NATIONAL RENEWABLE ENERGY LABORATORY

State of the States 2010: The Role of Policy in Clean Energy Market Transformation

Elizabeth Doris and Rachel Gelman

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-6A20-49193
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Contract No. DE-AC36-08GO28308

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Prepared under Task No. IGST.0005

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Cover Photos: (left to right) PIX 16416, PIX 17423, PIX 16560, PIX 17613, PIX 17436, PIX 17721

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Acknowledgments

This report was produced with funding from, and in coordination with, the Department of Energy (DOE) Weatherization and Intergovernmental Program in the Office of Energy Efficiency and Renewable Energy.

The report content and design was greatly aided by input from Marguerite Kelly, Lori Bird, Kate Young, Doug Arent, Joyce McLaren, Sarah Busche, and Eric Lantz of NREL; Eleni Pelican of DOE; and Terry Schultz, an independent applied statistician.

In addition to these reviewers, we appreciate the assistance of Michelle Kubik, Mary Lukkonen, and NREL's Technical Communications Office in providing editing support. Of course, any remaining errors are the responsibility of the authors.

NREL's Clean Energy Policy Analyses (CEPA)

The CEPA suite of analyses and activities explore clean energy development and policy implementation at the regional, state, and local levels and disseminate that information to interested stakeholders. The activities gauge the effectiveness of and interactions between clean energy policies, provide insight into regional activities, investigate the interactions between local and state-level policies, and convene leading thought leaders to develop innovative regional, state, and local clean energy policies. The goal is to provide information to decision makers, researchers, and other stakeholders regarding the status of, barriers to, and possibilities for increased energy efficiency and renewable energy development at various levels of governance. For more information, see http://www.nrel.gov/cepa/. This report focuses primarily on energy use in electricity and buildings. For more information on transportation policies at the state and local level, please see the Alternative Fuels Data Center: http://www.afdc.energy.gov/afdc/.

Executive Summary

The increase in the use of state policy to drive energy efficiency and renewable energy market transformation is leading to extensive research on determining the best policies and policy designs to achieve this goal. In recent years, numerous best practice and state policymaker guidebooks have emerged to inform and assist the development of effective policy (e.g., DOE 2009; EPA 2008; LBNL 2009). In addition, there is growing interest in quantifying the connection between policies and development. To date, much of this work has been specific to wind resource development (Bohn and Lant 2009; Menz and Vachon 2005) or has focused specifically on renewable portfolio standard (RPS) effectiveness (Carley 2009).

This report uses statistical methods to better quantify the connection between a broad array of energy efficiency and renewable energy (collectively known as clean energy) policy and actual reductions in energy use and increases in renewable resource development. Using a multi-faceted dataset including policies, socioeconomic factors, and electricity information, ordinary least-squares regression is used to identify relationships between policy implementation and development. For energy efficiency, these methods led to an adjusted R^2 of 46% for residential energy use and an adjusted R^2 of 67% for commercial energy use. For renewable resource development, an adjusted R^2 of 43% to 63% was achieved depending on the technology (Table ES-1).

Table ES-1. Percent of Variation Between States Explained by Models (Adjusted R^2)

	2009 Capacity/Generation vs 2008 Policies (One Year Lag)		2009 Capacity/Generation vs 2007 Policies (Two Year Lag)	
Technology	**Capacity (MW)**	**Generation (MWh)**	**Capacity (MW)**	**Generation (MWh)**
Biomass	43.7%	46.7%	49.8%	52.6%
Geothermal	47.2%	47.4%	49.8%	50.5%
Photovoltaic	58.2%		63.3%	
Wind	47.5%	45.7%	45.5%	43.6%

	Impact of Policy on Efficiency
Commercial	67.5%
Residential	46.1%

R^2 is the proportion of variation among states in their capacity or generation that is explained by the regression analysis and is an indicator of how well the model fits the data. It ranges from 0.0 to 1.0, and an R^2 value of 1.0 means that the regression model fits the data perfectly. As shown in Table ES-1, approximately 58% of the variation in the states' 2009 photovoltaic capacity is explained by the 2008 policies and additional socioeconomic variables chosen for the regression.

The adjusted R^2 modifies the R^2 slightly by adjusting for the number of independent variables in the model. The adjusted R^2 only increases when a new independent variable improves the regression model more than what would be expected by chance alone. It is important to note that the adjusted R^2 does not indicate that the independent variables cause the variation in the renewable energy capacity or generation among states; it is simply a measure of how well the model fits the data.

While consistent with similar reports, the seemingly low adjusted R^2 values reflect both the lack of policy information available for incorporation into the statistical analysis and the potential for factors not tested here to drive clean energy development. The methodological limitations include:

- The relatively small sample size (50 states plus the District of Columbia) limits the observations to a maximum of 51 for any regression.
- The time series data for policies dates back to only 2007.
- The policy terms can vary from state to state, and the differences are difficult to reflect in this type of analysis. Additionally, not all policies are designed to spur in-state development but rather target regional growth, and this methodology is specifically designed to identify policy impacts on in-state development.
- It is possible that omitted variable bias would cause the independent variable (capacity/generation) to be correlated with the error term, therefore distorting the coefficients estimated in the analysis and producing inconsistent estimates. This methodology attempts to capture omitted variable bias by including more variables then necessary and reducing down to an optimal regression equation. However, macroeconomic variables (including changes in demographics) could have impacted energy use and capacity development and unintentionally been omitted from the analysis.
- The dependent variable in this analysis is absolute renewable capacity or generation, not the percent of total capacity or generation that is a renewable resource. RPS policies typically target growth of the percent of total generation that is composed of renewable energy and may be a better metric to test in the future.
- Biomass and geothermal projects typically require a construction schedule in excess of two years, and therefore the effects of a policy would have corresponding longer lag.

