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The Influence of State-Level Renewable Energy Policy Instruments on Electricity Generation in the United States :;a Cross-Sectional Time Series Analysis

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THE INFLUENCE OF STATE-LEVEL RENEWABLE ENERGY POLICY INSTRUMENTS ON ELECTRICITY GENERATION IN THE UNITED STATES: A CROSS-SECTIONAL TIME SERIES ANALYSIS

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ABSTRACT

Since the late 1990s, state governments in the U.S. have diversified policy instruments for encouraging the electric power industry to deploy renewable sources for electricity generation. While observing the increasing number of new renewable energy policies at the state level governments, this study raised two research questions: (1) how do state governments intervene in the renewable energy market? and (2) how do various policy approaches taken by state governments affect renewable energy development? To answer for these questions, this study attempts to identify the trends and variations in renewable energy policy designs among states in terms of the combination of aggregate level policy instruments used by state authorities. Additionally, this study aims to examine and compare the effectiveness of policy instruments in the deployment of renewable energy sources for electricity production.

This study examined 18 state legislative, renewable energy related regulations, programs, or financial incentives existing between 2001 and 2010 in 48 states. Those 18 individual renewable energy policies were classified into three types of policy instruments: command-and-control, market-based, and information instruments. For the analysis, this study measured the amount and share of the electricity generation from non-hydro renewable sources as renewable energy policy effects. In order to isolate policy effects, this study also considered state specific characteristics such as natural endowment, economic and political environments, and the market conditions of electric power industries in different states.

This study employed fixed-effects models to analyze cross-sectional time series data. The results showed that states' adoption of diverse command-and-control types of policy instruments have significantly influenced the increase of both the amount and share of renewable electricity, while informative policy tools helped increase the share of renewable sources used by electric power producers. However, diversification of market-based policy instruments—especially financial incentives—did not significantly affect the increase of renewable electricity generation in states. Besides governmental intervention, state wealth and citizen interest in environmental issues played important roles in inducing more investment in renewable energy technologies. Also, natural gas price, wind speed, and states' export of electricity determined the proportion of renewable electricity in states.

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CHAPTER I

INTRODUCTION

Since the late 1990s, state governments in the United States have restructured their electricity market systems to adopt numerous policies and programs that regulate the sources of power generation and promote renewable energy development. State governments began deregulating electricity market systems during the 1990s, believing that privatization of utility provision and competition between electricity utilities would enhance the efficiency of energy production and thus lower electricity rates. In reality, however, signs of market failure began to appear in the United States' electricity market. Electricity rates rose across the states due to the monopolized (or oligopolized) electricity markets. Increasing energy dependence and lack of sustainable energy resources drove up the electricity rates. Electricity production's heavy dependence on fossil fuel also generated a significant amount of greenhouse gas (GHG) emissions, influencing global climate change.

In the late 1990s, when the U.S. state governments re-regulated their electricity market, they magnified and diversified regulations and programs for promoting renewable energy. During and after the restructuring of electricity market systems, new environmental policy instruments such as renewable portfolio standards (RPS) and performance-based incentives ("feed-in tariff") have been increasingly adopted at the state level. For instance, the number of states that adopted mandatory renewable portfolio standards increased from only five in 2000 to 29 states and D.C. today. Market-based incentives such as tax differentiation and marketable permits (cap-and-trade) have been proposed and implemented for purposes of cost efficiency and compliance. A state's social and political contexts affect the policies designed and utilized within the state (Berry and Berry, 1990; Matisoff, 2008; Yi and Feiock, 2012), which, when used appropriately, could positively influence the outcome of its policies. However, recent renewable energy policies adopted by many states do not seem to explicitly reflect their social and policy contexts; at least not in any readily recognizable way. Rather, the states' latest renewable energy regulations and taxations seem to follow the national trend of emphasizing energy independence and novel environmental policy instruments. Throughout the United States, renewable energy policies at the state level have been increasing in magnitude as well as diversifying in terms of the types of policy instruments, generating considerable variation among states (Gan, Eskeland, and Kolshus, 2007).

As the number of new renewable energy policies at the state level has increased, so have policy analyses and evaluations focusing on individual programs (Carley, 2009; Delmas and Montes-Sancho, 2011; Delmas, Montes-Sancho, and Shimshack, 2010; Menz and Vachon, 2006; Shrimali and Kniefel, 2011; Yin and Powers, 2010). Effectiveness of states' renewable energy policies has not yet been entirely evaluated and understood (Carley, 2011). Moreover, no study has clearly examined how well various renewable energy policy instruments work together (Carley, 2011). In order to trace and understand policy changes over time, categorization of policy instruments has been considered to be necessary as a step in developing an effective indicator (OECD, 2001; Persson, 2006; Richards, 2000). Analyzing the aggregate level policy instruments could provide an overview on the diversity of policy mixes, enabling the analysis of the effectiveness of each policy instrument and thus the development of optimal combinations of policy design (Lascoumes and Le Gales, 2007; Vedung, 1998).

This research is expected to provide a perspective on the extent of U.S. states' (as a whole and also as individuals) involvement in renewable energy deployment. By comparing the magnitude of renewable energy policies/programs adopted and implemented over the last decade, the research will also show the variation in and changes of states' interest in renewable energy development. Then, this study will categorize the renewable energy policies into three types based on coerciveness and behavioral assumptions: (1) command-and-control, (2) market-based, and (3) information policy instruments. Categorization of renewable energy policy instruments will be analyzed in relation to the states' contexts of natural resource, economic and political circumstances, and electric power market conditions, which are considered as determinants of policy choices and implementation. This will provide explanations for the variation in renewable energy policy choices among states; such variation will be accounted for in the research design to control the determinants' effect on renewable energy development.

The primary purpose of this study is to identify the variation in renewable energy policy designs among states in terms of the combination of policy instruments used by state authorities. This study additionally aims to examine the marginal effects of corresponding policy instruments. It will contribute to states' policy designs by showing the overall trends of U.S. renewable energy policy adoptions at the state level. It will offer a comprehensive overview of the evolution of energy policies since the 1990s in all of contiguous 48 states; which in turn will hopefully help states make better energy policy decisions in light of their own contextual variables. In addition, this study will contribute to the body of knowledge of public policy instrument mixes and their effectiveness.

CHAPTER II

RENEWABLE ENERGY POLICIES AND POLICY INSTRUMENTS

2.1 Background of Renewable Energy Evolution in the United States

In the history of renewable energy development in the world, the United States led the early development of renewable energy industries through federal level legislation beginning in the late 1970s. By the 1990s, however, European countries had outperformed the US in developing renewable energy markets. During this period, countries across Europe adopted and implemented a variety of policy instruments to develop renewable energy production. Examples of these policy instruments include national legislation such as Renewables Obligations (U.K.) or national quotas (Austria, Belgium, Italy, Denmark, and Sweden) (Haas, et al. 201; Reiche and Bechberger, 2004)[1], as well as non-legislative instruments such as green pricing activities and self-obligations (Enzensberger, Wietschel, and Rentz 2002). In the meantime, state governments in the United States began electricity market restructuring and renewable energy development

[1] Detailed overviews on the national policy instruments promoting renewable energy development in Europe, IEA (1997) and Moore and Ihle (1999).

through innovative policy designs. The U.S.'s renewable electricity industry has expanded even more dramatically in the last few years with a Federal stimulus package given to states for the purpose of recovery from economic recession of 2008.

The development of renewable energy policies in the United States features three distinct phases. The first phase is the birth of modern renewable electricity industry in the U.S. through Federal legislation from the late 1970s to the 1980s. Between the late 1980s and to early 1990s is the phase of stagnation in the growth of renewable energy industry in the U.S. Since the late 1990s, state governments opened the new era for renewable energy industry through innovative policy designs. The Federal enactment of the Public Utilities Regulatory Policy Act of 1978 (PURPA) started the first phase—the era of modern renewable energy industry. PURPA of 1978 required that electric utilities purchase power from qualifying third parties—meaning independent renewable energy generators or cogenerators—at the utilities' "avoided cost" (Martinot, Wiser, and Hamrin, 2005; Wiser, Pickle, and Goldman, 1998). This was the first use of a "feed-in" policy that offered electric utilities to purchase renewable electricity at the projected wholesale cost of conventional or fossil-fuel electricity, which approximately equals the "avoided costs" to the utilities.

Since the 1990s, European countries chose feed-in tariffs as a popular strategy to promote generation of electricity from renewables. Germany, Denmark, Italy, Austria, France, and Netherlands have adopted feed-in tariffs as their main electricity support schemes, combined with quota obligations or other tax incentives (Haas, et al., 2011). Their feed-in prices are usually fixed by law for each renewable energy technologies and/or set based on a certain percentage of the average electricity price (Martinot, Wiser, and Hamrin, 2005).

In response to the PURPA of 1978, several states developed ‘standard offer’ contracts, long-term contracts at a fixed tariff open to renewable power plants. California succeeded in development of its renewable energy industry through its aggressive implementation of PURPA along with generous state and federal tax incentives in the 1980s (Wiser, Pickle, and Goldman, 1998).

However, various tax incentives given to renewable energy industry were eliminated in the late 1980s and renewable energy markets remained stagnant in the following decade. Several reasons contributed to the declined interest in renewable energy: Fossil fuel prices, especially natural gas prices, dropped drastically and electric power utilities no longer had incentives to enter into ‘standard offer’ contracts because feed-in tariffs based on avoided cost declined (Martinot, Wiser, and Hamrin, 2005).

