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Renewable energy across the 50 United States and related factors

Cynthia Brit Christenson
Louisiana State University and Agricultural and Mechanical College

RENEWABLE ENERGY ACROSS THE 50 UNITED STATES
AND
RELATED FACTORS

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ABSTRACT

Renewable energy production replaces diminishing non-renewable energy sources including fossil fuels. Major sources of renewable energy include biofuels, geothermal, hydroelectric, solar thermal and photovoltaic, wind, wood, and biomass. Greater use of renewable energy sources can fill gaps in energy as non-renewable sources are depleted, provide more energy independence at a state and national level, and help address climate change by reducing greenhouse gas emissions from combustion of fossil fuels. The research objectives of this thesis are two-fold. First, which U.S. states are leaders in renewable energy production? Second, what factors may account for variation among U.S. states in levels of renewable energy production?

The five state leaders in production of renewable energy are Washington, California, Iowa, New York, and Texas. Potential influences on renewable energy production include these factors: total energy importation or exportation by state, education level of residents, retail electricity cost, gross state product, poverty level, total population, along with indicators of political and religious ideology including Republican presidential voting, belief in God, and renewable energy potential. A Pearson correlation analysis was conducted to identify multi-collinearity between the independent variables and a factor analysis was used to explore possible associations between all variables. Finally, linear regression analysis is conducted to identify those independent variables significantly associated with the dependent variable, renewable energy production levels for each state. Factors found to be associated with higher renewable energy production are a larger state economy as measured by higher gross state product (GSP) and greater renewable energy potential. The analysis yields insights into the conditions under which U.S. states are more likely to produce higher levels of renewable energy, relevant information for state and federal planning for increased energy independence and greenhouse gas reduction.

INTRODUCTION

Non-renewable energy sources, including fossil fuels such as coal, oil, and natural gas, provide approximately 83% of all energy used in the United States (EIA Annual Energy Review, 2011). Given the finite nature of non-renewable sources, alternative, renewable energies need to be harnessed to fill the energy gap created as these non-renewable sources are exhausted. Renewable energy sources include biofuel, geothermal, hydroelectric, solar thermal and photovoltaic, wind, wood, and biomass sources. Renewable energy production varies state by state across America. For example, in 2010 Arizona produced 93.3 trillion Btu (British thermal unit) of renewable energy, while the state of New York produced nearly four times that amount in the same year (EIA SEDS, 2010).

The research objectives of this thesis are two-fold. First, which states are leaders in renewable energy production? Second, what factors may account for variation among state renewable energy production? Potential influences on state-level renewable energy production include: energy production and use, educational level of residents, socioeconomic characteristics of the population, environmental policy climate, political and religious orientation of residents, and environmental conditions. The dependent variable used in this study is renewable energy production. All 50 states are included in this analysis and the target year is 2010 to give a snapshot of renewable energy production levels and potential influences. The importance of renewable energy is discussed in the introduction, followed by the related literature review, data and methods, results and discussion, and conclusions.

Renewable energy production, in addition to replacing non-renewable depleting sources, can improve energy independence (both at the state and national level) and reduce climate change risks associated with fossil fuel energy pollution. Energy independence among states in the Unites States is desirable so that they do not have to rely on one another, or some more than others, because energy transportation between states uses additional energy over in state-production. Approximately seven percent of transmitted electricity in the United States is lost every year. Table 1 shows total energy production minus total energy consumption by state, giving a simple idea of whether or not a state exports (+ sign) or imports (- sign) total energy. Only five states are included as examples here, chosen alphabetically. However, production-consumption data is included for all 50 states in the analysis.

Table 1 – Examples State Export or Import for Selected States for 2010

State	Production-Consumption	Export or Import
Alabama	-539.981	Import
Alaska	1101.332	Export
Arizona	-811.822	Import
Arkansas	129.982	Export
California	-5300.726	Import

It could be argued that energy independence on a national level, country to country, is more important for energy and economic security than at the state level. At the national level, imports from other countries, as opposed to states, can cause issues. As a most basic example, countries suddenly unwilling or unable to sell energy to the United States, as in the form of oil for instance, could cause problems for international policy and politics. Table 2 shows imports and exports for oil and oil products into the United States as a nation with imports by country (randomly selected). This table is not used for quantitative purposes in this instance, but only to display that the United States relies upon diverse countries for various amounts of energy importation.

Table 2 – United States Import by Selected Country of Origin 2011

Country	2011 Thousand Barrels
Argentina	11,522
Aruba	26,714
Canada	1,020,604
Colombia	158,060
India	17,859
Iraq	167,690
Kuwait	69,890
Mexico	440,252
Nigeria	298,732
Russia	227,774
Saudi Arabia	436,020
South Korea	19,185
Spain	19,419
United Arab Emirates	3,645
United Kingdom	58,216
Venezuela	346,989
Virgin Islands (U.S.)	68,048

Renewable energy does not rely on combustion as does conventional, non-renewable energy. Due to concern about global climate change through greenhouse gas emissions, some of which originate from combustion, renewable energy is an alternative to reduce these emissions. Global warming, as part of global climate change, is associated with sea level rise through ice melt, thermal expansion, and changes in air temperature. This can be a worrisome trend, as a large percentage of the world's population lives along coastlines. As sea level rises along coastlines, many individuals may be displaced as a result. Also, some organisms have temperature thresholds in which they can live or reproduce. These organisms may find it difficult or impossible to move from one habitat to another with conditions that allow for survival.