Generally, results from this analysis align with the existing literature (Bohn and Lant 2009; Carley 2009; Menz and Vachon 2005), especially in the conclusions that policy in concert with other macroeconomic factors is connected with renewable energy development. The findings of this report expand the current body of work to include a more detailed evaluation of the connections between energy use and energy efficiency policies as well as a broader review of renewable energy policies and renewable energy resources. That is, the current body of literature is primarily focused on the development of wind resources and RPSs; this work reviews a broader array of clean energy resources and policies, as well as certain macroeconomic factors (e.g., electricity price and population). Several broad conclusions can be drawn from this work:

- Policy alone does not explain variability in state clean energy growth. When other variables (including population, electricity price, and number of years a policy is in place) were incorporated into the analysis, the results indicated better explanation of the variation between state clean energy developments.

- It appears from the methodology used that the current set of policies is targeted more at influencing wind and solar development than development of biomass and geothermal renewable resources. This indicates that state policies, while broadly applicable across renewable energy resources, may not be usable by developers of those resources because the policies do not meet the resources' needs. Furthermore, biomass and geothermal can require a substantially longer timeline for development than wind and solar projects (especially distributed generation projects), and it may take more time before the results of incentives are visible in increased generation capacity.
- Where significant relationships were found, mixes of policies explain growth best, indicating that an environment for investment in clean energy through implementation of a suite of policies may be more effective at driving clean energy development than those that choose a single or small number of mechanisms.
- Policies are more connected with clean energy development the longer they are in place, indicating that policy longevity (and resulting market certainty for investors) may be an important aspect of effectiveness.

This research provides another piece in understanding how policy interacts with market development of clean energy. Additional policy experience and research are necessary to develop further understanding of these relationships. As policies are in place for longer periods of time, their impacts on clean energy development will become clearer since it takes time to develop a clean energy project once the environment is established for its development. Further research using more refined data inputs or alternative quantitative methods to better connect policy and clean energy development could help refine the understanding of clean energy development and the role of policy.

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1 Introduction

Significant efforts have been made to document success stories and lessons learned from past and recent policy implementation. Case studies reviewing the anecdotal evidence of policy effectiveness are common; they provide important insights and inform the growing field of literature on policy design practices (e.g., DOE 2009; Hurlbut 2008; Lantz and Doris 2009; LBNL 2009; Wiser et al. 2007; Wiser et al. 2002).

The general understandings resulting from these case studies and other experience regarding effective policy actions have been compiled into best practices and step-by-step guides to assist policymakers in their efforts to develop policies and programs tailored to their state clean energy goals. The Environmental Protection Agency (EPA) published a state and local guide to action that outlines a strategy for developing energy efficiency and renewable energy through planning and policy implementation and provides lessons learned for 16 commonly used policies (EPA 2008). The Lawrence Berkeley Laboratory has an extensive list of downloadable case studies on energy efficiency and renewable energy project and policy implementation (LBNL 2009). The U.S. Department of Energy (DOE) also provides case studies and examples of energy efficiency and renewable energy projects (DOE 2009). The DOE Solar Market Transformation program, through the Solar America Cities project, has compiled design best practices at the state and local level and developed a local policymakers' guidebook (SAC 2009).

Less common, but growing in number, are quantitative evaluations of policy effectiveness. To date, most of the research has focused on wind energy development. Menz and Vachon (2005) looked at the connection between wind resource development and various state policies, finding supporting evidence that some mix of mandatory rules and regulations [i.e., renewable portfolio standards (RPS), fuel generation disclosure, and mandatory green power purchasing] is associated with increased wind energy development. Bohn and Lant (2009) found that states with standardized siting and permitting procedures have a strong association with increased wind resource development. This work also looked at factors beyond policy and resource availability that drive the development of wind, finding that population distribution, electricity demand, and access to transmission are determinates in resource development. More generally relating RPS to renewable energy generation, Carley (2009) found that there is a relationship between the number of years an RPS is in place and higher generation from renewable sources but not the existence of the policy alone.

In this context, the aim of this research is to augment and build on traditional case studies and narrower quantitative analyses to develop a quantitative understanding of policy impacts using statistical and empirical methods, as well as to open the door for more thorough analyses of policy options, inform future policy development, and ultimately optimize the market share of renewable energy resources. Ideally, the outcomes will be useful for policymakers to elect policies that will work within their context to meet the goal of increased clean energy development. The remainder of this introduction describes the concepts behind our definitions of clean energy as well as outlines how this streamlined version of the *State of the States* (SOS) differs from earlier versions. Following that, Chapter 2 presents the methodology used for evaluating policy effectiveness, Chapter 3 summarizes the results, and Chapter 4 presents a discussion of the findings as well as next steps.

Clean Electricity

Clean electricity is defined by the entire spectrum of non-extractive technologies for meeting the nation's electricity needs. This report is limited to the discussion of policies addressing clean electricity and does not include a discussion of clean fuels for the transportation sector. Clean electricity and fuels together represent the range of clean energy options. "Clean energy" comprises the entire spectrum of non-extractive technologies for meeting the nation's energy needs. The concept exists on a continuum (Figure 1), from conservation of energy as a behavioral change to energy efficiency measures, which both minimize the amount of energy used to meet the need. Finally, renewable energy technologies meet the remaining need for energy.