In addition, electric power markets began restructuring at both the federal and state levels in the early 1990s. The electric power sectors were forced to reorganize their systems into competitive regimes, including competitive wholesale markets and retail power competition along with unbundling of generation, transmission, and distribution. Developers in electric power industries deferred their decision of investment until the completion of electricity market restructuring and the preparation of final rules (Martinot, Wiser, and Hamrin, 2005).

In the late 1990s, however, a new era for renewable energy began in the United States. While electric power markets lost their taste for the federal level incentives under the PURPA of 1978, a number of new renewable energy policies were adopted at the state level in the process of the electricity market restructuring. Examples of state level policies driving renewable energy development included state tax and financial incentives, wholesale market rules, renewable portfolio standards (RPS), voluntary purchases of green power, and information disclosure. State governments' designs for renewable energy policy vary considerably in magnitude and diversity of policy instruments adopted.

Energy industries also have continued to deploy renewable energy technologies and reduce carbon emission voluntarily with the encouragement of federal financial incentives such as production (PTC) and investment tax credits (ITC) or grants in lieu (Section 1603) for renewable energy. In addition to the Public Utility Regulatory Policies Act of 1978 (PURPA), the Federal Production Tax Credit and Renewable Energy Production Incentive created under the Energy Policy Act of 1992 also contributed to the development of renewable energy industry (Bird, et al., 2005; Menz and Vachon, 2006). Facing the 2008 financial crisis, the U.S. Congress enacted the Energy Improvement and Extension Act of 2008 and the American Recovery and Reinvestment Act (ARRA) of 2009. §1603 program under ARRA, administered by the Department of Treasury in conjunction with the Department of Energy, offers cash grants in lieu of tax credits to renewable energy project developers. Section 1603 program aims to help expansion of investment in large solar and wind energy projects (Steinberg, Porro, and Goldberg, 2012).

2.1.1 Definition of Renewable Energy Policy

For the purpose of this study, "renewable energy" is restricted to the electricity production sector (also exchangeable with supply or generation) side and pertains only to the on-grid electricity generated from renewable resources, which excludes non-electricity energy use such as transportation or other methods to secure energy supply such as energy efficiency.

According to the U.S. Energy Information Administration (EIA)'s Energy Glossary, renewable energy resources (or renewables) are "energy resources that are naturally replenishing but flow-limited; inexhaustible in duration but limited in the amount of energy available per unit of time." Renewable energy resources for electricity generation, in general, include hydro, solar, wind, biomass[2], geothermal[3], ocean thermal, wave action, and tidal action.[4] Conventional sources of electricity generation – petroleum, natural gas, coal are excluded from renewables in this study. This study also excludes the "advanced energy technologies"[5] from the scope of renewable energy sources.

Policy instruments aimed at promoting renewable energy generation consist of legislative instruments implemented by governmental authorities and non-legislative instruments supported by market players (Enzensberger, et al., 2002). Renewable energy

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[2] Biomass is non-fossil material of biological origin such as wood and combustible renewable and waste (International Energy Agency). Solid biomass, liquid biomass, biogas, industrial and municipal wastes consist of renewable energy resource of biomass (EIA).
[3] Electricity can be generated from heat (hot water or steam) under the Earth's surface.
[4] EIA's Energy Glossary, http://www.eia.gov/tools/glossary/index.cfm.
[5] Ohio's Energy Bill (Senate Bill 221), passed in 2008, includes the "Alternative Energy Portfolio Standard," which considers "renewable energy" and "advanced energy" as alternative energy technologies to meet the mandated goal for electricity generators and suppliers. "Advanced energy" includes clean coal, advanced nuclear, fuel cells, energy efficiency, etc. The renewable energy in this study excludes the sources and technologies defined as "advanced energy."

policies that are discussed in this study stand for the legislative instruments including government mechanisms, efforts, and measures to promote the process of electricity production from renewable energy resources.

2.1.2 Goals of Renewable Energy Policy

This section reviews the policy goals that current renewable energy policies are intended to accomplish. The common goal of renewable energy policies can be simply stated to use more renewable energy technologies. There are, however, various goals that governments expect renewable energy to achieve (Komor and Bazilian, 2005). Komor and Bazilian (2005) define three broad goals of renewable energy policies: energy goals (energy supply security, energy price volatility reduction, and low energy price), environmental goals (pollution reduction and environmental sustainability promotion), and economic and industrial development goals (local/regional economic development, domestic employment increase). Beck and Martinot (2004) classify currently implemented renewable energy policies pertaining to their primary policy goals: renewable energy promotion, transport biofuels, emission reduction, power sector restructuring, distributed generation, and rural electrification policies.

This study is to select a policy goal and analyze and compare the effectiveness of different types of policy instruments aiming at the same goal. Governments develop different policy designs and combinations of various policy instruments to meet different policy goals. Expected policy outcomes vary depending on policy goals because they strongly influence the effectiveness of policy implementation. Depending on its stated goals, different indicators are needed to measure the achievement of given policy goals.

Governments often adopt renewable energy policies with various implicit and explicit objectives. Depending on the definition of the goal of renewable energy policy, the output measures of renewable energy development vary among net renewable electricity generation, renewable electricity purchase, renewable electricity consumption, etc.

This study limits its scope of analysis to the renewable energy policies aiming at promotion of the production of electricity from renewable resources. The entire range of legislative regulations, programs and incentives that the U.S. state governments have adopted and implemented to directly and indirectly support electricity generation from renewable resources are found in the analysis section of this study. This study analyzes in-state renewable electricity generation from all types of power producers. There are various electric producers consisting of utility and nonutility power producers that generate and transmit (purchase and distribute) electricity. Not all electric producers, however, generate renewable electricity to meet the mandated goal set by legislative authority, such as renewable portfolio standards. Instead, they may purchase renewable electricity generated from other states through transmission. An electric utility is a corporation, agency, authority, person, or other legal entity delivering electric energy primarily for commercial, industrial, and residential use. Electric utilities include publicly-owned utilities such as municipal and state utilities, Federal electric utilities, investor-owned utilities which are privately owned entities, and cooperative electric utilities. In the United States, there are more than 3,233 electric utilities, ensuring a reliable source of electricity to all consumers as of 2010 (EIA, 2012b, p.311). As of 2007, 210 investor-owned electric utilities represented about 38% of utility installed capacity, 42 % of electricity generation and served about 71% of ultimate consumers (EIA, 2007).

Nonutility power generation refers to electric generation by end-users, or small power producers. Nonutility power producers include independent power producers, qualifying co-generators, and small power producers. About 1,738 nonutility power producers exist across the nation. Independent power producers (IPP) operate within the territories of host utilities and must use renewable as a primary source of electricity generation. They do not sell electricity on the retail market; instead they sell electricity on the wholesale market at non-regulated prices (EIA, 2007). They do not file forms listed in the Code of Federal Regulations, Title 18, Part 141.

2.2 Public Policy Instruments

2.2.1 Definition of Public Policy Instruments

This section addresses the importance of policy instruments in practical public policy design, implementations, and studies. Public policy instruments are defined as "a set of techniques by which governmental authorities—or proxies acting on behalf of governmental authorities—wield their power in attempting to ensure support and effect social change" (Vedung, 1998). With the same policy goal, the result could be different depending on the policy instruments that the governments choose to implement, which determines the mechanisms for enforcement. "The use of various policy instruments for governance purposes will probably have different consequences on the nature of addressee responses" (Vedung, 1998).

Policy instrument choice affects the level of responsible government and types of institution. Policies enacted at the Federal government (or national government) level generally require a great degree of complexity and consensus. Policies that influence and utilize natural resources tend to be assigned to the state and regional levels (Bernstein, 1993). A World Bank report (Bernstein, 1993) suggested several lessons about alternative approaches to designing environmental policy, after the successful models of developed countries. Market-based instruments (or economic incentives) cannot replace command-and-control (or regulatory) instruments nor be effectively implemented without pre-existing standards.

Bernstein (1993) calls for further studies to 1) evaluate the effectiveness of various regulatory and economic instruments; 2) analyze the circumstances under which (economic) policy instruments can be successfully implemented; and 3) suggest the appropriate combination of policy instruments for developing countries. Also, Bernstein (1993) points out the importance of compatibility of new environmental policy instruments mixes with given political, economic, administrative, and judicial conditions as well as consistency with overall environmental policy.

Bennear and Stavins (2007) justified optimal implementation of multiple policy instruments in pursuit of a policy goal. They argued that for different types of problems under different environments, different instruments are appropriate. The use of "hybrid" instruments that combine a quantity and a price instrument has been explored recently. The authors asserted that multiple policy instruments could be optimal under the circumstances where multiple constraints exist such as political constraints, market failures, or policy failures. They framed that multiple constraints prevent attainment of multiple Pareto optimality, so that adjustment of one constraint (use of one type of policy instrument) does not enhance welfare (Lipsey and Lancaster, 1956). Therefore, market failures generated from multiple constraints can be “jointly ameliorating,” “jointly reinforcing,” or “neutral” through second-best policy making.

In the contemporary public policy environment of governance, policy instruments have undergone development and diversification. However, diversification and magnification of policy instruments without supportive evidence of their effectiveness through carefully designed and conducted evaluation of given policy instrument mixes or combinations do not guarantee governments better to achieve policy goals. Another topic to explore concerns the conditions and context under which a particular combination of policy instruments would be utilized and appropriate (Bennear and Stavins, 2007; Howlett, 2004).

