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Solar energy strategies in the U.S. utility market

Wesley Herche

Arizona State University – Global Security Initiative, United States

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ABSTRACT

Given the exponential cost decline trend of solar energy generation technologies, and the targeted tax incentives and loan guarantees for renewable energy in the American Recovery and Reinvestment Act of 2009, and other policy measures, solar energy generation has been enjoying rapid growth in the United States. This paper examines the incorporation of solar renewable energy into generation portfolios, and the effects of natural capital – specifically the geospatially calculated potential solar energy generation as measured by potential average annual kilowatt-hours per square meter per day – and respective state mandated “renewable portfolio standard” targets on utility-scale solar energy generation. Findings suggest that a state's natural solar energy potential is a predictor of solar energy generation development, and further this relationship is significantly moderated by state-specific renewable energy portfolio standard targets.

1. Introduction and background

1.1. Introduction

Consumer demand for a greater emphasis on renewable energy generation is very high in the U.S.; a 2013 Gallup poll of Americans showed support for “more emphasis” on solar and wind energy at 76% and 71% respectively [20]. The poll further indicated that support for solar power was high regardless of geographic region with “East”, “Midwest”, “South”, and “West” indicating support at 79%, 75%, 74%, and 78% respectively. Meanwhile prices for solar generation technologies continue to rapidly decrease; unsubsidized costs for solar photovoltaic systems have become cost-competitive with fossil fuels, utility scape PV specifically is on average cheaper than all forms of fossil fuel based generation [23]. Further, this strictly economic comparison ignores the externalized costs of fossil fuels in terms of environmental degradation and public health, thus when factoring in these negative externalities renewable technologies become even more attractive [5]. Despite large consumer appetite and falling prices, the most current estimates show renewables making up just 13% of US electricity production with solar (utility scale and distributed) being just under 1% [13].

Policy initiatives at the national and state level have directly targeted renewable energy production. At the federal level Section 1603 of the American Recovery and Reinvestment Act of 2009 (ARRA) had investment tax credits (ITC) of 30% for qualifying commercial renewable installations. These took effect in 2009, were extended twice, and have run through 2016 [37].

At the individual state level many states have created some version of a “Renewable Portfolio Standard” (RPS). An RPS mandates a specific target percentage for production of energy that must be from renewable sources such as solar, wind, geothermal, and biomass; electric utility companies must source their energy generation according to these minimum targets or face penalties imposed by the state. The RPS concept was first proposed and developed in the 1990s and implementation varies widely across states [26]. Fig. 1 shows the 29 U.S. states have some form of statutory RPS, usually these are a targeted percent of renewable generation by a certain year with a graduated schedule of advancement to the target goal, and an additional 8 states have non-binding voluntary renewable goals [11].

States differ on their overall target goals as well as respective “carve outs” and “multipliers” for specific renewable technologies that legislatures may be trying to promote in their state.[1] It should also be noted that many states without an existing RPS still have sizeable renewable energy generation collections.

The RPS, ITC utilization rates, and the natural capital potential of solar irradiance within each state are all examined against solar energy generation for electricity. The results provide a contribution to the literature on identifying the relative strengths and interaction effects of key correlates of electrical generation from solar. Because this examination is across multiple sets of data with varying degrees of temporal currency various annual ranges were utilized to have valid comparisons across datasets. In all cases the most current points or ranges of available data were used where appropriate.

E-mail address: wherche@asu.edu.

[1] i.e.: Within an overall goal of “15% renewables by 2015” a particular portion may be mandated for residential rooftop solar, or a wind energy generation may be counted towards the goal as at “1.5 times” rate.

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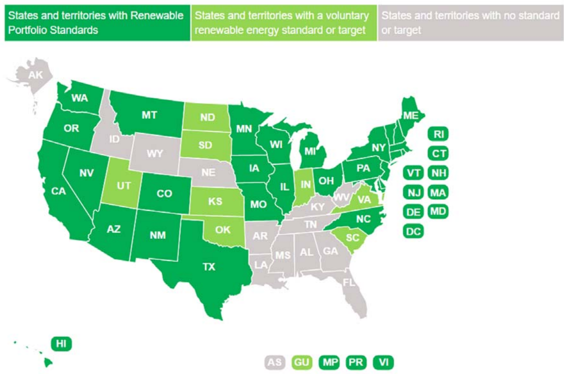

Fig. 1. Renewable portfolio standards [11].