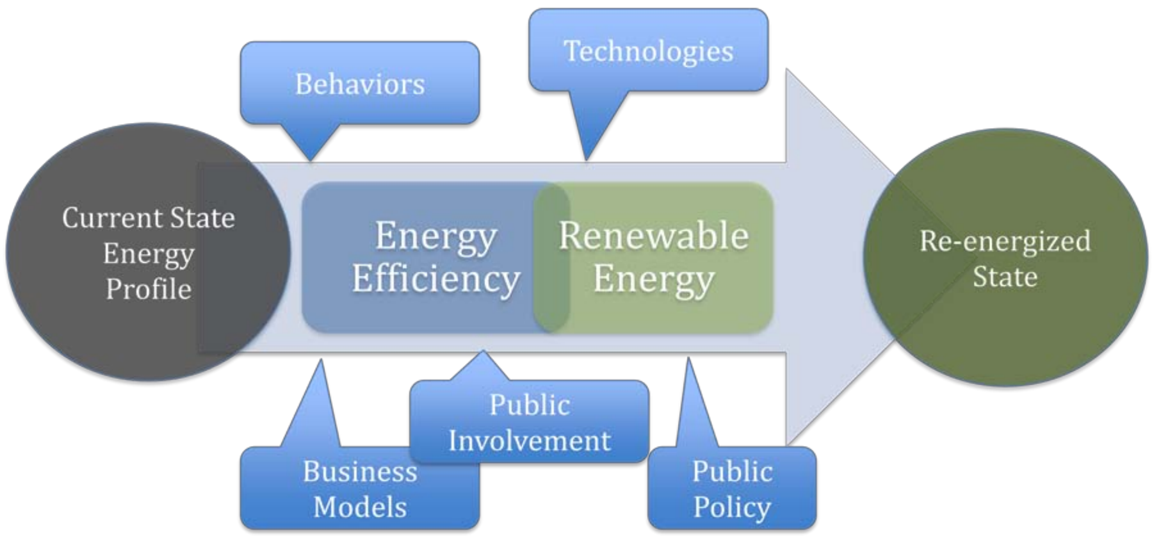

Figure 1. Continuum of clean energy market transformation

Capturing all of these opportunities for clean energy adoption requires multiple policy levers over time. Some of these levers are represented in Figure 2.

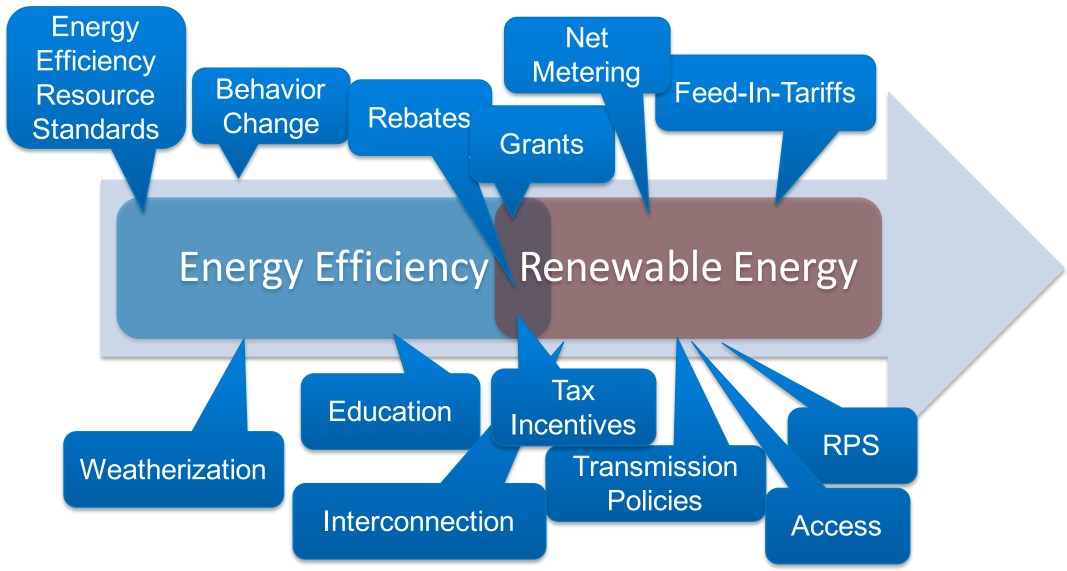

Figure 2. Sample of possible policy levers for developing clean energy

State policymakers have many policy options aiming at the development of clean energy resources, including various rules, regulations, and incentives.

For full descriptions of the policies currently used by states, please see the DSIRE glossary, available at: http://www.dsireusa.org/glossary/.

Evolution of the *State of the States* Report

There are three primary differences between the 2010 and previous (Brown and Busche 2008; Doris et al. 2009) SOS reports:

- Targeting of statistical analyses to specific policies and resources
- Widening of data used to evaluate policy effectiveness and more graphical display of that data in other CEPA documents
- Transitioning of extensive context factor discussion to other documents in the CEPA series.

This work aims to look more critically at the development of renewable energy resources and the role of policy. Earlier versions of the report (Brown and Busche 2008; Doris et al. 2009) attempted an en masse approach, lumping together all state energy policies and clean electricity generation. Drawing results from these analyses was challenging because of the number of policies and other factors contributing to the development of clean energy, the limited experience with clean energy policies over time, and variability among state policies even within the same general policy mechanism.

This year, while still looking toward the big picture of assisting policymakers in decision making across policy and resource options, the methodology is more targeted towards resources and specific policies that emerged in previous years' efforts and the literature as likely effective policies. While this may lead to overlooking some lesser used policies, it has the benefit of more clearly identifying the connection between specific policies and resource development. In addition to targeting the analyses to specific technologies, this methodology integrates multiple factors external to policy, including population, restructuring, state gross domestic product, competing energy costs, and length of time policy has been in place. This methodology is designed to give policymakers a clearer view of the role of policy within the existing context.

For standardization purposes in earlier reports, data used were limited to U.S. Energy Information Administration (EIA) renewable energy generation data. This year, a broader dataset was used to more accurately reflect the existence of distributed generation resources, including capacity and generation, which EIA does not track as closely due to methodological challenges. These datasets include Larry Sherwood's "U.S. Solar Market Trends" (2009), Solar Energy Industries Association's (SEIA's) "US Solar Industry Year in Review 2009" (2009), Geothermal Energy Association's (GEA's) "U.S. Geothermal Power Production and Development Update: April 2010" (2010), and American Wind Energy Association's (AWEA's) "Year End 2009 Market Report" (2010a). Because the methodology has been targeted to specific policies and technologies, the different collection methodologies from the various datasets is less of a concern than it has been in previous years. Previous reports included extensive tables and graphics of available data from EIA. In addition to using this diverse dataset this year, those data are presented in a highly visual way in the CEPA State Energy Data Book, available at: http://www.nrel.gov/cepa.