Of particular concern in terms of global climate change, transportation – automobiles, trains, airplanes, and ships - is an issue as far as fossil fuel combustion pollution. For instance, in 2011, 28% of energy in the United States was used by the transportation sector (EIA, 2012). Larger cities worldwide, like Mexico City, Los Angeles, Cairo, and Beijing, have problems caused by emissions from transportation and resulting hazards such as smog and particulate matter. Not only can these emissions of greenhouse gases contribute to global climate change, but they can also be hazardous to humans living in polluted areas. Renewable energy, especially as a replacement for fossil fuels, can dampen the negative effects associated with combustion pollution.

This analysis is unique in that the dependent variable, renewable energy production, is not tested in previous literature. Renewable energy is important for sustainable energy use due to depleting non-renewable sources, energy security at a state and national level, and global climate change due to processes such as combustion. This analysis using renewable energy production can give states an idea of which variables may or may not be related to renewable energy production to increase their own production, if desired.

REVIEW OF RELATED RESEARCH

Existing literature pertaining to this analysis and discussion consist of five published articles. As mentioned in the introduction, renewable energy production by state is the only dependent variable used here. However, the existing literature discussed uses different dependent variables, for instance, measures of renewable portfolio standards by state. A RPS (renewable portfolio standard) by law requires a certain percentage of electric energy produced within a state to come from renewable sources. This literature is not reviewed as a direct comparison, as the dependent variables are different, but as references. Only the dependent and independent variables of relative importance to this analysis and discussion will be included in this literature review. Directions of significant variables throughout this review are displayed in Table 3.

Carley (2009) discussed renewable energy electricity production by state (dependent variable) in relation to multiple independent variables. In terms of relevance to this paper, Carley (2009) used per capita GSP (gross state product); average retail electricity price; house scores (league of conservation voters on “green” policies); and wind, biomass, and solar potential as independent variables. Of the six independent variables listed above, four were found to be significantly related to renewable energy electricity production excluding electricity price and LCV scores. The model in which Carley (2009) found significance for these independent variables was a fixed effects vector decomposition model.

Chandler (2009) used SEPS (sustainable energy portfolio standard) as a dependent variable. A SEPS includes renewable energy electricity production, as a RPS would, and efficiency improvements. Relevant independent variables include disposable personal income, renewable potential, and government ideology (more liberal). Chandler (2009) ran an internal determinants model running from 1997 to 2008. In the first model, logistic regression including all internal determinants, only two dependent variables were found to be significantly related: disposable personal income and government ideology. In the second, third, and fourth logistic regression models, personal disposable income was significantly related to the dependent variable.

Huang et al. (2007) used RPS adoption as the dependent variable in logistic regression modeling. The applicable independent variables are state GSP, education (bachelor degree attainment), and political party dominance (Republicans and Democrats in Senate and House). Education and political party dominance were significantly related to RPS adoption at the $p<0.05$ level.

Lyon and Yin (2008) modeled RPS adoption as the dependent variable using a logistic model. Wind, solar, and biomass potential; median income; average electricity price; democrat percentage in state house; league of conservation voters scores; and republican governorship were the independent variables. In the fourth logistic model run almost all independent variables were included (more so than in the first three model runs), excluding democrat percentage. Wind potential and league of conservation voter scores were the two found to be significantly related to RPS adoption.

Matisoff (2008) used adoption of a RPS in each year between 1997 and 2005 as a dependent variable. GSP per capita, wind potential, solar density, and citizen liberalism (active electorate scale 0-100) are the four relevant independent variables entered into the Matisoff (2008) models. The difference between the first and second model was that wind potential and solar density were replaced by a renewables index in the second model. In both models citizen liberalism was significant and in the second model renewables index was significant.

Table 3 – Summary of Literature Review

Author	Dependent Variable	Independent Variable	Sign of Relation	Significant p<0.05
Carley	Renewable Energy Electricity Production	GSP Per Capita	+	Yes
		Electricity Price	+	No
		Regional RPS	+	Yes
		Wind Potential	-	Yes
		Biomass Potential	+	Yes
		Solar Potential	+	Yes
		LCV Score	-	No
Chandler	SEPS Adoption	Personal Income	+	Yes
		Renewable Potential	+	No
		Government Ideology	+	Yes
Huang et al.	RPS Adoption	GSP	+	No
		Education	+	Yes
		Political Party	-	Yes
Lyon and Yin	RPS Adoption	Wind Potential	+	Yes
		Solar Potential	+	No
		Biomass Potential	-	No
		Median Income	-	No
		Electricity Price	+	No
		Democrat Percentage	NA	NA
		LCV Score	+	Yes
		Republican Governor	NA	No
Matisoff	RPS Adoption	GSP Per Capita	+	No
		Wind Potential	+	No
		Solar Density	+	No
		Renewables Index	+	Yes
		Citizen Liberalism	+	Yes

It is important to keep in mind, as mentioned earlier, that the literature discussed here is not directly comparable to this analysis because the dependent variables are not identical. Table 3 summarizes each author, dependent variable, independent variables, sign of relation, and significance for the literature review. In terms of this analysis, the existing literature may help to predict which independent variables may be significantly related to renewable energy production.