Vedung (1998) argues that empirical evaluations of the effectiveness of governing instruments constitute a valid test of classification schemes for policy instruments. Also, the theoretical issues addressed in policy instruments theories help raise important research questions for future empirical evaluation. For example, what policy instruments are mixed and combined in horizontal[6] and vertical dimensions? What are the variables affecting the choice of policy instruments in organizational, political, and social (cultural) contexts? How does a chosen policy instrument affect public’s receptiveness of the programs, the politics of policy implementations, and the effectiveness and efficiency of government programs or policies (Vedung, 1998)? This study applies empirical analysis in a quest to answer these crucial research questions.

[6] Vedung (1998) refers the “horizontal packaging of policy instruments as the use of combined instruments for the same purpose.

2.2.2 Categorization of Public Policy Instruments – Typology of Policy Instruments

Although interest in policy instrumentation and policy mixes has increased, there exists limited policy analysis and public administration literature about a general and universal classification of policy instruments. The basis of the classification of policy instruments, however, can be found in literature, which discusses the general features of policy instruments and their relevance to the classification of renewable energy policy instruments.

The definitions of the types of policy instruments vary based on differing assumptions. This section reviews a previous literature that discusses classificatory schemes of policy instruments and the basis of policy instrument classification. Categories depend upon the defining features of each study, from a dichotomous approach such as regulation and incentives to six types. The traditional distinction divides policy instruments into either regulatory versus market-based or economic instruments (Bernstein, 1993; Callan and Thomas, 2004; Harrington, Morgenstern, and Sterner, 2004; Stavins, 1991). Discussions about market-based approach or economic instruments began since the 1980s through 1990s as an alternative approach to command-and-control type of environmental policy initiatives. Economists incorporated the market-based approach into the environmental policy such as pollution control, sewage and waste management, and energy conservation. Using economic incentives, market-based instruments are designed to allow polluters more flexibility to respond according to their own self-interests (Callan and Thomas, 2004; Harrington et al., 2004).

Schneider and Ingram (1990) classify policy tools into five groups based on the behavioral characteristics of each policy tool. They emphasize the importance of the motivational devices embedded in policy tools that empower people. Policies implicitly guide people to take actions that conform to policy goals. With well-designed policy tools, people might comply with policy rules, utilize the policy opportunities, or take self-initiated action. Schneider and Ingram (1990) point out five reasons that people do not take actions: (1) lack of authority of law to direct them, (2) lack of incentives, (3) lack of capacity, (4) disagreement with the implicit value of policy goals, and (5) high level of uncertainty. They define five policy tools addressing those five reasons—authority, incentive, capacity, symbolic and hortatory, and learning tools—and argue that the policy tools reflect the political culture. Vedung (1998) and OECD (1994) define policy instruments with a trifold classificatory scheme: regulation (the stick), economic means (the carrot), and information (the sermon) based on the degree of authoritative force involved. Vedung (1998) embodies Etzioni (1975)'s work[7] as a basis of the trifold scheme of policy instruments. There is an assumption that policy instrument choice is related to a society's dominant political and administrative ideologies and strategies. Vedung (1998) attempts to characterize policy instruments with three defining properties: (1) coercion, (2) the use of material resources, and (3) intellectual or moral appeals.

The degree of the coerciveness characterizes policy instruments (Linder and Peter, 1987; Salamon, 2002; Vedung, 1998). The degree of coerciveness measures the extent to which a tool set by governments can intervene in and restrict individual or group

[7] Etzioni (1975) claims three kinds of power which are means to control subject to comply and to achieve organizational purposes. He defines coercive, renumerative, and normative power as means for control purposes.

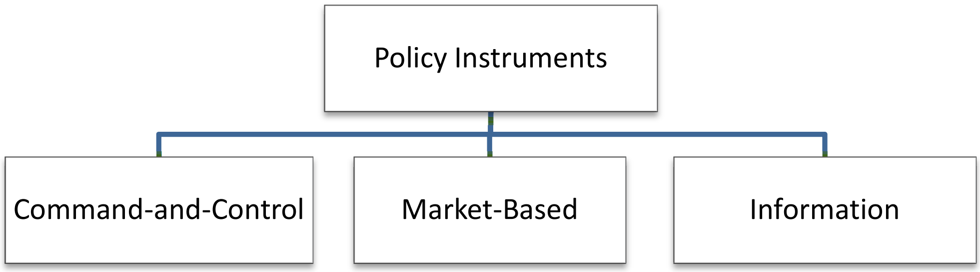
behavior as opposed to merely encouraging or discouraging it (Doern and Phidd, 1983; Salamon, 2002). There is at least some degree of coerciveness involved in most forms of governmental intervention. Based on the extent to which policies rely on this, however, individual policies can be grouped together (Salamon, 2002). Salamon (2002) classifies illustrative policy tools into three groups by degree of coerciveness—high, medium, and low— and hypothesizes likely impacts of policy tools according to the degree of coercion. Social and economic regulations are considered highly coercive instruments imposing formal limitations on undesirable activities. Market-based approaches of policy instruments that involve a medium degree of coerciveness include grants, loans, subsidies, and corrective taxes. Tax expenditures are considered less coercive. Information and voluntary instruments have the least coerciveness (Doern and Phidd, 1983; Salamon, 2002). In addition, Doern and Phidd (1983) further discuss that government corporations and government purchase of assets represent policy tools involving the maximum degree of coerciveness. Salamon (2002) expects that all other things being equal, more coercive tools are more effective, based on previous policy implementation literature,

Some studies categorize policy instruments based on their functional features (Lascoumes and Le Gales, 2007; OECD, 2001). Lascoumes and Le Gales (2007) categorize the types of policy instruments into five groups: (1) legislative and regulatory, (2) economic and fiscal, (3) agreement based and incentive based, (4) communication based and information based, (5) de jure and de facto standards instruments. OECD (2001) claims that appropriate "policy packages" need to be well designed to deal with market failure and achieve environmental goals. OECD (2001; 2003a) classifies the environmental policy instruments into six types: (1) regulatory instruments, (2) economic instruments, (3) liability and damage compensation[8], (4) education and information, (5) voluntary, and (6) management and planning.

Three categories of policy instruments—command-and-control, market-based, and information instruments—are not only found in the trifold scheme of policy instruments (Vedung, 1998; OECD, 2001), but also commonly used in other literature categorizing policy instruments with a typology containing five or six categories (Lascoumes and Le Gales, 2007, Mickwitz, 2003; Salamon, 2002; Schneider and Ingram, 1990). These studies add several categories to the existing command-and-control, economic means, and information instruments. Additional categories other than trifold schemes such as education or planning, however, are not exclusive and distinct in their behavioral assumption and authoritative coerciveness. An empirical study that classifies and evaluates policy instruments on a certain issue needs a classificatory theme which is exclusive among categories and applicable to a variety of issues. In that, three categories of command-and-control, economic incentives, and information instruments represent effective renewable energy policies classification. This study employs Vedung (1998)'s definition of three types of policy instruments and applies the defining property of each instrument based on the coerciveness (Vedung, 1998) and behavioral assumptions (Schneider and Ingram, 1990) to the classification of renewable energy policies. Figure 1 illustrates the three types of policy instruments that this study refers to for the analysis.

[8] In OECD (2001) report, one of six policy instruments is "incentives for technological development and diffusion." OECD (2003a) refers its report in 2001, but it changes incentives for technology to liability and damage compensation.

Figure 1. Basic Trifold Typology of Policy Instruments



Command-and-Control Policy Instruments

Policy instruments implemented by governmental units to influence targets through authoritative means are defined as command-and-control (regulatory) instruments. Under the command-and-control policy, target persons or agents respond to what they are told by the controllers. This policy instrument modifies the set of options of agents face in their choice sets of alternative actions by formulating rules and directives, and setting supervisory systems (OECD, 1994; Schneider & Ingram, 1990; Vedung, 1998). The defining property of command-and-control (or regulation) instruments is the authoritative nature in the relationship between controller/government agency and target population (Vedung, 1998).[9] Subtypes of command-and-control policy instruments include performance and process standards, licenses/permits, bans, and zoning (Gunningham and Sinclair, 1999; Vedung, 1998).

Although command-and-control instruments have been criticized for their inefficiency due to relatively higher administrative costs and less flexibility given to

[9] The term regulation defined in this paper is different with some definitions frequently used in the U.S., which include all types of government intervention and political control (Meier, 1985; Vedung, 1998).

market players, the components of these instruments such as rules, standards, and regulations are still believed to provide higher certainty of policy outcomes compared to economic principles or suasion (Harrington, et al., 2004; Weimer and Vinning, 1999). A wide applicability of regulatory instruments partially accounts for the effectiveness of regulatory instruments (Campbell, Johnson, and Larson, 2004).

Market-Based Instruments

In an effort to convince people to find the government-desired behavior more economically attractive than the undesired one, governments try to alter the market conditions or economic frameworks through economic instruments (Enzensberger, et al., 2002). Underneath the market-based approach or economic instruments lies an assumption that individuals are utility maximizers who take opportunities to make choices in their own best interests. Incentive instruments rely on tangible pay-offs to motivate target people to comply with or utilize policies. Tangible pay-offs here refer to money, life, and liberty, to name a few. State governments usually offer (positive) monetary benefit as incentives for renewable energy development (Schneider and Ingram, 1990). Economic policy instruments alter the costs or benefits for the target persons or agents, but the target agents are not obligated to comply with and use the measures involved. The most suitable use of economic and market-based policy instruments involves cases where the policy fosters long-term development in a given market place rather than risking a disaster management (Enzensberger, et al, 2002). Economic instruments include charges, subsidies, grants, and loans operated with a medium degree of coercion on public units; also, tax expenditures such as tax credits, deductions, and exemptions are considered relatively less coercive economic incentives (Vedung, 1998; OECD, 1994; Salamon, 2002).