1.2. Background

Benefits from both economies of scale [32] and technological innovation [15], have yielded exponential and consistent performance improvements in solar PV technology when examined on a global scale. The notion of “Swanson's law” has emerged; similar to “Moore's law” for computers [27], this phenomenon was named after SunPower Corporation founder Richard Swanson, who first noted, "module prices reduce 20% for every doubling of cumulative volume." [33,35]. Fig. 2 illustrates Swanson's Law with the non-linear (inflation adjusted) dollars per watt from 1977 to 2013. Thus considering a broader framing that also considers policy, geospatial explicitness, and market factors might yield more heterogeneous, and therefore more interesting, insights. Numerous bodies of literature have identified the need to incorporate these types of sociocultural and sociotechnical dynamics into the energy discussion [2,25,31,36,39,4,9].

For this analysis only the RPS goal for the state, if applicable, will be used as a general proxy indicator of the state's civic appetite for renewable energy within their electricity generation portfolio mix. Prior research on RPS policies have found that initial adoption of RPS by a state varies depending on the political makeup of the state legislature, the size of the existing renewable energy industry within the state, the state's reliance on natural gas, and the regulatory state of the electric utility market [24]. Further, not recognizing the heterogeneity of implemented RPS programs across various U.S. states has been insufficient for analysis in explaining variation among specific properties and provisions of the state's RPS and the resulting growth of renewables in that state [38].

This discussion extends the discourse on market effects of state and federal policies and incentives on a still emerging industry [10,29]. Further it extrapolates from well-established geographic theories of spatial autocorrelation [34]. Understanding these interaction effects has significant strategic implications for state and national policy makers, renewable energy advocates, entrepreneurs, and utility industry managers.

2. Hypotheses

The overall effect of RPS policies on the retail price of electricity is contested in both the political and academic arena. Generation is certainly the dominant factor in price; Fig. 3 illustrates estimates by the U.S. Environmental Information Administration revealing 58% of retail electricity prices are determined by generation, with transmission and distribution making up the other major components of the cost [6].

While critics often make unsubstantiated claims that renewable generation is more expensive than fossil fuels, if true this would logically indicate that the influence on markets of RPS laws would ultimately increase retail electricity prices. Yet previous research pursuits have been mixed arguing that RPS implementation could raise prices by increasing electricity generation costs or even lower prices because of reduced demand on non-renewables [12,16,17].

Those assumptions are tested here with empirical findings based on the state average change in retail energy price from 2005 to 2012 against the state's RPS percentage of renewables target for 2012. The years from 2005 to 2012 seem most critical as this is the general

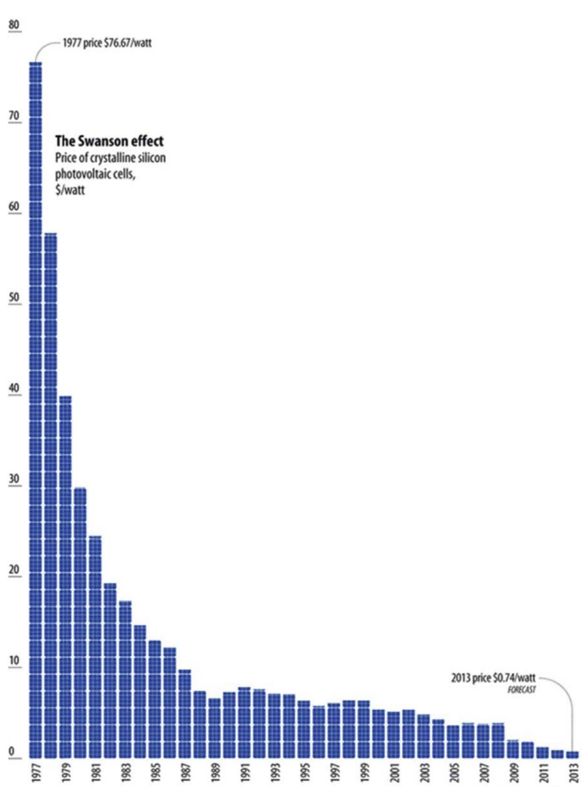

Fig. 2. The Swanson effect [35].