METHODS

Data:

The dependent variable and independent variables are divided into six groups (labeled A through F): energy, education, socioeconomic, policy climate, religious orientation, and environmental condition. In this section, the dependent and independent variables will be discussed one by one. Explanations for choice of a variable, how it connects to previous literature, and the sources of variable data are included in the descriptions. The majority of data used in these models and analysis are from 2010, but some data were not available for 2010 and this is specified for each variable.

A. Energy

1. Renewable Energy Production: This dependent variable is chosen as opposed to renewable portfolio standard (RPS) adoption, as used in some previous literature, because it allows actual amounts of data to work with, in the form of either TBtu (trillion British thermal units) for modeling and analysis. Not all states have a RPS, but all states produce some amount of renewable energy. In addition, not all states with an adopted RPS actually meet the RPS requirements or goals. RPS only applies to electricity, and not all renewable energy is used for electricity production. Hydropower energy production is also included in this variable as it is considered renewable. Renewable energy could be bought from other states (which produce and sell it). Therefore, actual renewable energy production should be a more accurate, albeit a different measure as compared with RPS of how much is genuinely produced in each state. Renewable energy production data are provided from EIA SEDS database.

2. Production-consumption (Import or Export): The difference between total energy consumption and production represents whether a state imports (positive sign) or exports (negative sign) energy. As this difference increases, importation increases, and renewable energy production should also increase. If this occurs, it will provide energy independence for states relying on importation from other states or other nations. Whether a state imports or exports data is unique to this paper and is not found in existing literature. The 2010 initial energy amounts were drawn from EIA's SEDS database (then calculated manually).

B. Education

3. Advanced Degree: Percent of population by state with at least an advanced degree is the measure of education level used here. Huang et al. (2007) predicted that a state would be more likely to have an RPS with higher education levels, for which the bachelor's degree variable was used. The reason for this prediction, given by Huang et al. (2007), is that "a person's knowledge of the negative consequences of fossil fuel use and political problems associated with higher dependency on foreign oil". Because Huang et al. found bachelor degree attainment to have a positive and significant relationship with the dependent variable, a different education measurement is used in this modeling and the same outcome is expected to be found. Although attainment of a bachelor degree is modeled in existing literature, advanced degree attainment is not. 2009 advanced degree data were provided by the U.S. Census Bureau.

C. Socioeconomic

4. Retail Electricity Price: The idea that if electricity costs more in a particular state, then people within that state may be more willing to switch to a renewable energy source

for their electricity for relatively competitive pricing. As electricity costs increase, renewable energy production should increase. Much of the time, however, electricity prices are consistently greater from renewable sources than non-renewable sources. Carley (2009) did not find a significant relationship between this variable and renewable energy electricity production. Lyon and Yin (2008) also used electricity price as an independent variable in their modeling and find it, as Carley (2009) did, to not be significantly related. Even though previous literature has found this to be insignificant, it is added here because the data used are more recent. Average electricity pricing for 2010 is provided by EIA SEDS database.

5. Gross State Product: As GSP rises, so might renewable energy production. The more money a state has to spend, the more it might spend on initial costs or incentives for renewable energy production at both a commercial and residential scale. GSP per capita was tested as an independent variable by Carley (2009) and Matisoff (2008). These data collected for this variable are more recent than those used in existing literature, but also slightly differ in this modeling as per capita is dropped. A state with a higher GSP may be more inclined to fund renewable energy production than an individual with a higher GSP (GSP per capita) within a state. Huang et al. (2007) used GSP, as it is used here, as an independent variable. Similar to GSP per capita, Chandler (2009) used personal income by state. Carley (2009) and Chandler (2009) found a significant relationship, while Huang et al. (2007) and Matisoff (2008) did not. 2010 GSP data came from the Bureau of Economic Analysis.

6. Poverty Level: This variable is mentioned alongside GSP because both are socioeconomic measures, but more specifically both are financial measures. Carley

(2009) found a significantly positive relationship between per capita GSP and renewable electric energy production, and so poverty levels might show the opposite. With greater poverty, people within a state may not have the financial inclination or ability to promote renewable energy production. Therefore, as poverty increases, renewable energy production should decrease. 2008-2010 average poverty data retrieved from the U.S. Census Bureau.

7. Total Population: Total population is an independent variable because with an increase in total population (by state), an increase in total energy consumption should occur. If more people are using more energy within a state, then it could be that renewable energy increases to keep pace with demand from a larger state population. Total population is an original variable in this modeling. 2010 population data are provided by the U.S. Census Bureau.

D. Policy Climate

8. Republican Presidential Vote Percentage: The percentage of recent votes in Presidential elections in favor of the Republican Party is meant to act as a measure of political will towards renewable energy by state. In this analysis, actual percentages of total votes are used. Carley (2009) used LCV scores (not significant); Lyon and Yin (2008) LCV scores (significant), democrat percentage, and republican governorship (not significant); Chandler (2009) government ideology (significant), Huang et al. (2007) political party dominance in house and senate (significant), and Matisoff (2008) citizen liberalism (significant) as measures of political tendency. Because the majority of models in previous literature found political will significant, it is predicted that it will also be significant here. Although political independent variables are used in previous

literature, presidential election data have not been used. They are chosen here for political will because more voters turn out for presidential elections and a larger sample of the population is accounted for in the voting percentages (U.S. Census Bureau, 2012). Data on Presidential elections in 2008, the most recent to date, are gathered from the U.S. Census Bureau.