2 Methodology

Policies fall into several general categories (e.g., incentives and mandates) but are uniquely applied to different situations and implemented in different ways, creating challenges in generalizing their success at driving the clean energy market. In addition, different policies are applied to different types of clean energy technologies. The methodology for these analyses splits clean energy resources into energy efficiency and renewable energy technologies, primarily because the metric for success differs between the two. Energy efficiency improvements in the commercial sector are measured by commercial energy use (EIA 2010b) normalized for economic change by gross state product in the same year. Energy efficiency improvements in the residential sector are measured by residential energy use normalized for population in the same year. Renewable energy improvements are measured by increased energy supply and are therefore measured by increased capacity and generation of electricity from renewable resources. It is crucial to note that this methodology tests only in-state development and some policies are designed to target regional growth. The regional clean energy impacts of these policies will not be directly captured by this methodology.

In this methodology we focus on individual policies as they are currently being implemented and, to a limited extent, combinations of policies. The methodology will not result in recommendations for altering policy implementation strategies but instead reflects clean energy development impacts of the current mix of state policies.

Table 1 summarizes the definitions of statistical terms used in this analysis.

Table 1. Definitions of Terms Used in the Statistical Analysis

Adjusted R^2	• A measure of the amount of variation about the mean explained by the model, adjusted for the number of independent variables • Increases *only* when the additional variable in question improves the model more than what would be expected by chance
Constant	• Linear regressions often require a constant (a y-intercept term) to be present
Beta	• The change in the dependent variable per a one-unit change in the value of the independent variable
P-Value	• The probability of obtaining a test statistic at least as extreme as the one observed • At the 5% significance level, a p-value of less than 0.05 means that the observed result cannot be ascribed to chance alone
Error Term	• An estimate of the unobservable statistical error

Energy Efficiency[1]

In this analysis, the dependent variable for commercial energy efficiency is commercial energy use normalized for economic changes by the gross state product in the same year, and the dependent variable for the residential sector is residential energy use normalized for population in the same year. For both commercial and residential energy use, it was assumed that state population demographics had not materially shifted from 2008 to 2009. The independent variables in this analysis are the existence of:

1. High efficiency (equal to or better than ASHRAE 90.1 2004) statewide commercial building code (OCEAN 2010)
2. High efficiency (equal to or better than IECC 2006) statewide residential building code (OCEAN 2010)
3. Average commercial electricity price in 2009 (EIA 2010d)
4. Average residential electricity price in 2009 (EIA 2010d)
5. Energy Efficiency Resource Standard (EERS) (ACEEE 2010)
6. State personal tax incentives (DSIRE 2010b)
7. State rebates (DSIRE 2010b)
8. State loans (DSIRE 2010b)

EERS data, state personal tax incentives, state rebates, and state loans appear in both the commercial and residential energy efficiency models, while building codes and electricity prices correspond to the dependent variable being tested. Only commercial and residential energy consumption were used as a proxy for overall building efficiency; the industrial sector was omitted because it consumes energy in a different way, through industrial processes as well as building efficiency.

The general form of the two models estimated can be written as:

Commercial Energy Use/Gross State Product (GSP) = $\beta_0 + \beta_1$ High Commercial Building Code + β_2 Commercial Electricity Price + β_3 EERS + β_4 Personal Tax Incentives + β_5 Rebates + β_6 Loans + ε

Residential Energy Use/Capita = $\beta_0 + \beta_1$ High Residential Building Code + β_2 Residential Electricity Price + β_3 EERS + β_4 Personal Tax Incentives + β_5 Rebates + β_6 Loans + ε

Every independent variable in this energy efficiency analysis was expected to have a negative impact on energy use (lower commercial energy use/GSP and lower residential energy use/capita), and therefore, coefficients β_1 through β_6 were expected to be significant at the 5% level and negative. Regardless of whether a state had all four incentives/standards or not, it was kept in the dataset (since every state consumes energy in the commercial and residential sectors), resulting in 51 observations in each model.

[1] For a broader look at the impact of policy and different factors on the development of energy efficiency resources, see ACEEE's Scorecard for Energy Efficiency (http://www.aceee.org).

The coefficients were estimated using ordinary least-squares (OLS) methodology. The variables were analyzed for multicollinearity through a bivariate correlation table. Intercorrelations were found not to be a concern, and a test of the variance inflation factors (VIF) was conducted as well, which is commonly used as an indicator of the severity of multicollinearity (Neter et al. 1996). A VIF value in excess of 10 is an indication that multicollinearity is influencing the least squares estimates, and the average electricity price (both residential and commercial) is the only variable that exceeded this threshold, albeit only slightly. Given the lack of multicollinearity based on this test, the analysis proceeded with the original variables, taking into consideration that the electricity price variable may be inflating the variance of the estimated coefficients.

Renewable Energy

Two dependent variables for each renewable technology [wind, photovoltaics (PV), geothermal, and biomass] were used: end-of-year 2009 cumulative capacity (MW) and 2009 annual generation (MWh). For PV, only capacity data was utilized because the state-by-state generation data that EIA classifies as "solar" is over 90% concentrated solar power, which is not included in this analysis due to its limited geographic application. Capacity data for wind is from the AWEA's "Year End 2009 Market Report" (2010a), PV capacity data is from Larry Sherwood's "U.S. Solar Market Trends 2009" (2010), geothermal capacity data is from GEA's "U.S. Geothermal Power Production and Development Update" (2010), and biomass capacity data is from EIA's "Electric Power Monthly" (2010). Generation data for biomass, geothermal, and wind are gathered from Form EIA-923 (EIA 2010a). Discrepancies between capacity and generation may stem from a number of factors, including but not limited to: varying data reporting regulations and data collection methods, ranges of efficiencies, plant outages, and power purchase agreements. The independent variables vary based on the typical technology to which the policy applies. Table 2 summarizes the policies that serve as the independent variable in comparison to the dependent renewable resource variable. In addition to tests comparing the currently available policy information and capacity and generation data, time lag analyses were completed for several policies (the independent variable being 2007 policy existence) to measure if the length of time a policy has been in place is correlated with increased renewable energy generation.

