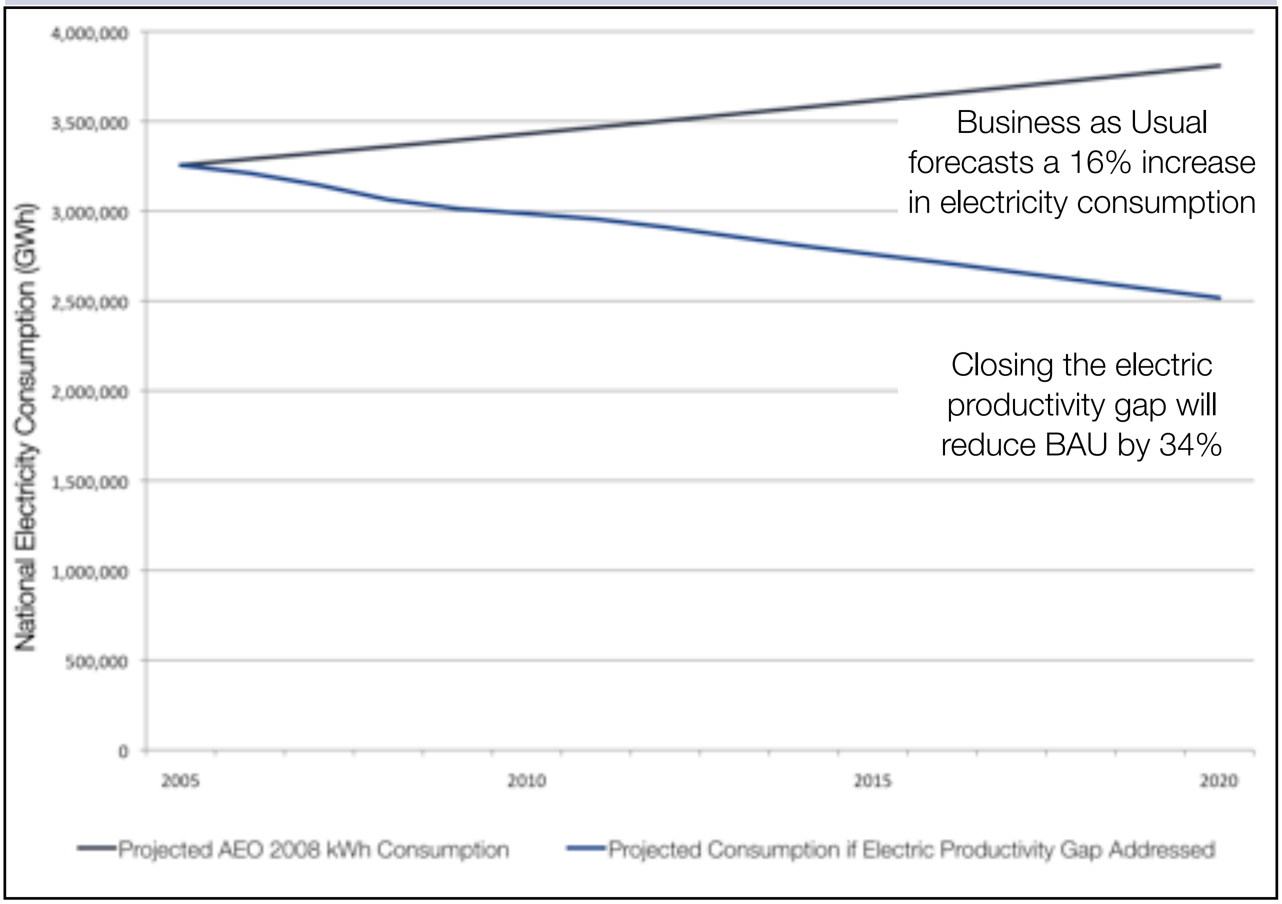
In order to have a measurable impact or drastically reduce our greenhouse gases, eliminating the electric productivity gap will need to be done in a relatively short period of time, and stakeholders will need to begin acting now.

RMI believes that the U.S. can close the electric productivity gap in ten years because the technology and policy solutions are already known, available and tested.

Closing the gap will be require a large and concerted effort. States must immediately begin installing all cost-effective efficiency measures to ensure that they achieve the electric productivity of today's top performing states.

As shown in Figure 9, Business as Usual (BAU) will result in a 16 percent increase in electricity consumption, and a 2.5 percent annual growth in GDP by 2020. However, if states begin to implement energy efficiency measures to close the electric productivity gap now, the nation can reduce electricity consumption by 34 percent from Business as Usual in 2020, while maintaining the 2.5 percent annual GDP growth.[7]

Figure 9: Addressing Productivity Gap by 2020
If the national electric productivity gap in 2020 is the productivity of the top 10 states today, a 34 percent reduction in demand will occur, more than flattening load growth.