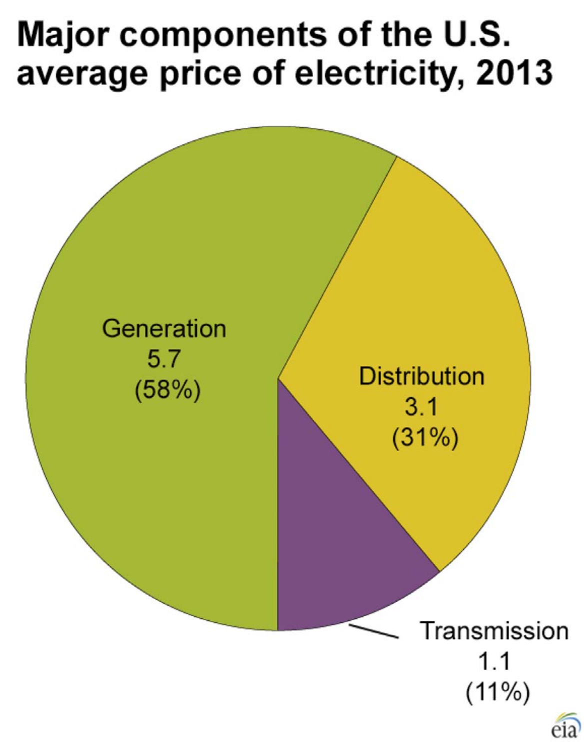

Fig. 3. Major components of the U.S. average price of electricity [6].

timeframe when most states began implementing initial, incremental targets to meet overall RPS goals the state had set. There were 26 states with enforceable RPS policies during this timeframe existing within both regulated and deregulated electric utility markets. The price data were aggregated by state across all electricity providers including federal, state, municipal, political subdivisions, cooperatives, retail providers, and investor-owned utilities. In 2012 non-hydroelectric renewables only accounted for 7% of total U.S. electric energy generation so the expected effects on prices should be small, yet given the high proportion of costs associated with generation these effects should be noticeable.

Hypothesis 1. *Utility companies in states with an RPS will increase prices to accommodate extra expenses associated with renewable energy generation.*

Another fundamental indicator to be empirically verified is whether the increase in RPS targets are positively associated with net level energy generated from renewable sources on a state by state basis.

Hypothesis 2. *The overall RPS percentage target within a given state will be positively associated with total solar energy generation within a given state.*

Admittedly this particular supposition is susceptible to a confounding variable effect (Fisher, 1935). Further, it may be difficult to definitively determine whether RPS policies are causing an increase in renewable energy generation or rather that states that are already predisposed towards renewable energy technologies are also more likely to enact legislation to support renewables. Nevertheless even if more aggressive RPS targets are a proxy for general proclivities towards renewables it is still important to understand empirically if the desired intent is for an expansion of clean energy, as measured in renewable energy generation. If the null hypothesis is supported for H2, this would call into serious question the validity of RPS programs in their ultimate ability to result in generation of electricity from renewables. However, since this analysis only examines the solar energy generation in H2 it will likely not explain a large portion of the variance in that (proposed) relationship.

The notion that solar energy generation potential should be positively and strongly associated with energy generated from solar seems intuitive but also needs to be tested empirically. Previous concerns with confounding variables are apropos here as well. Perhaps residents of a perceived “sunny state” such as Florida or Arizona are more likely to see themselves as potential benefactors of solar investments thus leading to more solar energy generation. However this relationship is still important to ascertain whether these states are actually capturing their natural capital[2] from this natural resource [28–30,7].

Hypothesis 3. *Values of potential solar energy generation (measured by average annual potential kW h/m^2/day) within a given state will be positively associated with total solar energy generation within that state.*

Indeed if the null hypothesis is supported or findings are insignificant for H3 this would call into question the relative importance of natural capital and geographic specificity in solar energy generation [29] and instead point to other factors such as policy and financing as the more important determinates [38].

A further test for better understanding this phenomenon can draw from complex adaptive systems literature. Perhaps a piece of the “emergence” that may occur between multiple factors effecting net solar energy generation can be revealed here, “wherein the whole of the system's behaviour goes beyond the simple sum of the behaviours of its parts,” [21]. While this discourse will not fully capture the totality of complexity within this system with only a few empirical measures, this could give good indication as to the complex nature of the phenomenon discussed here.

Hypothesis 4. *The overall RPS percentage target within a given state will have a moderating interaction effect with potential solar energy generation (measured by average annual kW h/m^2/day) such that when RPS targets are high the positive relationship of solar energy potential to generation will be stronger.*

3. Data, methods, and analysis

Examining natural solar energy potential, RPS policies, and their specific empirical relationship to the generation of energy from solar will serve to test these hypotheses. Additional data sources include the Energy Information Administration's copious data holdings on all electric utility companies within the U.S., the installed capacity of major solar power plants and the history of claimed federal income tax credit (ITC) awards for qualifying renewables.