Table 2. State Policy Options and Typical Application to Renewable Resources

	PV	Wind	Geothermal	Biomass
Access Laws	x			
Bonds				
Construction and Design				
Contractor Licensing	x	x	x	x
Corporate Tax Incentives	x	x		x
Equipment Certification	x			
Generation Disclosure				
Grants	x			
Industry Support		x	x	x
Interconnection	x	x		
Line Extension Analysis	x		x	
Loans			x	x
Net Metering	x	x		
Personal Tax Incentives	x		x	
Production Incentives	x	x	x	x
Property Tax Incentives	x			x
Rebates	x			
RPS	x	x		
RPS with Solar Set Aside	x			
Sales Tax Incentives	x	x		
Voluntary and Mandatory Green Power	x	x		

In previous editions of this study, correlations and t-tests were used to identify relationships between policy and renewable energy resource build-out. While valid in their own ways, these methods are highly susceptible to outliers. A test that ranks data would be more robust to outliers, giving less weight to outlying data. Because the data are ordinal (megawatts of capacity, gigawatt-hours of generation) from two samples (states with a policy, states without a policy), non-parametric testing is used in this analysis, meaning that the samples are not required to come from any specific distribution (Navidi 2010). The Wilcoxon Rank-Sum Test (also called the Mann-Whitney test) was chosen as it tests the chance of obtaining a higher observation in one population versus the other. For this analysis, this translates to testing whether a state with a certain policy is likely to have higher renewable energy capacity/generation than a state without the policy.

Initial attempts at utilizing the Wilcoxon Rank-Sum Test failed to identify a subset of variables explaining the connections between policy and renewable energy development. This is likely the result of too many extraneous or confounding variables included in the set of variables. Variables outside of the ones being tested (policy versus renewable energy resource) may lead to a spurious relationship between the test variables. This is called a "Type 1 Error," or an erroneous conclusion that the dependent variable (capacity or generation) is affected by the independent variable (policy implementation); in other words, a "false positive" (Navidi 2010). Therefore, the outcomes of these tests are not presented here but rather are considered with a collection of other analyses and built on in future years as more data becomes available.

Regression models for each of the renewable energy technologies were structured in the same way as the energy efficiency models shown earlier (definitions for variables can be found at http://www.dsireusa.org):

Wind Capacity/Wind Generation = $\beta_0 + \beta_1$ Contractor Licensing + β_2 Corporate Tax Incentives + β_3 Industry Support + β_4 Interconnection + β_5 Net Metering + β_6 Production Incentives + β_7 RPS + β_8 Sales Tax Incentives + β_9 Green Power + β_{10} Average Electricity Price + β_{11} Freeing The Grid (FTG) Interconnection Grade[2] + β_{12} Number of Policies + β_{13} Population + β_{14} Restructuring + β_{15} RPS Effective Years + ε

PV Capacity = $\beta_0 + \beta_1$ Access Laws + β_2 Contractor Licensing + β_3 Corporate Tax Incentives + β_4 Equipment Certification + β_5 Grants + β_6 Interconnection + β_7 Line Extension Analysis + β_8 Net Metering + β_9 Personal Tax Incentives + β_{10} Production Tax Incentives + β_{11} Property Tax Incentives + β_{12} Rebates + β_{13} RPS + β_{14} RPS with Solar Disclosures + β_{15} Sales Tax Incentives + β_{16} Green Power + β_{17} Average Electricity Price + β_{18} FTG Interconnection Grade[3] + β_{19} Number of Policies + β_{20} Population + β_{21} Restructuring + β_{22} RPS Effective Years + ε

Geothermal Capacity/Geothermal Generation = $\beta_0 + \beta_1$ Contractor Licensing + β_2 Industry Support + β_3 Line Extension Analysis + β_4 Loans + β_5 Personal Tax Incentives + β_6 Production Tax Incentives + β_7 Average Electricity Price + β_8 Number of Policies + β_9 Population + β_{10} Restructuring + β_{11} RPS Effective Years + ε

Biomass Capacity/Biomass Generation = $\beta_0 + \beta_1$ Contractor Licensing + β_2 Corporate Tax Incentives + β_3 Industry Support + β_4 Loans + β_5 Production Tax Incentives + β_6 Property Tax Incentives + β_7 Average Electricity Price + β_8 Number of Policies + β_9 Population + β_{10} Restructuring + β_{11} RPS Effective Years + ε

The coefficients were estimated using OLS methodology. A bivariate correlation table was constructed for each model, and the resulting intercorrelations were found not to be a concern. A VIF test was conducted on each model. Forbiomass, geothermal, and wind (both capacity and generation), average electricity price and the number of policies were of concern in terms of intercorrelations. Both variables had a VIF in excess of 10 and were therefore dropped from the model. For PV capacity, the average electricity price, net metering, and the number of policies all exhibited a VIF in excess of 10 and were removed from the model.

[2] Refers to the Network for New Energy Choices report, "Freeing the Grid: Best and Worst Practices in State Net Metering Policies and Interconnection Procedures." (NNEC 2009).

As each model was run, variables that were not significant to the model and that degraded the R^2 were removed until the model was left with the most efficient set of variables to explain renewable energy build-out for each technology. If a variable was not significant at the 0.05 level but improved the R^2, it remained in the model.

3 Results

The analysis produced several unexpected results, and while they may appear to indicate that certain policies are not associated with clean energy development, further research with refined datasets is necessary. It should also be noted that there are methodological challenges in this type of quantitative analysis. Specifically in this exercise, the limitations include:

- The relatively small sample size (50 states plus the District of Columbia) limits the observations to a maximum of 51 for any regression.
- The time series data for policies dates back to only 2007.
- The policy terms can vary from state to state, and the differences are difficult to reflect in this type of analysis. Additionally, not all policies are designed to spur in-state development but rather target regional growth.
- It is possible that omitted variable bias would cause the independent variable (capacity/generation) to be correlated with the error term, therefore distorting the coefficients estimated in the analysis and producing inconsistent estimates. This methodology attempts to capture omitted variable bias by including more variables then necessary and reducing down to an optimal regression equation. However, macroeconomic variables (including changes in demographics) could have impacted energy use and capacity development and unintentionally been omitted from the analysis.
- The dependent variable in this analysis is absolute renewable capacity or generation, not the percent of total capacity or generation that is a renewable resource. RPS policies typically target growth of the percent of total generation that is composed of renewable energy and may be a better metric to test in the future.
- Biomass and geothermal projects typically require a construction schedule in excess of two years, and therefore the effects of a policy would have corresponding longer lag.