Ever since the demonstration of benefits and cost effectiveness of market-based policy instruments, a growing consensus has been made over the advantage of applying market-based instruments to environmental areas such as greenhouse gas emissions, renewable energy development, waste management, and natural resources (Hammar, 2006). Even though cost effectiveness in the implementation process marks the market-based instruments' strength, it does not guarantee a better achievement of policy goals. In other words, when it comes to policy outcomes or policy effectiveness, market-based policy instruments might not deliver as much as policy makers expect them to (Hammar, 2006).

Information Instrument

The third category of policy instruments is information instruments[10] which influence target people through knowledge transfer, communication, and persuasion. Information instruments assume that lack of information and skills prevents potential targets from making the best decision possible. If target agents are informed, they will choose the preferred alternative policy (Schneider and Ingram, 1990).

There are two types of information regarding policy instruments: information *as* and information *on*. One is information as a policy instrument as itself. The other is "metapolicy instrument" which is used to convey the knowledge of other policy instruments' existence, availability, and meaning (Vedung, 1998). Vedung (1998) calls

[10] Schneider and Ingram (1990) defined information, training, and education as capacity tools. Vedung (1998) used the term "sermons," and OECD (1994) called it as "suasive instrument."

the latter type of information, "information on policy instruments." Information instruments are regarded as modern forms of governmental intervention and the least coercive instruments, which is called a sermon or exhortation (Vedung, 1998). This paper deals with both types of information—information *on* policy instruments and *as* policy instruments, which influence electricity generation from renewable sources and classify them into information instruments.

Stavins (2003) argues that information programs help economic instruments more effectively solve the environmental problems because they empower producers and consumers to make rational choices. Well-informed producers and consumers constitute a crucial characteristic of well-functioning markets. This study discusses two types of information programs. One is product labeling requirements which provide consumers the information set. According to the reporting requirements, producers must make their products' information and manufacturing process publically available. Reported information helps increase public awareness of producer's activities and prompts the producers to operate more transparently (Stephan, 2002).

Information instruments complement other policy instruments by helping people understand and interpret other policy instruments. Information instruments encourage people to comply with regulations or take advantage of available services (Weiss, 2002).

Based on the discussion above, this study hypothesizes a positive correlation between a state's use of information instruments and the likelihood of developing more renewable energy. In addition, information instruments in conjunction with other policy instruments are expected to push the deployment of states' renewable electricity.

2.2.3 Policy Mixes

Direct regulation or command-and-control instruments were the predominant means of government intervention in environmental policy until the 1990s. In recent years, however, shortcomings of direct regulation such as diminishing effectiveness and increasing costs have prompted neoliberal ideas to gain a larger influence over environmental policy and natural resources management. A wider range of policy instruments has been proposed as regulatory alternatives (Baldwin and Cave, 1999; Gunningham and Sinclair, 1999; OECD, 2002). They include process-based regulation, economic instruments, financial incentives, information disclosure, self-regulation, and voluntarism (Gunningham and Sinclair, 1999; Cho, 2008). New market-based environmental policy instruments have been viewed more favorably. Economic or market-based instruments incentivize polluters/target population to act in ways stipulated by policy goals. Economic incentives are considered to be more flexible and cost-effective instruments compared to traditional command-and-control instruments (Bailey, 2007; Bernstein, 1993).

Interest in "policy mixes," or combining policy instruments, has been increasing since the 1990s (OECD, 2001; Persson, 2006; Sorrell and Sijm, 2003). The following reasons account for the preference for a policy design combining different types of policy instruments over a single instrument. Combined policy instruments complement and reinforce each other to enhance the overall effectiveness and efficiency of policy implementation compared to a single instrument (Rist, 1998). In reality, environmental problems tend to be too complex to solve with a single strategy (Gunningham and Sinclair, 1999). Selecting the most appropriate combination of instruments comprises a crucial component of a policy design that would maximize the goal achievement and minimize political economic costs (Peters, 2002).

2.3 Classification of Renewable Energy Policies

This section reviews the policies and incentives that state governments in the U.S. developed to promote electricity generation and distribution from renewable sources. These are 18 state renewable energy policy instruments and incentives which are classified into three categories of policy instruments: command-and-control, market-approach, and information instruments. These three policy instruments are derived from both the previous literature that categorizes renewable energy policies and the general policy instruments classification. Categorization of the renewable energy policy instruments, adopted in the United Sates at the state level, enables one to trace the trends of how the United States has employed its policies for promoting renewable energy over the past decade.

Classification of renewable energy policies is conducted based on the criteria discussed in the previous section. Policies that use authoritative tools to motivate people to respond to and comply with policy goals belong in the category of command-and-control instruments. Market-based instruments are policies and programs that motivate and incentivize people with tangible trade-offs. Information instruments attempt to influence people to act voluntarily by knowledge transfer and communication.

Some previous empirical studies (Beck and Martinot, 2004; Enzensberger, et al., 2002; Jonstone, Hascic, and Popp, 2008; Menz, 2005) classify renewable energy policies and programs into several groups. These groups trace state governments' policy design trends. Enzensberger, et al. (2002) divide legislative instruments for renewable energy development into regulatory and economic instruments. In addition, they distinguish economic instruments into supply-push and demand-pull approaches in the context of renewable energy fostering projects. A supply-push approach includes renewable energy policy instruments that influence the electricity price or production costs of renewable electricity (feed-in tariffs, tax advantages, subsidies for investment). Demand-pull approach fixes a certain demand—i.e. a certain percentage of the total electricity generation (or consumption) from renewable—by obliging market industry (Enzensberger et al., 2002).

Menz (2005) describes state level renewable energy policies with three distinctions based on the means and degree of authoritative intervention: state financial incentives, state rules and regulations, and voluntary measures. Beck and Martinot (2004) and Jonstone, Hascic, and Popp (2008) also classify renewable energy policies into three categories: price-setting and quantity-forcing policies (RPS, REC), investment cost reduction policies (rebate, tax relief, grant, loan), and public investment and market facilitation activities (PBFs, industry support, contractor certification, equipment standards, disclosure, access laws, government procurement). These categories differ from Menz's (2005) in that the function of each instrument defines them.

This study overviews states' policies in support of renewable energy development and classifies those individual policies into three categories—command-and-control, market-based approach, and information instruments. The defining features used to classify renewable energy policies are the degree of authoritative forces (Vedung, 1998; OECD, 1994; Salamon, 2002) combined with the behavioral assumptions that determine the relationship between government and target population (Vedung, 1998; Schneider & Ingram, 1990).

2.3.1 Command-and-Control

In this study, five renewable energy policies or programs are identified as the command-and-control instruments: (1) green power purchasing programs, (2) renewable portfolio standards, (3) public benefit funds, (4) interconnection, and (5) contractor licensing.

Green Power Purchasing Programs

Many state and local governments purchase a certain percentage of their electricity consumption from renewable sources or buy renewable energy credits (RECs). Governments, businesses, schools, residents, and NPOs can enter into contracts with green power marketers or developers through utility green power programs or community aggregation (DSIRE, 2010). No mandates for governmental units to consume their electricity from renewable sources existed before 2000. As of October 2010, nine states had green power purchasing programs, while the federal government had a green power-purchasing goal. This program entails government entities directly purchasing renewable energy. State governments, through authority bested in them, also set the amount or percentage of the consumption of electricity generated from renewable sources. The green power purchasing program carries high degree of coerciveness.

Renewable Portfolio Standards (RPS)

RPSs require electric utilities to own or acquire renewable energy or renewable energy credits (RECs) to account for a certain percentage or amount of its generating capacity or retail electricity sales according to a specific timeframe. Only six states had adopted RPS with mandatory or voluntary goals in 1998. As of August 2010, 29 states and the D.C. had legally binding RPSs, seven of which had renewable portfolio goals. Today, RPS is considered the most important and popular policy to promote renewable energy development at the state level. Numerous previous literatures have described RPS as a "market-friendly" policy instrument (Wiser, Namovicz, Gielecki, and Smith, 2007). RPS, however, is closer to a command-and-control type of policy instrument because it restricts eligible renewable technologies and requires electricity producers to adopt a specific technology to increase supply and/or demand of renewable energy (Delmas and Montes-Sancho, 2011). In regard to the quantity-based obligation set by states, the RPS is defined as a command-and-control type of policy instrument with a high degree of coerciveness.[11] Since RPS includes few market dimensions, the key to policy success depends on policy implementation and enforcement (Pressman and Wildavsky, 1973). RPS is relatively easy to implement in terms of political dimension because its effect starts after its enactment/adoption.

[11] Use of tradable renewable energy credits in the process of RPS implementation is considered a market-based mechanism to provide flexibility and compliance costs.