While average annual solar energy potential is relatively constant from year to year, the rest of the data sources examined are on a year by year average annual basis and range from the years 2005–2014, though not all are current up to 2014. This helps bolster the longitudinal efficacy of analysis and results.

3.1. Variables

The dependent variable for analysis here is net generation of power from utility-scale solar sources aggregated by year and state. Actual electricity generation was chosen as dependent variable over measures such as installed capacity because it represents a more stringent hurdle of analysis and is more indicative of actual realized benefit of renewable energy generating technologies. This data is obtained from the Energy Information Administration, a division of the US Department of Energy, who collect and publishing data on petroleum, natural gas, coal, electric, nuclear, and renewable energy. A number of independent variables are examined and a hypothesized moderating interaction effect. These variables include potential solar energy generation measured by average annual kWh/m^2/day (EIA data), yearly RPS targets from the “Database of State Incentives for Renewable & Efficiency” (DSIRE) for each state,[3] income tax credit (ITC) awards from section 1603 of the American Recovery and Reinvestment Act of 2009 as administered by the U.S. Department of the Treasury.[4]

Of special note, the ITC awards data as an independent variable is presumed to be highly endogenous with the outcome variable of energy generation during the same time period. Companies that have installed utility-scale solar during the qualifying time period would be remiss to not claim the 30% tax credit. However, this analysis is not without merit, even with its presumed endogeneity, because it is not certain that construction of a solar plant will necessarily be consistent with successful operation and maintenance of the facility, and successful transmission of the energy produced to a utility provider willing to pay for that energy. This is consistent with the decision to use actual generation over installed capacity for the dependent variable. This can serve as a validity check for the successful execution of the intent of the ITC in adding more utilized renewable energy (specifically solar in this examination) to the utility grid. A null or insignificant finding would call into serious question the legitimately and cogency of this federal tax credit program.

[2] The notion of “natural capital” goes back at least to 1937 when while addressing a small informal audience in Montana U.S. President Franklin D. Roosevelt remarked, "we have lost sight of the fact that the natural resources of our land – our permanent capital – are being converted into those nominal evidences of wealth at a faster rate than our real wealth is being replaced."

[3] DSIRE is a joint effort by The U.S. Department of Energy and the North Carolina Clean Energy Technology Center: http://www.dsireusa.org/

[4] 1603 Program: Payments for Specified Energy Property in Lieu of Tax Credits http://www.treasury.gov/initiatives/recovery/pages/1603.aspx

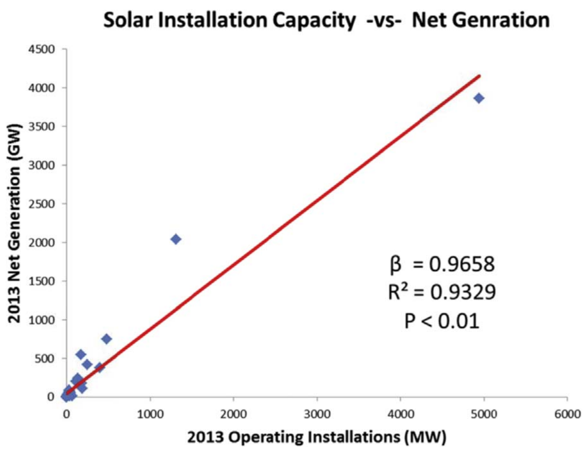

Fig. 4. Solar installation capacity –vs- net generation.

3.2. Analysis

Before delving into the formal hypotheses a quick check is in order on the relationship of net solar energy generation regressed on operating, utility-scale solar capacity, as well as net solar energy generation regressed on the claimed tax credits, on a state by state basis.

As suspected, shown in Figs. 4 and 5, both of these potentially endogenous relationships are positive, statistically significant, and highly correlated. Both have standardized coefficients (beta) of .96 and explain 93% of the variance. However, with the very high correlation we can potentially infer that installed solar projects, which also happen to have largely taken advantage of the tax credit, seem to be adding additional solar-generated energy into the utility grid.

4. Results

H1 anticipated that increased RPS requirements would be positively correlated with increased costs of retail energy to the end customer. This relationship was not supported, see Fig. 6, as it failed to achieve statistical significance (p=.7436) and explained none of the variance in price. This lends credence to the position by Fischer [16] that analysis of the effects of RPS on retail energy prices will take a more in-depth and nuanced model to derive useful explanatory power.