As a result of these limitations, results from this analysis should be taken in hand with other quantitative and qualitative work in the area of clean energy policy and its relation to clean energy technology development.

Table 3 shows that in general, this methodology produces an adjusted R^2 of 46% for residential sector state energy use and 67% for commercial sector state energy use. For renewable energy resources, policy and the other macroeconomic factors tested produce an adjusted R^2 of 43%–63% for capacity and generation, depending on the measure and the renewable technology being tested.

Table 3. Percent of Variation Between States Explained by Models (Adjusted R^2)

	2009 Capacity/Generation vs 2008 Policies (One Year Lag)		2009 Capacity/Generation vs 2007 Policies (Two Year Lag)	
Technology	**Capacity (MW)**	**Generation (MWh)**	**Capacity (MW)**	**Generation (MWh)**
Biomass	43.7%	46.7%	49.8%	52.6%
Geothermal	47.2%	47.4%	49.8%	50.5%
Photovoltaic	58.2%		63.3%	
Wind	47.5%	45.7%	45.5%	43.6%

	Impact of Policy on Efficiency
Commercial	67.5%
Residential	46.1%

The remainder of the results section is structured to show detailed results by resource evaluated. For the energy efficiency evaluations, only a one-year time lag of the policies (2008) produced meaningful results, so only those are presented. For each renewable technology, the first table presents results using a one-year time lag with 2008 incentive data, and the second table presents the results of the two-year time lag analysis (e.g., incentives available in 2007 compared to current capacity or generation).

Energy Efficiency

Tables 4 and 5 are the results from the energy efficiency analysis. In this analysis only the one-year time lag data led to meaningful results, so only those are presented here. Table 4 shows that in the residential analysis, none of the incentives (e.g., personal tax incentives, rebates, and loans) were significant in explaining energy use per capita. There was a relationship with high efficiency residential building codes with a p-value of 0.072, making it significant only at the 0.10 level. A state having an EERS is also more likely to exhibit lower energy use per capita. Residential electricity price had a significant, negative relationship with per capita energy use. Of all the rules, incentives, and macroeconomic factors tested, this methodology can explain only 46.1% of the variation in residential state energy use.

Table 4. Impact of Policy on Residential Efficiency: Residential Consumption/Capita (2008 Incentives)

Variable	Beta	P-Value
Constant	101.8	0.000
High Efficiency Residential Building Code	-5.1	0.072 *
Average Residential Electricity Price (2009)	-1.8	0.000
Energy Efficiency Resource Standard (EERS)	-5.6	0.047
Adjusted R^2	0.461	
Number of Observations	51	

**Not significant at the 5% level.*

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

In the commercial sector, the model is able to explain 67.5% of the variation between states consumption/GSP. There is a relationship between high efficiency commercial building codes, EERS, higher commercial electricity price, and reduced commercial consumption. However, the existence of personal tax incentives is associated with increased commercial energy use in the model. It is not clear why personal tax incentives would affect commercial energy use, but it is possible that the existence of those incentives indicates a prioritization of residential energy use reduction. Further refinements of the datasets and additional data could increase the understanding of why these variables are significantly correlated with commercial energy efficiency.

Table 5. Impact of Policy on Commercial Efficiency: Commercial Consumption/GSP (2008 Incentives)

Variable	Beta	P-Value
Constant	2,029.5	0.000
High Efficiency Commerical Building Code	-104.7	0.042
2008 Personal Tax Incentives	154.4	0.010
Average Commercial Electricity Price (2009)	-48.8	0.000
Energy Efficiency Resource Standard (EERS)	-193.8	0.000
Adjusted R^2	0.675	
Number of Observations	51	

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

Biomass

Very little biomass capacity has come online in recent years, so finding relationships between current policies and increased development was a challenge. In addition, state policies do not target biomass development in the same way that wind and solar are targeted. In general, biomass development is impacted by factors outside of the policy arena, including feedstock availability and the ability to meet emissions criteria. That being said, this initial analysis into the policies that may be related to biomass development is a first step and indicates that further analysis and refinement of the data is necessary to better understand the relationship between policy and biomass resource development.

Only contractor licensing and population are associated with higher capacity and generation from biomass resources, though only population was significant at the 0.05% level. A time lag of two years for loan programs was also associated with higher biomass levels, though not at the 0.05 significance level. Corporate and property tax incentives appear to be a deterrent to biomass development, but those results are not statistically significant and more targeted datasets in subsequent research may illuminate this relationship more clearly.

Table 6. Impact of Policy on Biomass Power Development (2008 Incentives)

Variable	Capacity (2009) Beta	Capacity (2009) P-Value	Generation (2009) Beta	Generation (2009) P-Value
Constant	144.6	0.023	671.5	0.014
2008 Contractor Licensing (Yes/No)	88.6	0.297 *		
2008 Corporate Tax (Yes/No)	-77.4	0.223 *	-381.7	0.159 *
2008 Property Tax (Yes/No)	-74.0	0.281 *	-372.0	0.204 *
2009 Population	29.1	0.000	136.5	0.000
Adjusted R^2	0.437		0.467	
Number of Observations	50 (1)		50 (1)	

** Not significant at the 5% level.*

(1) District of Columbia is removed: zero capacity and generation and none of the policies being tested.

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

Table 7. Impact of Policy on Biomass Power Development (2007 Incentives)

Variable	Capacity (2009) Beta	Capacity (2009) P-Value	Generation (2009) Beta	Generation (2009) P-Value
Constant	123.0	0.087 *	475.5	0.120 *
2007 Contractor Licensing (Yes/No)	116.8	0.157 *	401.0	0.252 *
2007 Corporate Tax (Yes/No)	-103.7	0.094 *	-519.9	0.050
2007 Loans (Yes/No)	85.6	0.177 *	457.4	0.092 *
2007 Property Tax (Yes/No)	-119.8	0.062 *	-513.5	0.061 *
2009 Population	28.6	0.000	129.4	0.000
Adjusted R^2	0.498		0.526	
Number of Observations	49 (1)		49 (1)	

** Not significant at the 5% level.*

(1) District of Columbia and Wyoming are removed: zero capacity and generation and none of the policies being tested.