Public Benefit Fund (PBF) / System Benefit Charge (SBC)

During the state level electric utility restructuring in the late 1990s, public benefit funds (PBFs) were developed through a surcharge on electricity consumption and were used for rebate and loan programs, R&D, and energy education programs (DSIRE, 2010; Doris, McLaren, Healey, and Hockett, 2009). The PBF is categorized as a command-and-control instrument in this study. The states impose a certain amount of surcharge on all consumers of electricity and re-allocate the collected funds between renewable energy and energy efficiency. Therefore, public benefit funds are more likely considered a social regulation rather than an economic policy instrument. Among the 18 states and D.C. that implement PBFs as of August of 2010, 14 states had already created PBF before 2000 (EPA, 2007; Doris, et al., 2009).

Contractor Licensing

As of October 2010, 15 states have adopted and implemented contractor licensing requirements for renewable energy development (DSIRE, 2010). Contractors who want to install renewable energy can get specific licensing, which guarantees proper installation and maintenance of renewable energy by standardizing the contractors' experience and knowledge. Beck and Martinot (2009) explain that certificate requirement policy, such as contractor licensing, improves the efficiency of the renewable energy systems by ensuring uniform quality of equipment installation. However, there has been limited impact analysis on it so far. Contractor licensing is a typical command-and-control policy instrument. Twelve states granted contractor licenses in 1998, and 15 states have currently implemented licensing.

Interconnection Standards

Interconnection standards are a process standard which falls under the command-and-control type of policy instrument. The standards control the technical and procedural process through which customers connect to electricity grids. The Federal Energy Regulatory Commission (FERC) adopts standards for the transmission level, while the state public utility commissions (e.g. PUCO) establish standards for interconnection to the distribution grids (DSIRE, 2010).

In 1999, six states implemented interconnection standards. Over the last decade, most of the U.S. states have adopted interconnection standards (43 states and D.C. as of August 2010). Interconnection standards can remove market barriers to renewable energy development, and their design and implementation ensure a stable, safe, and economical connection to the electricity grid.

2.3.2 Market-Based Instruments

Financial incentives reduce the initial cost or the operating cost of renewable technologies in order to make renewable technologies more attractive than conventional technologies (Menz and Vachon, 2006).[12] Eleven programs and incentives for renewable energy development were placed in the market-based approach instruments in this study: net-metering, rebates, grants, loans, production incentives, and five tax expenditures.

[12] Conventional technologies for electricity generation have relatively low capital costs and high operating costs, whereas capital costs of renewable electricity sources are relatively high while its operating costs are low.

Net-Metering

Net-metering allows for electricity to flow from and to the customer. Electricity from the customer flows back to the grid when customers generate electricity that exceeds their consumption: this offsets electricity consumed by the customer because it uses the excess generation (DSIRE, 2010). Net-metering is considered a market-based policy instrument in this study because net-metering creates a niche market for on-site renewable energy generation, benefiting the customer (Forsyth, Tu, and Gilbert, 2000). Under PURPA of 1978, electricity consumers in states without net-metering programs have little financial incentives to invest in renewable energy systems: small wind or solar electric system owners were considered qualifying facilities, and were paid only utilities' avoided fuel cost for their excess generation. Despite variation in the treatment of consumers' net excess generation among states, states with net-metering can buy back net excess generation at higher rates, from wholesale to retail rates, than in states without net-metering (Forsyth, et al., 2000). This creates more attractive financial incentives to consumers to produce electricity through grid-connected renewable energy systems. While only 21 states had adopted the net-metering system in 1998, 43 states and D.C. implemented net-metering policies as of October 2010. Many states adopted rules for net metering for renewable energy systems as part of the states' electric-industry restructuring.

Renewable Energy Access Laws

Solar and wind access laws are established to protect a right to install and operate renewable energy systems at homes or facilities. Some states protect the property rights to solar access through legislation[13]. Others allow parties to voluntarily enter into solar easement contracts. UNEP (2004) considers property rights as being resident in the spectrum of economic instruments. Property rights constitute a baseline for the functioning of many economic instruments and also serve as an environmental instrument. May (2002) defines property rights as economic instruments used to implement social regulation. Fourteen states had implemented access laws in 1998, and 39 states have established renewable energy access laws as of August 2010.

Rebate Programs

Rebates programs provide the funding for solar or photovoltaic systems to promote the installation of renewable energy systems. As of August 2010, 27 states and D.C. had state-level rebate programs. As a market incentive, rebates reduce the cost of renewable energy installations. Rebates are flexible to the market changes because they represent relatively short-term policies to a specific project.

Grant Programs

States provide grant programs to assist the installation of equipment or systems by lowering the cost or encouraging the R&D of renewable technologies. Grant programs are available for the commercial, industrial, utility, education and government sectors. In 1998, 12 states operated grant programs for renewable energy development. By 2010, 22 states had grants as economic incentives. Grants are considered a market approach instrument, as they reduce high up-front costs with renewable energy installations and thus help small, customer-sited projects.

[13] Such as Arizona and Delaware

Loan Programs

Most of the states—to be exact, 42 states—use state loan programs to finance the purchase of renewable energy systems or equipment. Loan rates and terms are determined on an individual project basis.

Renewable Energy Production Incentives

Production incentives, or performance-based incentives (PBIs), provide cash payments based on the amount of electricity generated by a renewable energy system.[14] Only one state had production incentives in 1998, and fourteen states have implemented performance-based incentives as of August 2010.[15]

Tax Expenditures: Corporate, Industry, Personal, Property, and Sales Tax Incentives

States offer five categories of tax incentives for renewable energy development: corporate, industry, personal, property, and sales tax incentives. Corporate tax incentives are available when corporations purchase and install renewable energy and equipment. States offer industry tax credits, exemptions, or grants to recruit or develop renewable energy systems and equipment. States offer personal income tax credits and deductions to reduce the expenses of buying and installing renewable energy systems. Property tax incentives exclude the additional cost of the renewable energy system more than a conventional heating system in the property assessment. Sales tax incentives provide an exemption from or refund of the state sales tax for the purchase of renewable energy systems. Tax incentives have been adopted since the early stage of renewable energy

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[14] The "feed-in tariff" is a production incentive. Payments based on actual performances are more effective to ensure project quality.
[15] There is a federal renewable energy production incentive (REPI) established in 1992.

development. More than half of all states currently provide mixed tax expenditure as market instruments.

Tax expenditures or abatements can be important for renewable energy developers because renewable energy facilities are usually capital-intensive and financial incentives from tax abatements help developers to make decision to build and invest energy facilities. However, those tax exemptions may not be sufficient to stimulate new renewable energy development (Bird, et al., 2005). This is because a one-time tax benefit at the time of equipment purchase or installation is not sufficient for developers to decide investment for new facilities. Also, there is a concern regarding the use of tax exemptions due to possible reduction in tax revenues, which may interfere with the local economic development (Bird et al. 2005).

2.3.3 Information Policy Instrument

Required Green Power Option

Green power option requires and encourages electric utilities to offer customers the options of purchasing electricity generated from renewable resources at a premium above market electricity rate. Before 2000, no states had implemented green power options, and eight states had mandatory utility green power options as of October 2010 (DSIRE, 2010). The most common example of a green power option involves allowing customers to make voluntary contribution (Shrimali and Kniefel, 2011). Consumers contribute a premium for the amount of renewable power purchased.[16] This type of green power option is called “voluntary renewable energy tariffs.” In the other case, utilities

[16] The premium is usually about $2 per 100kWh (Shrimali and Kniefel, 2011).

charge consumers a higher electricity rate to cover the additional cost for renewable power generation. Utilities typically provide green power owned by the utility or purchased under contract. This research classifies the required green power option as a type of information instrument. This is because it provides customers the knowledge that they can support renewable energy generation and thus allows consumers to voluntarily pay additional cost for this knowledge. Consumer purchase and demand for renewable electricity can contribute to renewable energy development. The premiums paid by consumers for green power can serve as a revenue stream to support investment in and operation of renewable energy facilities and technologies (Bird, et al., 2005). Shrimali and Kniefel (2011) show that states which require utilities to give their customers green power options are likely to increase renewable energy capacity.

Generation Disclosure or Environmental Disclosure Policies

Electric utilities are required to provide customers information on fuel mix percentages and related emissions. Generation disclosure allows customers to make informed choices on electricity and the provider they choose. Seven states had generation disclosure in 1998. As of May 2009, 22 states and D.C. have required some forms of generation disclosure (DSIRE, 2009).[17] At the firm level, mandatory disclosure programs have statistically significant impact on the increase of the firms' proportion of electricity generation attributable to renewable sources (Delmas, Monte-Sancho, and Shimshack, 2010).

[17] Twenty one states have full disclosure requirements and three state and D.C. have partial disclosure requirements, and three states have proposed and pending requirements as of June, 2010 (U.S. DOE 2010).

2.3.4 Summary of Renewable Energy Policy Instruments

Table1 offers a snapshot of classification result of currently adopted and implemented renewable energy policies at the state level. Based on the tri-fold classificatory scheme of policy instruments, this study classifies the 18 state legislative renewable energy policies and programs into three categories—command-and-control, market approach, and information policy instruments. In addition, under each group of policy instrument, renewable energy policies and programs are grouped or sub-categorized by the virtue of each illustrative tool [18] for better understanding of the classification criteria and rationale.

As of 2010, state governments used five types of command-and-control instruments are being used by state governments: renewable portfolio standards (RPS), green power purchasing programs, public benefit funds (PBF), contract licenses, and interconnection standards. Among these five policy instruments, RPS, PBF, and green power purchasing programs are identified as obligations because state governments mandate and enforce their setting policy goals on electric producers or governmental agencies through coercive and authoritative tools. Interconnection standards and contractor licenses are grouped separately as process standards.