E. Religious and Ideological Orientation

9. Belief in God or Universal Spirit with Absolute Certainty: This independent variable is chosen because literature has shown that environmentalism decreases with an increase in religiosity among Christians (Greeley, 1993 and Eckberg and Blocker, 1996). Since the United States is predominantly Christian with 80% of the population affiliated (PEW Forum on Religion and Public Life, 2011), it is an appropriate measure for the fifty states. As renewable energy could be seen as a solution to apparent environmental "problems", such as global warming, the states with a higher percentage measurement of this variable should show a lower amount of renewable energy production. This independent variable has not been examined in existing literature relative to the topic of renewable energy production. Data provided by PEW Forum on Religion and Public Life.

F. Environmental Conditions

10. Renewable Energy Potential (includes biomass, hydro, wind, solar, and geothermal energy potential): States with higher renewable energy potential should have higher renewable energy production. Carley (2009) and Lyon and Yin (2008) both utilized biomass potential as an independent variable, the first found significance and the second did not. Even though this variable is used in previous publications, it is added here because it is believed that this variable contributes much to a state's renewable energy

production. Biomass potential energy data are obtained from the National Renewable Energy Laboratory, given in GWh annually, and include resources from crop, forest, mill residue, urban wood waste, animal manure, domestic wastewater treatment plants, and landfills. Hydropower is not always included as or in an independent variable in existing publications because it is not always covered by a RPS. Here, hydro power is used because it is still a clean source of energy and does not rely on combustion. It has the desired effects of a renewable energy source and should not be discounted due to varied state policy. Hydro potential data are gathered from the National Renewable Energy Laboratory and given in GWh annually. Carley (2009), Lyon and Yin (2008), and Matisoff (2008) all employed wind potential as an explanatory variable in their modeling. Matisoff (2008) was the only one that did not find a significant relationship between wind potential and the dependent variable. Data for wind potential are procured from the National Renewable Energy Laboratory and given in GWh annually. Carley (2009) and Lyon and Yin (2008) included solar potential and Matisoff (2008) included solar density as variables. The last two mentioned here did not find significance in the relationship, but Carley (2009) did. The National Renewable Energy Laboratory contributed data for solar potential. Geothermal potential data were retrieved from the National Renewable Energy Laboratory and given in GWh annually. All data renewable energy potential data were given in GWh annually, but are converted here to trillion BTU.

Chandler (2009) and Matisoff (2008) use renewable energy potential and a renewable energy index, respectively, as opposed to using separate potential types for each state. Chandler (2009) finds no significant relationship with the dependent variable, while Matisoff (2008) finds significance with the renewable energy index.

Research Questions:

Aside from the predictions of positive or negative relations amongst variables, two research questions are included here. Question One: Which states are leaders in renewable energy production? Question Two: What factors may account for variation among state renewable energy production?

Due to the number and discussion of each variable, important variable information is shown in Table 4. The first column is the name of the group in which an independent variable resides with similar independent variables. The second column is the name of the independent variable used in modeling. The third column shows the type of variable. The fourth column states whether or not the independent variable has been modeled in existing literature. Similar is also an option in the fourth column, which denotes that an analogous variable is used in previous publications but is not exactly the same as the independent variable used here. The fifth column gives the prediction of relationship, positive or negative, for the dependent variable.

Table 4 – Summary of Independent Variable Discussion

Group	**Independent Variable**	**Variable Type**	**Previous Literature**	**Predicted Relationship**
Energy	Production-Consumption	Continuous	No	+
Education	Advanced Degree	Continuous	Similar	+
Socioeconomic	Retail Electricity Price	Continuous	Yes	+
	Gross State Product	Continuous	Yes	+
	Poverty Level	Continuous	Yes	-
	Total Population	Continuous	No	+
Policy Climate	Republican President Vote	Continuous	Similar	-
Religious and Ideological Orientation	Belief in God with Absolute Certainty	Continuous	No	-
Environmental Conditions	Renewable Energy Potential	Continuous	Yes	+

Statistical Analyses:

All modeling was performed in two parts for this analysis using SPSS 19 software. The first includes two linear regressions and the second includes one factor analysis (principal component analysis) and one linear regression. These are divided into two parts because factor analysis is a completely different type of modeling than linear regression and the outcomes for each of the two sections should not be confused. For each linear regression performed, the output includes Pearson Product Moment Correlation for each variable, model summary, ANOVA (Analysis of Variance) output with significance, standardized coefficients, coefficient correlations, collinearity diagnostics, and residuals statistics. The linear regressions output one model and include all variables initially included in the model. The model summary gives R, R-square, and adjusted R-square values and ANOVA then gives a p-value for significance of the model.

Two linear regressions were run for the first part of data testing. The first linear regression included all variables, one dependent and nine independent. The second linear regression uses the same dependent variable but draws a select number of the independent variables from the first model run. The independent variables chosen from the first run for the second are determined by Pearson Product Moment Correlation. Collinearity can be a problem when using a number of possibly related independent variables. To reduce collinearity in these models between independent variables, only those with a correlation of less than $\pm$ 0.7 are allowed in the second linear regression run.

The second part of data testing includes a factor analysis (principal component analysis) and a linear regression with independent variables selected from the factor analysis using a specific criterion (specified below). The factor analysis performed first in this part of the modeling includes all ten variables and explains the portion of variance contributed by each variable. Although renewable energy production is placed in the model with all other variables, it does not act as a dependent variable here. Varimax rotation is used for the factor analysis to maximize the explanation of variance for each variable. The factor analysis groups together the variables that load on similar components. The top loading variable for each component, whether positive or negative, is taken from the factor analysis and entered into a linear regression. Also, renewable energy production is entered as the dependent variable. This is done to show the possible significance of certain variables that are top loading. Also, issues with collinearity are decreased by choosing only one variable from each component, as components contain variables that are possibly related and load together. The function returns a model and statistics, as described above.