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

Geothermal

Similar to biomass, very little geothermal capacity has come online in recent years, and finding relationships between the current portfolio of policies and an increase in geothermal development is difficult. Much of the geothermal capacity in the United States was brought online decades ago, spurred by incentives that have since expired. Like biomass, policies specifically targeting geothermal do not currently exist in the same way that there are policies targeting wind and solar production. While this initial effort at identifying connections between policy and geothermal resource development may illuminate the relationships, further research and data refinement to better connect policies that are truly targeting geothermal development are necessary to better understand the relationship between geothermal development and policy implementation.

Industry support, both in 2008 and 2007, is negatively associated with electricity development from geothermal sources. Contractor licensing, loans, personal tax, and production incentives are all positively associated. The number of years an RPS is effective is not a significant variable in any of the biomass or geothermal regression models, but it does appear significant in every wind and solar model. An interpretation and implications of these results are discussed in the following chapter.

Table 8. Impact of Policy on Geothermal Power Development (2008 Incentives)

	Capacity (2009)		Generation (2009)	
Variable	**Beta**	**P-Value**	**Beta**	**P-Value**
Constant	-130.4	0.042	-1,016.8	0.034
2008 Contractor Licensing (Yes/No)	232.4	0.034	1,172.4	0.035
2008 Industry Support (Yes/No)	-185.1	0.039	-851.2	0.062 *
2008 Loans (Yes/No)			450.3	0.322 *
2009 Population	33.6	0.000	172.3	0.000
Adjusted R^2	0.472		0.474	
Number of Observations	46 (1)		46 (1)	

** Not significant at the 5% level.*

(1) Delaware, Indiana, South Dakota, West Virginia, and District of Columbia are removed: zero capacity and generation and none of the policies being tested.

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

Table 9. Impact of Policy on Geothermal Power Development (2007 Incentives)

	Capacity (2009)		Generation (2009)	
Variable	**Beta**	**P-Value**	**Beta**	**P-Value**
Constant	-225.3	0.004	-1,167.4	0.003
2007 Contractor Licensing (Yes/No)	160.5	0.163 *	809.4	0.161 *
2007 Industry Support (Yes/No)	-220.5	0.032	-1,105.6	0.032
2007 Personal Tax (Yes/No)	178.2	0.043	926.1	0.037
2007 Production Incentives (Yes/No)	218.7	0.081 *	1,019.9	0.104 *
2009 Population	31.4	0.000	162.2	0.000
Adjusted R^2	0.498		0.505	
Number of Observations	44 (1)		44 (1)	

** Not significant at the 5% level.*

(1) Kentucky, Illinois, Georgia, Indiana, South Dakota, West Virginia, and the District of Columbia are removed: zero capacity and generation and none of the policies being tested.

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

Photovoltaics

Compared to biomass and geothermal, policies appear to play a stronger role in the PV models, potentially because more policies are tailored toward the development of PV resources. Policies currently available, including corporate tax incentives, equipment certification, grants, interconnection, sales tax, and green power all appear to have a negative relationship with PV capacity. However, as stated above, the number of years an RPS is positively associated with PV resource development, implying that it is not the existence of a policy but rather the length of time the policy is in place that drives PV development. Contractor licensing, production incentives, rebates, access laws, and personal tax incentives are all positively associated with PV capacity.

Table 10. Impact of Policy on PV Development (2008 Incentives)

Variable	PV Capacity (2009) Beta	P-Value
2008 Contractor Licensing (Yes/No)	65.0	0.027
2008 Equipment Certification (Yes/No)	-68.2	0.226 *
2008 Grants (Yes/No)	-53.2	0.011
2008 Interconnection (Yes/No)	-41.1	0.081 *
2008 Production Incentives (Yes/No)	86.3	0.016
2008 Rebates (Yes/No)	35.2	0.146 *
2008 Sales Tax (Yes/No)	-37.9	0.060 *
2009 Population	8.8	0.000
RPS Effective (Number of Years)	2.7	0.226 *
Adjusted R^2	0.582	
Number of Observations	51	

** Not significant at the 5% level.*

PV capacity includes grid-tied only.
Solar generation from EIA not used because it is over 90% concentrating solar power (CSP).

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

Table 11. Impact of Policy on PV Development (2007 Incentives)

Variable	PV Capacity (2009) Beta	P-Value
Constant	-28.2	0.265 *
2007 Access Laws (Yes/No)	30.0	0.181 *
2007 Contractor Licensing (Yes/No)	47.9	0.081 *
2007 Corporate Tax Incentives (Yes/No)	-71.6	0.005
2007 Grants (Yes/No)	-41.1	0.054 *
2007 Green Power (Yes/No)	-33.0	0.189 *
2007 Interconnection (Yes/No)	-24.3	0.313 *
2007 Personal Tax Incentives (Yes/No)	72.1	0.003
2007 Production Incentives (Yes/No)	43.6	0.155 *
2007 Rebates (Yes/No)	27.4	0.225 *
2007 Sales Tax (Yes/No)	-37.5	0.081 *
2009 Population	9.8	0.000
RPS Effective (Number of Years)	3.3	0.163 *
Adjusted R^2	0.633	
Number of Observations	51	

** Not significant at the 5% level.*

PV capacity includes grid-tied only.
Solar generation from EIA not used because it is over 90% concentrating solar power (CSP).

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

Wind

Wind regression results (Tables 11 and 12) are similar to the existing literature in terms of the policies that are shown to influence development. Contractor licensing, state production incentives, and having a grade of "C" or better from the "Freeing the Grid…" report (NNEC 2009) are negatively associated with wind resource build-out. Industry support and the number of years an RPS was effective are both positively associated with wind power development.