[7] Auffhammer (2006), Chinkatron and Millimet (2006), Bernstein, et al. (2003)

V. Next Steps

For the next papers released in this series, RMI will show how this gap can be addressed through efficiency. RMI believes there are two major levers that states can pull to encourage efficiency and close the electric productivity: physical levers and policy levers.

The next step of RMI's analysis will focus on the impact that efficiency measures can have on existing building stock in the residential, commercial and industrial sector, and if a combination of these measures will cost-effectively close the electric productivity gap in each state.

The physical levers RMI will analyze include measures such as CFLs, weatherization, installation of more efficient appliances, and updating heating and air conditioning systems.

The policy levers will include measures such as stricter building energy codes and appropriate utility compensation for energy efficiency.

The final step for RMI's electric productivity research is implementation. RMI's hypothesis is that in order to actually achieve higher levels of energy efficiency penetration, a new approach is necessary. The most critical element of implementing energy efficiency solutions to close the electric productivity gap is to bring together diverse stakeholders in a state, or utility jurisdiction that have historically been divided.

Appendix A. State Adjusted Electric Productivity and Efficiency Goals

State	2005 electric productivity	Adjusted electric productivity	Electric productivity gap (GWh)	Annual electric reduction to meet goal in 10 years (%)
New York	6.47	7.18	-	--
Alaska	6.65	6.53	-	--
Connecticut	5.87	6.46	-	--
Delaware	4.72	6.27	42	--
California	6.44	6.27	1,333	--
New Jersey	5.21	5.89	4,663	--
Massachusetts	5.59	5.83	4,071	--
Rhode Island	5.35	5.72	689	--
New Hampshire	4.75	4.88	2,463	--
Colorado	4.41	4.71	11,479	--
Illinois	3.84	4.43	37,204	--
Hawaii	5.21	4.41	3,744	--
Utah	3.56	4.14	7,345	0.3%
Pennsylvania	3.27	4.04	42,955	0.5%
Maryland	3.59	3.93	23,420	0.7%
Michigan	3.37	3.77	39,725	0.9%
Vermont	3.87	3.72	2,511	1.0%
Texas	2.93	3.69	110,298	1.0%
Minnesota	3.52	3.67	26,332	1.0%
Virginia	3.22	3.67	39,872	1.0%
Nevada	3.46	3.60	13,375	1.1%
Florida	2.98	3.50	85,307	1.3%
New Mexico	3.30	3.48	8,779	1.3%
Maine	3.59	3.46	5,770	1.4%
Arizona	3.11	3.39	29,341	1.5%
Wisconsin	3.04	3.39	29,115	1.5%
North Carolina	2.72	3.34	49,255	1.6%
Ohio	2.74	3.33	62,092	1.6%
Georgia	2.72	3.17	56,520	1.8%
South Dakota	3.11	3.15	4,833	1.8%
Indiana	2.19	3.09	38,472	1.9%
Iowa	2.70	3.08	19,243	2.0%
Washington	3.28	3.06	45,812	2.0%
Louisiana	2.38	3.04	31,366	2.0%

State	2005 electric productivity	Adjusted electric productivity	Electric productivity gap (GWh)	Annual electric reduction to meet goal in 10 years (%)
Missouri	2.63	3.02	36,788	2.0%
Oregon	2.98	2.98	24,352	2.1%
Kansas	2.65	2.84	19,986	2.3%
Nebraska	2.64	2.79	14,252	2.4%
Tennessee	2.16	2.75	46,073	2.5%
West Virginia	1.76	2.60	11,960	2.7%
Oklahoma	2.25	2.58	27,636	2.7%
Arkansas	1.87	2.38	22,550	3.0%
North Dakota	2.27	2.32	6,695	3.1%
Montana	2.22	2.32	8,183	3.1%
Wyoming	1.88	2.30	7,335	3.1%
Idaho	2.12	2.30	12,838	3.1%
South Carolina	1.71	2.29	38,515	3.2%
Alabama	1.69	2.29	41,973	3.2%
Kentucky	1.55	2.25	39,670	3.2%
Mississippi	1.73	2.15	24,331	3.4%

Appendix B. Methods for Normalizing Productivity

Climate

Climate is perhaps the most cited reason state electricity consumption and productivity vary. Academic literature discussing the composition of weather normalizations, their value and implications is extensive. For this reason, understanding how regional differences in climate skews electric productivity was very important for determining the size of the gap between high and low electric productivity states. By conducting this analysis, RMI hope that laggard states no longer attribute their low productivity to their climate.

For the purposes of our analysis, RMI determined that the major end uses affected by climate are space cooling and space heating. The need for an adjustment to space heating exists despite the fact that many states use natural gas for the majority of space heating needs. According to the Energy Information Agency (EIA), space heating accounts for a significant proportion[8] of end-use electricity consumption in all regions for the residential and commercial sectors.