RESULTS AND DISCUSSION

In answer to the first research question, ‘which states are leaders in renewable energy production?’, Table 5 shows a list of all 50 states with their corresponding amount of renewable energy produced in each. The top five renewable energy producing states include Washington, California, Iowa, New York, and Texas (higher to lower, respectively).

Figure 1 then shows a United States map and the varying amounts of renewable energy produced within each state within a particular range. Visually, it seems that the lowest producing areas are the Western United States (except for the coastal states) and the central and southern coastal Eastern states. The states within the South and Midwest regions show little pattern and seem to vary in production. Top producing states appear mainly along the northeast coast, but do show in the South, Midwest, and Northeast.

A. Part One: Correlation and Regression Analyses

The first linear regression completed for analysis includes one dependent variable and all nine independent variables discussed in the data section. Correlation between only the dependent and independent variables is shown in Table 6. Four of the nine independent variables are highlighted in light red to show the predictions do not match the actual correlation. These include production-consumption, advanced degree, retail electricity price, and poverty level. Independent variables with a correlation of above ± 0.5 are highlighted in light blue. These are gross state product and total population.

It is important to keep in mind that correlation does not imply causation. However, it could be that one or more of the highly correlated variables are significantly related to renewable energy production. The correlation table (Table 6) remains constant for each of the models, three linear regressions and factor analysis, in both parts one and two.

Table 5 – State Renewable Energy Production in TBtu
Five highest producing state highlighted in yellow
Table created by author from EIA SEDS Database

State	Production	State	Production
Alabama	231.591	Montana	117.27
Alaska	15.409	Nebraska	270.671
Arizona	93.328	Nevada	49.423
Arkansas	116.307	New Hampshire	38.389
California	701.456	New Jersey	22.657
Colorado	77.93	New Mexico	36.434
Connecticut	25.31	New York	398.943
Delaware	2.876	North Carolina	151.378
Florida	236.419	North Dakota	113.188
Georgia	208.375	Ohio	117.693
Hawaii	16.291	Oklahoma	89.944
Idaho	136.491	Oregon	388.803
Illinois	258.568	Pennsylvania	140.531
Indiana	182.753	Rhode Island	2.688
Iowa	630.503	South Carolina	108.644
Kansas	103.095	South Dakota	215.14
Kentucky	62.649	Tennessee	169.62
Louisiana	105.884	Texas	397.086
Maine	145.302	Utah	18.563
Maryland	40.931	Vermont	26.1
Massachusetts	40.761	Virginia	105.541
Michigan	150.822	Washington	807.87
Minnesota	288.345	West Virginia	34.655
Mississippi	62.755	Wisconsin	201.917
Missouri	88.989	Wyoming	45.527