For the intervention in electric power markets, states have diversified market-oriented policy instruments. State governments currently use eleven kinds of policies, programs or financial support that are designed to motivate electric producers to employ

[18] Salamon (2002) uses the term, "tool" or "instrument" interchangeably at the most descriptive level. He defines a tool of public action as "an identifiable method through which collective action is structured to address a public problem." Salamon (2002) calls them "illustrative tools" and groups them together based on various criteria such as degree of coerciveness, directness, automaticity, visibility, etc.

more renewable energy technologies. This study places net-metering programs and access laws under the policy instrument of market approach and identifies them as economic regulations that lower market barriers and assure property rights for the new developers entering the market. One of the most popular tools adopted by states is providing financial incentives to the power suppliers. State governments offer various tax expenditures such as sales, property, personal, and corporate tax abatements for the purchase or installation of renewable energy equipment. States also award grants or loan electric power producers for their investment in renewable energy development. Using the market approach, governments can render the electricity market environment more favorable for energy developers. However, the actors ultimately have to take responsibility in taking advantage of given incentives when making their decisions.

Increasing numbers of states have adopted a new type of policy instrument; information to alter the behavior of electric power suppliers. Some states require electricity suppliers to inform customers about the sources of energy or the amount of greenhouse gas emission. The other informative instrument that state governments encourage power companies to offer is green power options. Intellectual and moral appeals baseline these two informative instruments.

Table 1. Renewable Energy Policies in Three Types of Policy Instruments

Policy Instruments	Illustrative Tools[19]	Renewable Energy Policies and Programs
Command -and- Control (5)	Obligations	Green Power Purchasing Renewable Portfolio Standard Public Benefit Fund
	License/process standard	Contractor License Interconnection
Market-based (11)	Market Systems	Net-Metering Access Laws
	Subsidies and grants	Rebates Grants Loans Production Incentives
	Tax expenditures	Personal Tax Credit Corporate Tax Credit Sales Tax Credit Property Tax Credit Industry Support
Information (2)	Information	Required Green Power Option Disclosure

Source: by Author

[19] Salamon (2002) uses the term, "tool" or "instrument" interchangeably at the most descriptive level. He defines a tool of public action as "an identifiable method through which collective action is structured to address a public problem." Salamon (2002) calls them as "illustrative tools" and groups them together based on various criteria such as degree of coerciveness, directness, automaticity, visibility, etc.

CHAPTER III

LITERATURE REVIEW

This section reviews the empirical studies on renewable energy policies. The body of literature consists of (1) studies estimating the effects of states' renewable energy policies and (2) studies on policy instrument adoption, which identify circumstances under which state governments adopt certain mixes of policy instruments. Recently there has been an increasing research using econometric methods to evaluate the effectiveness of states' renewable energy policies. A majority of previous empirical studies focus on individual programs and policies, an effort to estimate the relationship between particular individual renewable energy policies and increase of renewable energy. However, this paper is more focused on the aggregate level of policy instruments that state governments adopt for promoting renewable energy. Though literature review, this section builds the research hypotheses with dependent and independent variables. This section reviews how previous studies quantify the variation in policy instruments adopted, identify and measure other variables.

3.1 Empirical Studies on Renewable Energy Policies

Among various goals of renewable energy policies, this study focuses on the effectiveness of renewable energy policies pertaining to the goal of renewable energy promotion. This section reviews a body of empirical studies that evaluate the effectiveness of renewable energy policy. The body of literature includes previous studies that operationalized and measured the outcome of renewable energy policies. Also, in order to evaluate the marginal effect of different types of policy instruments, this section also reviews other determinants of renewable energy development discussed in previous studies.

Menz and Vachon (2006) compared the impact of policy implementation for wind energy development across 37 states from 1998 to 2003 using multivariate techniques. They analyzed the impact of five renewable electricity policies classified under three policy regimes – financial incentives, mandatory rules, and regulatory changes – in regards to wind potential as a variable that affects wind power development. They constructed wind development indices measuring different dimensions of wind energy development for empirical analysis. They used the amount of installed wind capacity, the absolute growth in capacity between time periods of the study, and the number of large wind energy projects observed in each state. All wind electricity development indices showed similar results regarding wind electricity policies and wind potential in terms of their significance and directions. Their results demonstrated that renewable energy policies, taken all together, had a significant impact on wind energy development. RPS and mandatory green power offering programs, within the regulatory policy regime, had a statistically significant and positive relationship with wind power development. However, the retail choice was significant and negatively associated with wind power development. The public benefit funds (PBF) and disclosure did not have significant impacts on renewable energy development separately. There is a possible explanation that PBF supports demand side rather than supply side of renewable energy (Menz and Vochon, 2006). The contribution of Menz and Vochon's study (2006) was found in its finding that particular state policies as well as a state's natural endowment (wind potential) affect promotion of wind energy development, a finding supported by empirical assessment. A relatively small number of observations posed a limitation for their study.

Carley (2009) examined the effectiveness of renewable portfolio standards (RPS) and tax incentives designed to promote renewable electricity production at the state level. Two separate dependent variables were used to measure state-level renewable energy development. Carley (2009) used the total amount of annual renewable electricity generation, excluding hydropower, measured in thousands of megawatt-hours.[20] Her study also employed the renewable electricity (RE) share which was measured as percentage of electricity generated from renewable resources, excluding hydroelectricity, out of total state electricity generation. Different results were found depending on outcome measures in directions and significance of the association with RPS and other independent variables. RPS was positively related to total amount of electricity generation from renewable sources, but was not significantly associated with the share of renewable of total electricity. The variation in the size of renewable energy industry among states limited the statistical model measuring total renewable electricity.

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[20] Electricity generation data is available from the EIA state electricity database.

Yin and Powers (2010) measured the stringency of RPS and analyzed its impacts on renewable energy development. They measured the development of renewable electricity as the percentage of electricity capacity from non-hydro renewable resources of total capacity in a state. To calculate the share of non-hydro renewable electricity capacity, the capacity of all electric utility plants whose primary energy source was non-hydro renewables[21] was counted.[22] Yin and Powers (2010)'s definition of renewable energy development excluding hydropower was supported by historic background of the trend of renewable electricity industry. They also considered other factors such as other renewable energy policies, electric market characteristics, and political interest in the environment. Results showed that the existence of green power options in the power market and states' experience of import of electricity have consistent and positive impacts on the investment in renewable energy technologies.

Since the first commercial electricity-generating plant that used hydro power began its operation in 1882, the hydroelectricity's potential has increased considerably in the U.S. Hydro power accounted for over 30% of total U.S. electricity generation in the 1950s. The relative importance of hydropower, however, has decreased with increasing concerns about the environmental impacts of hydroelectric facilities and with advancement in alternative innovations in renewable energy technologies other than hydroelectricity. As of 2007, the share of hydro power of total electricity generation was about six percent (EIA, 2009)[23].

[21] Non-hydro renewable technology includes wind, geothermal, solar, and biomass.
[22] Utility level data on energy capacity by energy sources is obtained from EIA-906.
[23] Derived from Energy Information Administration, Annual Energy Review, 2008; Electric Power Annual, 2009.

Instead, non-hydro renewable resources have been of interest to policy makers aiming to develop a variety of policies promoting the use of non-hydro renewable in electricity generation. As of 2010, total net generation of electricity from non-hydro renewables or other renewables is 167,173 thousand MWh, which accounts for 4.1% of total U.S. net generation (EIA, 2013 State Power Monthly). There are considerable variations among states, ranging from less than 1% to more than 24% (EIA, 2013 State Renewable Energy). The absolute amount of electricity generation from non-hydro renewable energy has been increasing since 1990—except for a one-year decrease of non-hydro renewable electricity generation between 2000 and 2001. The growth rate of electricity generation from non-hydro renewable has been considerably increasing considerably since 2001.

This study employs two operational definitions of renewable energy development in states. Each is modeled as an effect of renewable energy policies. One is the amount of net generation of electricity from non-hydro renewable energy sources; the other is the relative use of renewables in electricity production, which means the share of non-hydro renewables in electricity generation in states.

The share of non-hydro renewables is used because the relative use of non-hydro renewables in electric power production is not always proportional to the absolute amount of the electricity generated from renewable sources in the states. For instance, Maryland and Massachusetts experienced a decline in the total MWh of electricity production from renewable sources between 2006 and 2010, but the proportion of renewable sources used in electricity generation increased for the same period due to the overall decrease in electricity production in two states.

With two different variables, this study aims to provide compelling evidence of the effectiveness of public policy instruments as well as to examine the determinants of absolute and relative use of renewable energy technologies in electricity markets respectively. Energy Information Administration provides data on annual net generation of electricity by state by source.[24]

3.2 Determinants of Renewable Energy Development

In order to isolate the effects of policy instruments (or the marginal increase of the effects from policies) on states' renewable energy development, alternative explanations have to be considered and factored in as control variables. This paper looks at the types of state governments' policy instruments as an important determinant of variation in renewable electricity generation between states. The effectiveness of different policy instruments varies depending on the nature of not only the instrument, but also the circumstances (Salamon, 2002). This study therefore considers the different state characteristics which are assumed to influence electricity generation from renewable sources from the previous studies. As determinants of renewable energy generation, this study includes state's policy instruments for renewable energy development, natural resources, state economy, political environment, and electricity market condition.