H2 proposed that the RPS percentage targets of a state will be positively associated with total solar energy generation. This hypothesis was supported, see Fig. 7, showing a moderate, significant, positive relationship (R^2=.1848). Other than in the case of specific solar “carve outs” utility companies within a state can choose to meet the state RPS

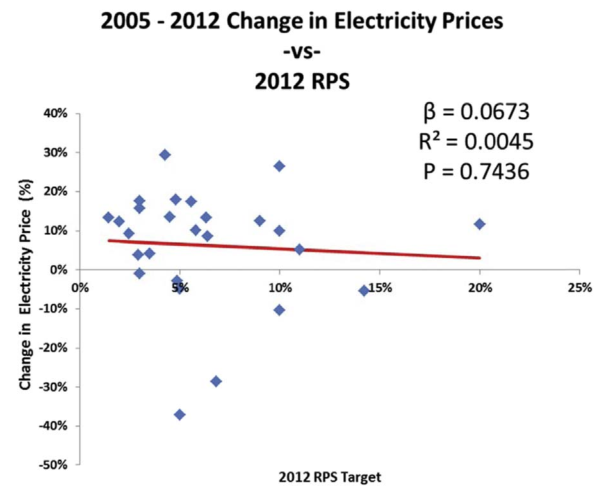

Fig. 6. 2005–2012 change in electricity prices –vs- RPS.

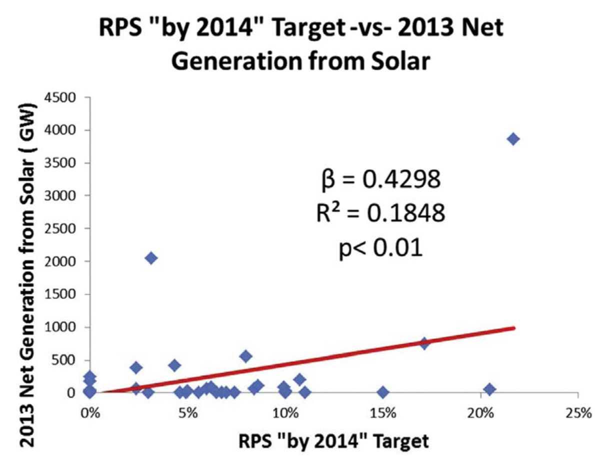

Fig. 7. RPS “by 2014” target –vs-2013 net generation from solar.

target with any renewable energy of their choosing. Thus the expected effect is shown here, but not necessarily a strong one, which is revealed in the results.

H3 proposed that potential solar energy will be positively associated with total solar energy generation within a given state. This hypothesis was supported, see Fig. 8, showing a moderate, significant, positive relationship (R^2=.2893). This result indicates that states with high, naturally occurring potential to generate solar energy are in fact doing so in many cases. Since these solar potential resources are heterogeneously distributed amongst states and stable over time this result

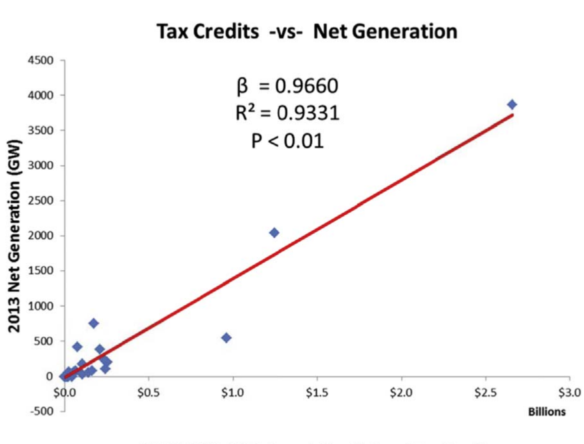

Fig. 5. Tax credits –vs- net generation.

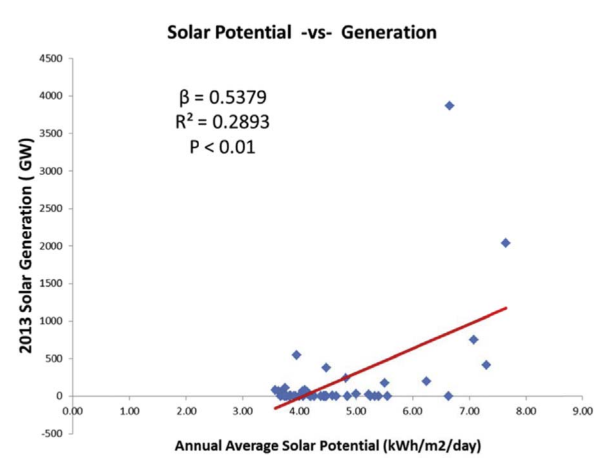

Fig. 8. Solar potential –vs- generation.