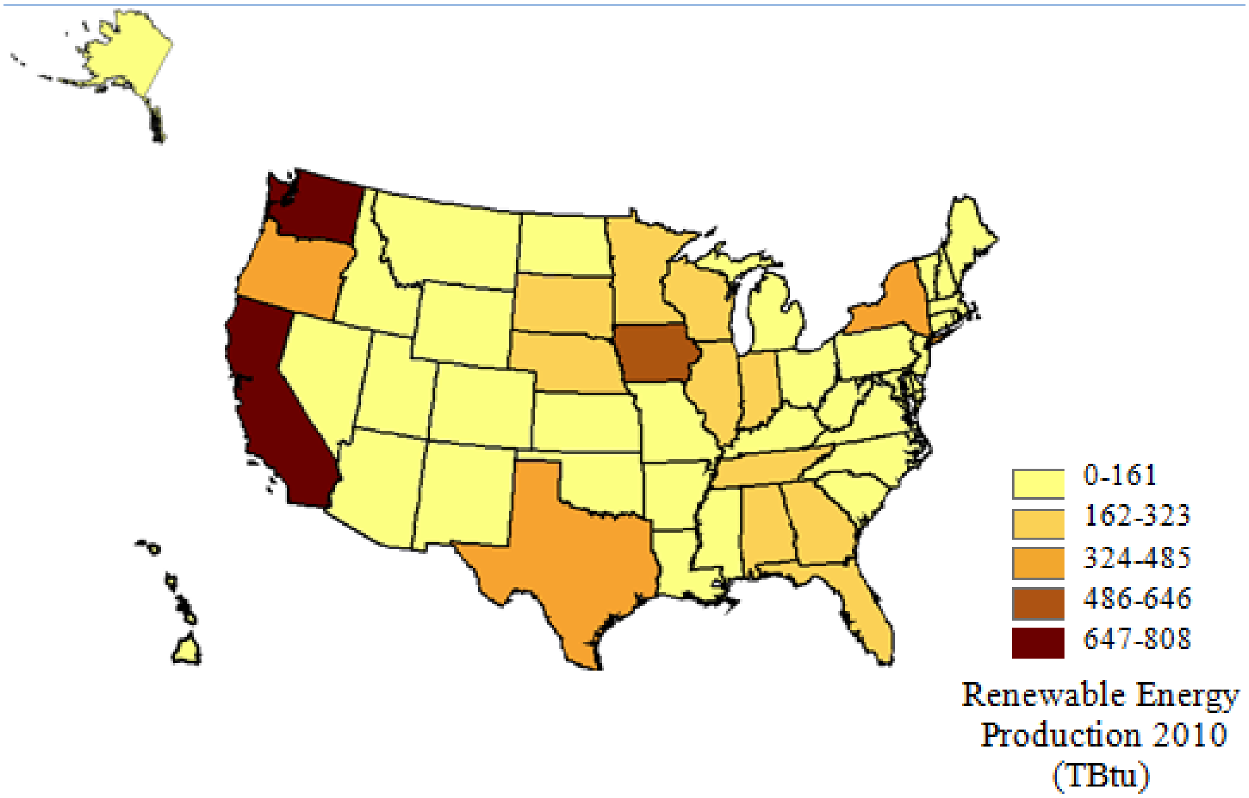

Figure 1 – United States Map Renewable Energy Production 2010
Map created by author from EIA SEDS Database

Table 6 – Summary of Correlation between Dependent and Independent Variables
Variables in light red do not have matching prediction and correlation signs
Variables in light blue have a significant correlation of >±0.5

Group	Independent Variable	Correlation	Sig. Correlated	Predicted Sign	As Predicted
Energy	Production-Consumption	-0.373	Yes	+	No
Education	Advanced Degree	-0.066	No	+	No
Socioeconomic	Retail Electricity Cost	-0.195	No	+	No
	Gross State Product	0.558	Yes	+	Yes
	Poverty	0.056	No	-	No
	Total Population	0.548	Yes	+	Yes
Policy Climates	Republican Presidential Vote	-0.132	No	-	Yes
Religious and Ideological Orientation	Belief in God with Absolute Certainty	-0.064	No	-	Yes
Environmental Conditions	Renewable Energy Potential	0.212	No	+	Yes

All nine independent variables are included in the first linear regression and are shown in Table 7. Table 8 displays the model summary for this regression run. The adjusted R-square value is 0.508.

Table 7 – Independent Variables Included in Part One, First Linear Regression (All Variables Entered)

Group	Independent Variable
Energy	Production-Consumption
Education	Advanced Degree
Socioeconomic	Retail Electricity Price
	Gross State Product
	Poverty Level
	Total Population
Policy Climate	Republican President Vote
Religious and Ideological Orientation	Belief in God with Absolute Certainty
Environmental Conditions	Renewable Energy Potential

Table 8 – Model Summary Part One, First Linear Regression Analysis (All Variables Entered)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.774	0.598	0.508	122.017	2.066

The ANOVA test for the model within the first regression is shown in Table 9. The model is significant with a p-value of 0.000. This means that, together, production-consumption, advanced degree attainment, retail electricity price, gross state product, poverty level, total population, Republican presidential votes, belief in God with absolute certainty, and renewable energy potential are significantly related to renewable energy production.

Table 9 – ANOVA Part One Linear Regression Analysis (All Variables Entered)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	887677.6	9	98630.85	6.625	.000
	Residual	595525.6	40	14888.14		
	Total	1483203	49			

The standardized coefficients vary between -1.651 and +2.207, while those for retail electricity cost, GSP, and advanced degree attainment are significant. Table 10 shows the standardized coefficient values for each of the nine independent variables. Research question two asks which variables may account for variation among state renewable energy production. In this case, all nine (together) are significantly related to renewable energy production, but those highlighted in blue have positive standardized coefficients and those in red text have negative standardized coefficients.

Table 10 – Independent Variable Standardized Coefficient Values
Part One, First Linear Regression Model
Highlighted in yellow are significant

Independent Variable	Standardized Coefficient (Beta)	t	Significance
(Constant)		4.457	0
Production-Consumption	-0.23	-1.563	0.126
Retail Electricity Cost	-0.522	-3.759	0.001
Gross State Product	2.207	2.721	0.01
Poverty Level	-0.2	-1.397	0.17
Republican Presidential Vote	-0.369	-2.012	0.051
Renewable Energy Potential	0.03	0.245	0.807
Advanced Degree	-0.509	-3.218	0.003
Total Population	-1.651	-2.009	0.051
Belief in God with Absolute Certainty	-0.118	-0.675	0.503

As mentioned in the methods section, collinearity can be an issue when independent variables are too highly correlated with one another. Therefore, independent variables with a correlation of >$\pm$0.7 to other independent variables are removed and the remaining variables are entered into a second linear regression model. Eight of the original nine independent variables, chosen as described, are entered into this second regression model and renewable energy production remains the dependent variable. The independent variables entered into this regression are shown in Table 11.

Table 11 – Independent Variables Included in Part One, Second Linear Regression Model

Group	Independent Variable Included
Energy	Production-Consumption
Education	Advanced Degree
Socioeconomic	Retail Electricity Price
	Gross State Product
	Poverty Level
Policy Climate	Republican President Vote
Religious and Ideological Orientation	Belief in God with Absolute Certainty
Environmental Conditions	Renewable Energy Potential

The model summary (Table 12) and ANOVA output (Table 13) for this second linear regression show the adjusted R-square, Durbin-Watson, and significance values. The adjusted R-square value is 0.472. Explanatory power (R-square value) is reduced due to the lesser number of independent variables. The incorporated independent variables, model summary, and ANOVA output are given here in table form.