Table 12. Impact of Policy on Wind Power Development (2008 Incentives)

	Capacity (2009)		Generation (2009)	
Variable	**Beta**	**P-Value**	**Beta**	**P-Value**
FTG Interconnection Good Grade	-944.6	0.004	-1,970.2	0.005
2008 Contractor Licensing (Yes/No)	-895.5	0.039	-1,845.7	0.042
2008 Industry Support (Yes/No)	538.6	0.118 *	1,126.5	0.119 *
2008 Production Incentives (Yes/No)	-627.2	0.218 *	-1,113.1	0.296 *
2009 Population	141.3	0.000	282.1	0.000
RPS Effective (Number of Years)	103.3	0.002	212.1	0.003
Adjusted R^2	0.475		0.457	
Number of Observations	49 (1)		49 (1)	

** Not significant at the 5% level.*

(1) Alabama and Mississippi have been removed: zero capacity and generation and none of the policies being tested.

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

Table 13. Impact of Policy on Wind Power Development (2007 Incentives)

	Capacity (2009)		Generation (2009)	
Variable	**Beta**	**P-Value**	**Beta**	**P-Value**
FTG Interconnection Good Grade	-793.1	0.014	-1,661.3	0.015
2007 Contractor Licensing (Yes/No)	-769.9	0.075 *	-1,605.1	0.077 *
2007 Production Incentives (Yes/No)	-621.5	0.190 *	-1,121.8	0.259 *
2009 Population	144.1	0.000	289.5	0.000
RPS Effective (Number of Years)	119.2	0.001	244.4	0.001
Adjusted R^2	0.455		0.436	
Number of Observations	49 (1)		49 (1)	

** Not significant at the 5% level.*

(1) Alabama and Mississippi have been removed: zero capacity and generation and none of the policies being tested.

Sources: BEA 2010; DSIRE 2010c; EIA 2010d; Ocean 2010

4 Discussion

Generally, results from this analysis align with the existing literature (Bohn and Lant 2009; Carly 2009; Menz and Vachon 2005), especially in the conclusion that policy, in concert with other macroeconomic factors, is connected with renewable energy development. The findings of this work expand the current body of research to include a more detailed evaluation of the connections between energy use and energy efficiency policies as well as a broader review of renewable energy policies and renewable energy technologies. That is, the current body of literature is primarily focused on the development of wind resources and RPSs, and this work reviews a broader array of clean energy resources and policies, as well as certain macroeconomic factors (e.g., electricity price and population). Several broad conclusions can be drawn from this analysis:

- Policy alone does not explain variability in state clean energy growth. When other variables (including population, electricity price, and number of years a policy is in place) were incorporated into the models, the results better explained the variation among state clean energy development.
- It appears from this methodology that the current set of policies is more targeted at influencing wind and solar development than developing biomass and geothermal resources. This indicates that state policies, while broadly applicable across renewable energy technologies, may not be usable by developers of those technologies because the policies do not meet the technologies' needs. For example, a rebate program with a capacity limit of 5 kW may be available to geothermal project developers, but because electricity generation from geothermal resources is commonly on a larger, multi-megawatt scale, the rebate program may not provide enough of an incentive to drive development. Policies, even if applicable to a wide range of technologies, often are designed to promote one or two specific resources—in this case, wind and solar are targeted far more frequently than geothermal and biomass. Programs tailored to the specific needs of the technology may be more beneficial to renewable energy development.
- Where significant relationships were found, mixes of policies explained growth best. For example, a wide variety of policies contributes to PV development across states. These policies, along with non-policy factors, explain variation among states in wind growth. This may indicate that the specific policies in place are less important than the grouping of policies. In other words, state policymakers that create an environment for investment in clean energy by implementing a suite of policies may be more effective at driving clean energy development than those that choose a single or small number of mechanisms.
- Policies are more connected with clean energy development the longer they are in place. The methodology presented here compared current development with current policies as well as those policies that were put in place in the previous two years. Findings indicate that connections are more pronounced when the time lag is incorporated. This indicates that policy longevity is an

important aspect of effectiveness. Furthermore, due to more intensive construction requirements for geothermal and biomass projects, a longer study period may be needed to quantify policy impacts on the development of these technologies.

While the methodology applied in this report produced valuable results, as previously discussed, an evolution of this methodology in subsequent reports may better handle the unique nature of this type of data. The current method of choice, OLS regression, assumes normality of data, and performing OLS on the ranks of data may result in a better fitting model. Not only would it address the issue of high-leverage values and data normality, but this adjustment would also address the clear outliers in both total renewable energy installed capacity and generation, California and Texas.

This research provides another piece in the understanding of how policy interacts with market development of clean energy. Further experience with policies and research are necessary to better understand these relationships. As policies are in place for longer periods of time, their impacts on clean energy development will become clearer, as it takes time to develop clean energy projects once the environment is established for their development.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
January 2011	Technical Report	

4. TITLE AND SUBTITLE
State of the States 2010: The Role of Policy in Clean Energy Market Transformation

5a. CONTRACT NUMBER
DE-AC36-08-GO28308

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
E. Doris and R. Gelman

5d. PROJECT NUMBER
NREL/TP-6A20-49193

5e. TASK NUMBER
IGST.0005

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/TP-6A20-49193

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
This report builds on the emerging body of literature seeking to identify quantitative connections between clean energy policy and renewable energy. The methods presented test the relationships between a broad set of policies and clean energy resources (energy efficiency, biomass, geothermal, solar, and wind). Energy efficiency findings are an initial foray into this type of analysis and indicate significant connections between reduced energy use and buildings codes, energy efficiency resource standards (in some cases), and electricity price. Renewable energy findings specify that there is most often a relationship between state policies and solar and wind development, indicating that while policies might apply to a wide variety of renewable resources, further tailoring of policy specifics to resource needs may lead to increased development of a wider variety of renewable energy resources. Further research is needed to refine the connections between clean energy development and policy, especially in the area of the impact of the length of time that a policy has been in place.

15. SUBJECT TERMS
clean energy; policy; renewable energy; energy efficiency; biomass; geothermal; photovoltaics; PV; wind; ordinary least-squares; OLS; United States

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
Unclassified	Unclassified	Unclassified	UL		19b. TELEPHONE NUMBER (*Include area code*)