Residential and Commercial Adjustment:

The first step of the analysis was to divide the country into five climate regions (Figure 10), and choose a climate representative city[9] to use for energy modeling[10]. To find the average cooling and heating needs for each region, RMI used data from the National Oceanic and Atmospheric Administration to create a population-weighted regional average. From the average number of cooling or heating degree-days, RMI matched a city to each region's climate for modeling purposes.

After identifying average cities, RMI used building energy modeling to determine the differences in electricity consumption for cooling and heating between the regions.

Figure 10: Regional-climate map

Next, to quantify how differences in cooling and heating affect electricity consumption and productivity, RMI scaled space-cooling and heating consumption to the temperate region. To scale space-cooling and heating consumption for each state, RMI took an estimated regional average percentage of end-use electricity consumption for space cooling in the residential, commercial, and industrial sectors and multiplied them by the energy model differences between space cooling and heating consumption in each region and the temperate region.

EIA's estimates for space heating as a proportion of end use consumption are very important in determining the size of the adjustment. RMI did our best to only adjust for electric space heating and not overall space heating needs. Though climate determines the amount of space heating needed, colder regions have a smaller adjustment because natural gas is more commonly used for space heating rather than electricity. Finally, RMI applied these scaled numbers to state kilowatt-hour cooling consumption (Appendix B Table 1).

Industrial Adjustment:

We expected that industrial electricity sector consumption would be the least impacted sector because a large proportion of industrial end-uses are not affected by climate. To make the industrial

[8] 10 percent residential, 5 percent commercial. RECS 2001, CBECS 2003.

[9] The representative cities were chosen by matching population-weighted NCDC cooling degree days data for each region to a city that most closely resembled the regional profile which was available in the DOE-2 eQuest TMY2 dataset.

[10] Regions were determined by maps from the Energy Information Administration (EIA) and the National Climactic Data Center (NCDC).

Appendix B Table 1: Size of Climate Adjustment for All Sectors.
% represents the change in electricity consumption if each region had the same climate as the temperate region

Region	Residential Electricity Consumption (%)	Commercial Electricity Consumption (%)	Industrial Electricity Consumption (%)
Temperate	None	None	None
Cold/humid	-9.5	-5.7	-1.7
Cold	-11.6	-8.4	-1.7
Hot/humid	-19.3	-11.9	-3.8
Hot/arid	-11.7	-8.7	-4.8

climate adjustment, we modeled one industrial facility. We adjusted the HVAC facility electricity consumption for climate, which on a national average accounts for 8.5 percent of industrial electricity consumption, as well the ability of the facility to reject heat.

Economic Composition

In order to address the idea that states with high electric productivity have low percentages of energy intensive industrial GDP, RMI analyzed state economic compositions. The primary finding is that, while there is a strong correlation between a state's economic composition and its electricity productivity, it does not consume the entire electric productivity gap that remains after adjusting for climate.

We looked at the nine most electric-intensive industrial sub-sectors by 3-digit NAICS code and estimated what percentage of the industrial electricity consumption they accounted for. To make our adjustment for electric-intensive sub-sectors, RMI adjusted state electricity consumption as if all states had the same proportion of industrial electricity consumption from high electric-intensive sectors. In this case, our adjustment varies, the range of this adjustment is between -0.8 and 0.4 $GDP/kWh.

Estimating electricity consumption by industrial sub-sector was difficult. Ultimately, we scaled EIA's *Annual Energy Outlook* national electricity intensities for industries to state value of shipments data from U.S. Census's Annual Survey of Manufactures[11]. This methodology provides little information concerning how efficiently industries in different states use electricity, but it does help us determine what proportion of state electricity sub-sectors consume. The table presented below consists of the most electric-intensive industrial sub-sectors.

To clarify the methodology, RMI compared 2005 state GDP economic mix and electric productivity to a scenario where GDP composition was equal. States with either high commercial or high industrial-compostion GDP's had the largest changes.

[11] Special thanks to our colleagues at ACEEE for help with this part of our methodology

Table 2: Electric-Intensity by Industry

NAICS Code	Industry	MMBTU/$VOS
322	Paper mfg	1.305
325	Chemical mfg	2.132
3272	Glass and glass product mfg	1.585
3273	Cement and concrete product mfg	5.43
3311	Iron & steel mills & ferro alloy mfg	1.85
3312	Steel product mfg from purchased steel	1.85
3313	Foundries	1.85
3314	Alumina and Aluminum	6.962
3315	Nonferrous Metals, except Aluminum	6.962

Other Factors

Electricity Rates:

Rates certainly impact efficiency because high electricity prices allow more efficiency measures to be cost effective. Given that our study was not a historical analysis, RMI made the decision that determining price elasticity for each state would not be accurate. Electricity rates impact on consumption will be accounted for in determining the cost-effectiveness of efficiency measures in the next phase of our analysis.

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