Table 12 – Model Summary Part One, Second Linear Regression Analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.747	0.558	0.472	126.456	2.089

Table 13 – ANOVA Part One, Second Linear Regression Analysis

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	827568	8	103446	6.469	.000
	Residual	655635	41	15991.1		
	Total	1483203	49			

Although explanatory power decreased for this linear regression, the significance of the model did not decrease from the first model. To restate research question two: what factors may account for variation among state renewable energy production? The p-value for this second model is 0.000, equal to the first model, and is significant at the $p \leq 0.05$ level.

The standardized coefficients for this second model range from -0.483 to +0.602 and the independent variables which have significant associations with renewable energy production include retail electricity cost, gross state product, and advanced degree attainment. The standardized coefficient represents the slope of the line in a linear function. When the standardized coefficient (beta) has a higher absolute value for an independent variable, the more it is related to the dependent variable. Table 14 shows standardized coefficient values for each of the independent variables.

Table 14 – Independent Variable Standardized Coefficient Values
Part One, Second Linear Regression Model
Highlighted in yellow are significant

Independent Variable	Standardized Coefficient (Beta)	t	Significance
(Constant)		4.13	0
Production-Consumption	-0.141	-0.97	0.338
Retail Electricity Cost	-0.483	-3.387	0.002
Gross State Product	0.602	4.139	0
Poverty Level	-0.223	-1.503	0.14
Republican Presidential Vote	-0.365	-1.919	0.062
Renewable Energy Potential	0.017	0.13	0.897
Advanced Degree	-0.415	-2.651	0.011
Belief in God with Absolute Certainty	-0.14	-0.777	0.441

B. Part Two: Factor Analysis with Top Loading Variables and Linear Regression

In order to gain additional insight into associations between the variables, and perhaps reduce the number of variables to be included in a regression analysis, factor analysis was conducted using the extraction method of principal component analysis. This provides insight into explained variance and variable loading – or how the variables in the data set are associated with each other. Varimax rotation is applied during this factor analysis to maximize variance explanatory power for each variable. All nine variables are entered into the factor analysis and shown in Table 15. Table 16 summarizes the percent of variance explained by each of three provided components and then cumulative for the components.

Table 15 – Variables Included Part Two, Factor Analysis

Group	Independent Variable
Energy	Production-Consumption
Education	Advanced Degree
Socioeconomic	Retail Electricity Price
	Gross State Product
	Poverty Level
	Total Population
Policy Climate	Republican President Vote
Religious and Ideological Orientation	Belief in God with Absolute Certainty
Environmental Conditions	Renewable Energy Potential

Table 16 – Total Variance Explained Part Two, Factor Analysis

	Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %
1	3.132	31.325	31.325
2	3.065	30.652	61.977
3	1.303	13.03	75.007
4			
5			
6			
7			
8			
9			
10			

With varimax rotation, three components are produced in the factor analysis. The rotated component matrix, Table 17, shows all variable loadings on each component. The top loading variable, positive or negative, for each of the three components is highlighted in light purple.

These top loading variables include belief in God with absolute certainty, total population, and production-consumption, respectively, for components one through three.

The first component explains about 31% of variance, the second about 62%, and the third and last component explains about 75% of variance. Percent of variance explained decreased with each additional component, but the total variance explained increased with each component.

Table 17 – Rotated Component Matrix Part Two, Factor Analysis
Highlighted in Purple are Top Loading Variables, Red Font Highly Loading Together

	Component		
	1	2	3
Renewable Energy Production	0.003	0.7	0.232
Production-Consumption	0.042	-0.66	0.598
Retail Electricity Cost	-0.69	0.059	-0.392
GSP	-0.112	0.947	0.001
Poverty Level	0.74	0.318	-0.161
Republican Presidential Votes	0.776	-0.237	0.357
Renewable Energy Potential	0.193	0.389	0.72
Advanced Degree	-0.793	0.139	-0.23
Total Population	-0.026	0.954	-0.013
Belief in God with Absolute Certainty	0.909	-0.028	-0.115

Also of interest in this factor analysis is the variables loading together and very highly on component one (denoted by dark red text in Table 17). Attainment of an advanced degree loads negatively around -0.8 on component one, while Republican presidential votes, belief in God with absolute certainty, and poverty level load positively and all above +0.74 on the first component. This indicates a possible negative relationship between education and political/ideological orientation with socioeconomic measures because they load oppositely on the first and same component.

The fourth model, linear function for part two of the analysis, uses independent variables identified by the factor analysis just examined. The list of independent variables entered is shown in Table 18, which are the top loading variables on each component for the three modeled in the factor analysis.

Table 18 – Independent Variables Included Part Two, Linear Regression

Group	Independent Variable
Energy	Import, Export
Socioeconomic	Total Population
Religious and Ideological Orientation	Belief in God with Absolute Certainty

The model summary for this linear regression is shown in Table 19. The adjusted R-square value for this model is 0.264. This value is far lower than the two R-square values in the first two linear regression models, which makes sense considering the number of independent variables entered into the model dropped to three from nine and eight. Therefore, the first two linear regressions in part one can be considered better models in terms of renewable energy production prediction. The standardized coefficients range from -0.091 to +0.496 and the only significant coefficient is for total population variable.

Table 19 – Model Summary Part Two, Linear Regression Analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.556	0.309	0.264	149.29849	2.075

The ANOVA output, Table 20, gives significance for this model (highlighted in yellow). As a reminder, research question two asks: what factors may account for variation among state renewable energy production? The model is found to be positively and significantly related to renewable energy production at the p≤0.05 level with a value of 0.001. This model is less significant than the first two models because the p-value is slightly higher and closer to 0.05.