Table 1
Model summary.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.679[a]	.461	.426	.765277057314

[a] Predictors: (Constant), RPS target * Solar Potential, Solar Potential, RPS target.

Table 2
Coefficients.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	−.031	.109		−.283	.778
	RPS target	.213	.113	.213	1.888	.065
	Solar Potential	.512	.109	.512	4.718	.000
	RPS target * Solar Potential	.498	.134	.419	3.724	.001

[a] Dependent Variable: Solar Generation.

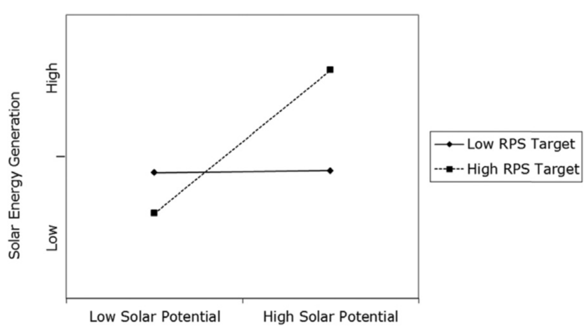

Fig. 9. Multiple regression slopes analysis.

Table 3
Correlation matrix.

	1	*2*	*3*
1. RPS Target (%)	–		
2. Solar Potential (kW h/m^2/day)	.01889	–	
3. Solar Generation (GW/year)	.20059	.53789	–

closely parallels foundational strategic management theory of "resource-based view" for sustained competitive advantage [3], and extends it to the realm of natural capital.

H4 suggested that the renewable portfolio standard target percentage would act as a moderator, amplifying the effect of solar natural capital on solar energy generation. This hypothesis is supported, see Tables 1 and 2, showing a significant, positive relationship (R^2=.4610). Additionally this statistical model has a better fit, with more variance explained, than considering the effects of either RPS or solar natural capital independently on solar energy generation. This is the most novel and significant finding of this examination. Support of H4 reveals states that have higher potential for solar energy generation ultimately have higher energy generation from solar, and states that have higher renewable portfolio standards have higher energy generation from solar; but most critically, states that have both higher potential and higher RPS targets have the strongest positive effect on solar energy generation. While much of the sustainability management literature operates across the three broad perspectives of natural, social, and economic realms, fewer studies have looked at specific interactions from these three in regards to solar energy efficacy [14,18,22].

A multiple regression slopes analysis, *see* Fig. 9, is necessary to confirm the moderator interaction in support of H4 [1,8]. To address concerns for tautology or multicollinearity a correlation matrix, see Table 3, for natural solar capital potential and RPS target demonstrate that the independent variable and moderator share almost no overlap (r=.01889). The issue of low correlation between solar potential and RPS is not trivial, it shows that just because a state has a potential to capture large amounts of natural capital from solar, this does not appear to affect the policy decision process on whether or not, and to what extent, a state should enact RPS targets.

5. Conclusion

Solar continues to emerge as a viable player in the energy generation portfolio of the United States; prediction models forecast its growth to continue for several decades [19]. One of the difficulties for managers in the utility industry, federal and state policymakers, and other stakeholder groups, is accounting for the myriad of complex interactions that can affect the development of this technology and market.

The contribution of this article is in extending the resource-based view to include considerations for natural capital, and in showing how highly variegated sources for measured variables still have a strong interaction effect on one another in this field of research. Solar energy potential measures a facet of natural capital available to a state, it is a geostatistical measure of a naturally occurring phenomenon. RPS target values are a reflection of civic and political will, driven largely by concerns for global sustainability. Energy generation from solar is an aggregate measure of electrical and mechanical engineering advancements as well as corporate strategy to muster the large amounts of capital necessary to build utility-scale solar projects. The significant interaction between these seemingly disparate streams of scientific inquiry highlights the complex and adaptive nature of these phenomena. The advent and rise of renewable energy technologies is somewhat of a shakeup to an otherwise stoic industry; this makes for fertile ground for policy and management research on these topics.

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