3.2.1 Renewable Energy Policy Instruments

Recently, numbers of empirical studies that evaluate the effectiveness of renewable energy policies have increased (Carley, 2009; Delmas and Montes-Sancho, 2011; Menz and Vachon, 2006; Shrimali and Kniefel, 2011; Yin and Powers, 2010).

[24] Energy Information Administration. State Renewable Energy, 2007; State Electricity Profiles, 2009.

These studies, however, have tended to focus on the effect of particular renewable energy regulation such as renewable portfolio standards (Carley, 2009; Yin and Powers, 2010); measure individual renewable energy programs and examine the relationship between each program and renewable energy development (and Montes-Sancho, 2011; Menz and Vachon, 2006; Delmas Shrimali and Kniefel, 2011).[25] A dichotomous variable is typically employed to measure an individual policy implementation in the majority of previous literature. Each renewable energy program such as renewable portfolio standards and mandatory green power option is measured as the value of "1" if a state has that policy in a given year (or prior to a certain year) and "0" if otherwise (Carley, 2009; Delmas and Montes-Sancho, 2011; Menz and Vachon, 2006; Shrimali and Kniefel, 2011).

This binary variable that measures the presence of individual renewable policies however cannot capture the policy implementation of states at an aggregate level pertaining to policy instruments. This study aims to measure the trifold scheme of policy instruments comparable to each other in order to examine the variation of policy effectiveness between policy instruments and their synergetic (interaction) effects of policy mixes instead of individual programs. However, there is a lack of empirical studies that classify and measure the entire range of individual programs and incentives in a certain issue into types of policy instruments in the purpose of comparison of effectiveness between them. Persson (2006) states, "Identifying instruments may involve problems of aggregation, in that it may be unclear what constitutes a single instrument and what measures are sub-components of an instrument. Consistency in the identification exercise is the only way to overcome this problem." In this respect, this

[25] Carley (2009) and Delmas and Montes-Sancho (2011) incorporate financial incentives in their analysis to control the effects of other renewable energy policies than their primary policy variables.

study is to develop aggregate indices to measure the magnitude and diversity of policy instruments.

3.2.2 Other determinants

Natural Resources

Renewable energy resources are assumed to partially explain the variation in renewable energy production between states (Bird et al., 2005). The natural potential of renewable energy resources – solar, wind, and biomass, etc. – is geographically-oriented, idiographic, and not transportable between states. Renewable energy resources are one of the important factors for the success of renewable energy policy implementation. Even though not all renewable energy potential can be developed due to economic and physical limitations, technical potential of renewable energy allows estimating available renewable sources and costs of renewable resources (Deyette, Clemmer, and Donovan, 2003).

Renewable energy sources are spread out unevenly across the country. The Great Plains, from the east of the Rocky Mountains to the west of the Mississippi River in the U.S. have a vast potential of wind energy (Business Wire, 2004). The West and Southwest regions of the U.S. have high quality solar radiation, the greatest solar insolation in the U.S., so that solar power can be effectively generated in those regions (EIA, 1993). Electricity production using biomass is highly site-specific and regionally concentrated. This is because the location, quantities and prices of biomass resources determine the potential for biomass power and most of biomass resources are used in the easternmost or westernmost States (EIA, 1993).

For the electricity generation from wind sources, wind speed is critical because wind power density, the amount of energy in the wind, is proportional to the cube of wind speed (Center for Sustainable Systems, 2012). The effectiveness of solar power, conversion to electricity, varies depending on the intensity of solar radiation. Biomass power is generated from trees, agricultural good and feed crops and wastes, wood and animal wastes and residues, and municipal wastes and other waste materials. Through direct-combustion equipment, co-firing in coal fired boilers and fuel cell systems, biomass can be converted to energy and fuel. Therefore, renewable energy resources given to each region or state are expected to explain the adoption and the implementation of states' renewable energy policies (Delmas and Montes, 2011; Haar and Theyel, 2006).

The association between states' renewable energy resources and renewable energy capacity or renewable energy generation has been analyzed (Carley, 2009; Delmas and Montes, 2011; Russo, 2003). However, there are inconsistent results found in previous empirical studies. Also, different types of renewable energy sources show different relationships to states' renewable energy development. States with higher solar and wind potential were likely to adopt a regulatory renewable energy policy – the renewable portfolio standards (RPS), higher potential of biomass was negatively related to RPS adoption (Delmas and Montes, 2011). Solar potential showed significant and positive impacts on renewable energy electricity generation, while wind and biomass potential were negatively related to renewable energy generation (Carley, 2009). In terms of wind energy potential, until 2006, states' natural endowment did not show a linear association with RPS adoption rates and renewable energy generation (Carley, 2011).

Most of those previous studies used time-invariant measures of natural resources, which would be helpful to understand between-states differences in natural endowment and the impact on renewable energy policy adoption and/or renewable electricity generation. However, state-fixed and time-invariant measures have limitations that they cannot account for the degree to which the given potential of natural resources in a state contributes to electricity generation from renewable sources in the electric power industry. In order to look at the association of natural endowment and renewable energy deployment of states, this study uses time-variant measures of wind and solar potentials. The assumption is that a state can generate more renewable electricity when more natural resources are available.

State Economic Characteristics

States' economic factors play significant roles in electricity production and supply. It is hypothesized that a wealthy state has the ability to invest more in environmentally friendly projects (Ringquist, 1994; Sapat, 2004). Some empirical analyses show that states with greater wealth, measured as per capita gross state product, show more renewable energy generation and a higher percentage of renewable energy generation (Carley, 2009). There are, however, different results about the relationship between state wealth and renewable energy capacity. Various indicators are used to measure state wealth in previous studies such as per capita Gross State Product (GSP) (Shrimali and Kniefel, 2011), per capita income (Delmas and Monte-Sancho, 2010), or median household income (Yin and Power, 2010). In previous studies, however, electricity generating capacity from renewable sources did not have statistically significant association with above mentioned variables measuring state wealth (Delmas and Monte-

Sancho, 2010; Shrimali and Kniefel, 2011; Yin and Power, 2010). It implies that the amount of electricity capacity does not seem to reflect the state's economic characteristics. This is because nameplate capacity of renewable electricity is rated by manufacturers as the amount of capacity that generators[26] produce under ideal conditions. Net generation of electricity, however, could vary depending upon various conditions. This study, therefore, expects that the more state wealth increases, the more electricity will be generated from renewable sources.

States' population growth is considered to affect the state demand for renewable electricity in either direction. A large population growth of a state can increase the renewable electricity generation in the respect that renewable resources may be an option for meeting rising demand. On the other hand, increasing demand for electricity because of a large population growth may increase electricity generation from fossil fuel due to its lower cost. Empirical studies (Carley, 2009), however, do not find a significant relationship between population growth and renewable energy development.

Economic interest groups are involved in the policy process and implementation, and affect the ultimate outcomes of policy implementation. Manufacturing and mining industries are considered to be obstacles to pro-environmental legislation because environmental policies increase the cost of their industry or reduce the demand for their products (Sapat, 2004; Vachon and Menz, 2006). Regarding renewable energy promotion, producers in coal and natural gas industries and other industries related to fossil fuels can be interest groups lobbying pressure to states' policy making and implementation process (Carley, 2009; Vachon and Menz, 2006). Hence, the presence of sizable stakeholder

[26] Which includes a generator, turbine, transformer, transmission circuit, station, or system (EIA Glossary).

groups which view renewable energy policies as negative propositions would detract the governmental support and regulations for renewable energy deployment and adversely influence the improvement of renewable electricity markets. In practice, when Ohio passed its "Energy Bill" (S.B. 221), in 2008, the Ohio Manufacturing Association first opposed the legislation, then lobbied later to change the contents. Especially in regards to renewable energy policies, fossil fuel manufacturing industries are one of the biggest stakeholders who are influenced by policy adoption and implementation. Interest groups based on fossil fuel manufacturing and mining industries, therefore, are expected to be negatively associated with renewable energy deployment in a state (Carley, 2009; Shrimali and Kniefel, 2011). The strength of fossil fuel based interest groups have been measured by the percentage of gross state product pertaining to fossil fuel related industries (Carley, 2009).

Political Environment

The comparative public policy literature and policy choice theory enables consideration of states' contextual factors driving variations in policy instruments choice (Berry and Berry, 1990; Daley and Garand, 2005; Feiock and West, 1993; Howlett, 2004). Policy instrument choice is not politically neutral and intervened by policy activities. A political environment not only affects instrument choice, but also the ultimate policy implementation (Peters, 2002). To evaluate policy instruments, therefore, political factors shaping policy instrument choice should be considered. Accordingly political environment has been measured by the preferences of state legislators and the nature of the constraints in the implementation process (Clark and Whitford, 2011; Daley and

Garand, 2005; Bressers 1998; Bressers and O'Toole, 1998; Schneider and Ingram, 1990).[27]

In consideration of these theories, recent empirical studies evaluating the effectiveness of renewable energy policies incorporate variables that represent states' political environment related to adoption and implementation of renewable energy policies (Carley, 2009; Delmas and Montes-Sancho, 2011). States' political environment has been operationalized with a variety of different variables. The presences of a democratic governor and majority democratic representatives have been shown to be positively associated with the adoption of renewable energy policies and investment in renewable energy infrastructure (Delmas and Montes-Sancho, 2011).