Table 20 – ANOVA Part Two, Linear Regression Analysis

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	457861	3	152620	6.847	.001
	Residual	1025342	46	22290		
	Total	1483203	49			

Although all models in all three linear regressions are found to be significant by ANOVA outputs, only the results from the second linear regression will be considered in the conclusion. It has similar results to the first regression with fewer variables, but a slightly lower adjusted R-square value and the same p-value of significance. However, the second model has better results than the third regression in part two in that is has a higher adjusted R-square value and more significant p-value.

The first linear regression tested all nine independent variables together and found them to be significantly related to renewable energy production with a p-value of 0.000 and an adjusted R-square value of 0.508. The second linear regression, from which conclusions will be drawn, tested eight of the nine independent variables with a p-value of 0.000 (significant) and an adjusted R-square value of 0.472. The three independent variables which are significantly associated with renewable energy production include retail electricity cost, gross state product, and attainment of an advanced degree, as shown by the second linear regression standardized coefficient values. The two independent variables associated with higher renewable energy production are gross state product and renewable energy potential. The principal component analysis gives production-consumption, total population, and belief in God or Universal Spirit with absolute certainty as the top loading variables on each of three components, meaning they explain much of the variance within the data. The linear regression analysis in part two, with three independent variables chosen from the factor analysis, shows that the model is significantly related to renewable energy production with a p-value of 0.001 and an adjusted R-square value of 0.264.

CONCLUSION

The purpose of this modeling and analysis is to determine if the defined independent variables significantly relate to renewable energy production by state. The two research questions are

Question One: Which states are leaders in renewable energy production?

Question Two: What factors may account for variation among state renewable energy production?

Each of these two questions is answered explicitly in the results section of this paper. The states of Washington, California, Iowa, New York, and Texas are the top five producers of renewable energy throughout the United States. All three linear regression models are found to be significant at the ≤ 0.05 level. Gross state product and renewable energy potential are factors associated with more energy production. In the principal component analysis, the top three component loading variables are production-consumption, total population, and belief in God with absolute certainty, meaning they explain much of the variance within the data.

Although literature exists on this topic, this paper constructs an original dependent variable (renewable energy production) and tests associations with several original independent variables (production-consumption, total population, and belief in God with absolute certainty). This is an important topic because state governments, if not the federal government, will need to produce or import energy as conventional energy sources (non-renewable, fossil fuels) decline. However, importation of energy, whether renewable or not, is less desirable due to cost of transportation and state and national security.

Determining those factors that may influence levels of renewable energy production at the state level provides insights relevant to state and federal energy planning and, also, efforts to reduce greenhouse gas emissions. The analysis indicates that a higher level of renewable energy production is more likely in states with a higher GSP and greater renewable energy potential. Factors associated with lower levels of renewable energy production include a higher amount of total energy importation, more poverty, more Republican presidential voting, higher percentage of a state's population with a belief in God or Universal Spirit with absolute certainty, lower retail electricity cost and, somewhat surprisingly, a less educated citizenry. While some of these apparent influences – both positive and negative – are not easily changed, if at all, awareness of them will be useful to energy planners. It can be valuable to know if a state does not have a large amount of renewable energy potential so the state can plan accordingly and perhaps focus on other determinants which they can shape or take advantage of. In addition, stakeholders could look to other high renewable energy producing states to see which variables they might improve upon.

Policy climate projections and modeling could also be improved in the future if these explanatory independent variables are taken into account as they change state by state. If efforts are made by states to increase renewable energy production to replace conventional energy using these variables, then these variables should be accounted for in modeling energy production and use, possibly resulting in greenhouse gases and climate change. Aside from state governments, the federal government might also be interested in these findings as they could also improve variables which reduce renewable energy production at a national level.

To improve upon this modeling and analysis, different variables could be entered that have not been seen in previous literature or this research and remain untested. By taking a more in depth look at states which produce relatively large amounts renewable energy, these states could act as case studies for other states which do not have the renewable energy production desired. In addition, the modeling here only enters one year of data for each variable, mostly 2010, to give a snapshot of renewable energy production. Adding multiple years of data could introduce a new aspect of variables changing over time to possibly better predict renewable energy production. Improvement upon this research could help states create better policies which help ensure lasting and secure energy sources. However enhanced it could be, though, these findings can be useful at present to states and the federal government in boosting renewable energy production.

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VITA

Cynthia Christenson is a native of New Orleans, Louisiana. She attended Tulane University in New Orleans, Louisiana, earning a Bachelor of Science in Environmental Science in May of 2011. Here, she received the Bamforth Prize in Environmental Science. During her undergraduate academic career, she studied abroad for two semesters in Cairo, Egypt from 2009 to 2010 and developed an interest in Egyptian renewable energy policy. After graduating from Tulane University, she is attending Louisiana State University and currently earning a Master of Science in Environmental Science and is a teaching assistant. She is a member of Gamma Phi Beta, an academic honor society. Her thesis is titled “Renewable energy across the 50 United States and Related Factors” dealing with renewable energy policy. The chair of the committee is Dr. Margaret Reams. Between degrees, she has worked for a learning center working with learning disabled children and also as a resident advisor and tutor for an Arabic Language youth camp.