State legislators' preferences regarding environmental policy is measured by their voting history on environmental issues, as found in environmental scorecard of the League of Conservation Voters (LCV) [28] (Clark and Whitford, 2011; Carley, 2009; Delmas and Montes-Sancho, 2011; Shrimali and Kneifel, 2011; Vachon and Menz, 2006). This study assumes that renewable energy development is a subset of environmental issues, so that a state legislators' preference toward renewable energy policies moves in the same direction where their commitment to overall environmental policy goes. LCV score is the average House of Representative score of a state, which is an average of all congressional votes by state's representatives on environmental issues. A high LCV score indicates that the state legislators tend to have greater preference for environmental

[27] Doern and Wilson (1974) argue that liberal democratic societies governments prefer to use the least coercive instruments (Persson, 2006).
[28] Scorecards range from 0 to 100, which are available from the National Conference of the State Legislature, www.lcv.org. The LCV score is used in previous studies to measure the policy preference of state representatives (Baldwin and Magee, 2000; Kalt and Zupan, 1984; Nelson, 2002).

protection. Therefore, a state showing a high LCV rating is assumed to be more likely to demand electricity generated from renewable resources. Previous empirical studies show that LCV score has a positive relationship with the adoption of renewable portfolio standards (Delmas and Montes-Sancho, 2011) and share of renewable electricity (Carley, 2009), but is not associated with total renewable electricity capacity or generation (Carley, 2009; Delmas and Montes-Sancho, 2011). This study hypothesizes that states with governing bodies favorable toward environmental policies have higher rates of renewable energy development.

In previous studies, social interest or citizen involvement in environmental groups were considered as a factor of renewable energy policy adoption (Delmas and Montes-Sancho, 2011; Vachon and Menz, 2006). Environmental interest groups have increased (Straughan and Pollak, 2008) and stood against the political influence by industry based interest groups. The presence and strength of environmental interest groups are considered to support the pro-environmental legislation. For the adoption and implementation of state renewable energy policies, citizen participation in environmental groups is expected to be positively associated with state renewable energy deployment. The number of membership of environmental interest groups[29] is used to measure the social interest in or citizen preference toward environmental issues (Delmas and Montes-Sancho, 2011; Hall and Kerr, 1991; Sapat, 2004). Empirical studies have shown that states with more participants in environmental interest groups are more likely to adopt the renewable energy policies (Vachon and Menz, 2006), and also are likely to deploy more

[29] The number of Sierra Club membership is the most common for measuring state interest in environmental issues and strength of environmental interest groups (Delmas and Montes-Sancho, 2011; Hall and Kerr, 1991; Sapat, 2004). Some use a combined various environmental groups such as Sierra Club, Greenpeace, and National Wildlife Federation together (Vachon and Menz, 2006).

renewable energy technologies (Delmas and Montes-Sancho, 2011). This study, therefore, hypothesizes that the strength of environmental interest groups in a state is positively related to the renewable energy deployment in the state.

Administrative institutions comprise another factor in policy adoption and implementation. Institutions directly and indirectly structure the frame in which policies are implemented. Therefore, once a policy is adopted, policy outcomes are affected depending upon the capacity of administrative institutions to monitor and enforcement the policy (Sapat, 2004). To capture the institution's administrative capacity, proxy measures are used such as the number of staff members in state environmental agencies (Sapat, 2004) and the number of state and local employees in natural resource positions (Carley, 2009). Carley (2009) analyzed the impact of institutional capacity on deployment of renewable energy. Her results showed that the share of renewable electricity is positively associated with, but state net generation of renewable electricity is negatively associated with, the number of state and local natural resource staff members. This study expects that renewable energy generation of a state is positively related to the number of state and local governments' employees working for the function of natural resources.

Market Conditions of Electric Power Industry

In the United States, the utility services of electricity generation, transmission and distribution have been traditionally operated by market systems. Hence, the electricity generation from renewable sources should be at least partially determined by the supply and demand equilibrium under the given conditions and characteristics of electricity markets.

One factor assumed to affect renewable electricity deployment is natural gas price and/or electricity price (Birds, et al., 2005; Carley, 2009; Shrimali and Kniefel, 2011). It is arguable, however, whether or not natural gas and/or electricity prices determine increases in renewable electricity generation. Some have argued that high natural gas prices are positively associated with renewable electricity generation. This is because high wholesale prices of natural gas make renewable energy relatively competitive and cause electric producers to shift to use of relative cost competitive alternative energy (Bird, et al., 2005; Shrimali and Kniefel, 2011). For instance, the Western energy crisis is associated with the imbalances of supply and demand of electricity sources, especially natural gas (Bird, et al., 2005; Weare, 2003). California State thereafter has emphasized the importance of renewable energy and diversification and dependence of energy sources (Weare, 2003). There is another argument that the higher the price of electricity, the less likely consumers and/or electric utilities will want further investment in relatively expensive renewable sources for electricity generation. Instead, electric generators may switch the source of electricity generation from natural gas to cheaper fossil fuel (Carley, 2009; EIA, 2009; Shrimali and Kniefel, 2011). Empirical studies show inconsistent results. Carley's study (2009) showed a negative association between the share of renewable energy and retail price of electricity, but an insignificant relationship was found between electricity price and total renewable electricity generation. Shrimali and Kniefel (2011) included both natural gas price and electricity price in their model. They found that electricity price is positively and natural gas is negatively related to states' renewable electricity capacity.

As a possible factor affecting the electricity industry's preference towards renewable sources, the pattern of net import/export of electricity between states is considered (Yi and Feiock, 2012; Yin and Powers, 2010). On one hand, states which heavily depend on importing electricity from other states may have incentives to search for diverse alternative energy sources available within states and reduce their energy dependence. On another hand, states that export electricity to outside states may generate electricity exceeding their needs using relatively cheap energy sources such as coal, natural gas, or nuclear power, and/or make profits through electricity transmission and distribution between states. Therefore those states may not benefit from adopting renewable energy technologies which cost a lot to start up and take longer time to gain returns. Yin and Powers (2010) included a variable measuring the ratio of electricity import/export in their model explaining the impact of states' renewable portfolio standards on the percentage of renewable electricity generating capacity. Their results showed that states' experience of increase in electricity import in the previous year positively affects the electricity markets to develop renewable energy in the following year. This study hypothesizes that the more a state imports electricity from other states, the more the state acts to develop renewable energy. In other words, a state that exports its electricity to other states is less likely to invest in developing renewable energy.

The existence and magnitude of nuclear power production within a state also needs to be considered. Even though there is a continued controversy over whether nuclear power is a form of renewable energy or not, nuclear power worldwide is expected to increase as concerns about greenhouse gas emission reduction and energy security (EIA, 2011).[30] Displacing electricity from coal-fired generation, together with natural gas and renewables, nuclear power is expected to strongly advance (EIA, 2011).[31] The use of nuclear power in a nation or a state can be interpreted either ways. A country or a state may operate nuclear power plants to substitute the source of electricity from coal to less polluting sources. In this case the existence or magnitude of nuclear power generation in a country or a state can be an indicator of its preference toward a diverse fuel mix or alternative energy sources, so does non-hydro renewables (Kneifel, 2009). However, a country or a nation's nuclear power generation capacity may also be an impediment to deployment of renewable energy technologies. This is because when a county or a state is to displace its existing coal-fired generation to other sources, together with natural gas, nuclear power and renewables would be competing alternatives. In cases like this, existing capacity of nuclear power generation in a state could rather stand in the way of investment in renewable energy development.

As of 2010, the United States produced 807 million megawatt hours of electricity from nuclear power plants. Thirty one states deployed nuclear power as their source of electricity generation and State of Illinois generated 96.2 million MWh, followed by Pennsylvania and New York states.[32] Nuclear power accounted for approximately 20% of total electricity generation in the electric power industry in the U.S. over the last two decades.

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[30] In the IEO2011 Reference case, electricity generated from nuclear power is projected to increase from 2.6 million megawatthours in 2008 to 4.9 million megawatthours worldwide (EIA, 2011, p.4).

[31] http://www.eia.gov/forecasts/ieo/pdf/0484(2011).pdf

[32] Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923), http://www.eia.gov/electricity/data/state/

This study includes the ownership of electric utilities as one of the organizational strategies considered as an important variable influencing the success of implementation of renewable energy policies. There is a body of literature on the tools of governance (Doern and Phidd, 1983; Salamon, 2002) that considers governmental organizational strategies as instruments or tools of governance. Organizational strategies are represented as socialization and privatization of governing entities. Socialization is the type of governing strategy that a government establishes or owns an organization providing goods and services directly; the ownership or the operation of activities are transferred from the private to the public. Privatization occurs when government transforms the ownership or the operation of services from the public sector to private sector (Salamon, 2002). Government organizational or administrative strategy however is considered apart from policy instruments in analytic policy instruments literature. This is because government organization is assumed as a prerequisite for policy instrument application rather than a kind of policy instrument (Vedung, 1998).

In most states, except Nebraska,[33] investor-owned electric utilities consist of a large portion of the total electricity industry (EIA, 1999; EIA, 2012b).[34] As private enterprises, investor-owned utilities provided about 62.6% of the total consumer base in the country in 2010 (EIA, 2012b, p.311). Delmas and Montes-Sancho (2011) incorporate the ownership of electric utilities for the first. They hypothesize that private utilities prioritize their consumers in order to maximize their profits. On the other hand, publicly-owned utilities, which are governed by public entities such as locally elected or appointed

[33] Nebraska serves its entire electricity by publicly owned or consumer owned electric power utilities. Source: Nebraska Power Review Board (http://www.powerreview.nebraska.gov/)

[34] EIA (1999), The Changing Structure of the Electric Power Industry 1999: Mergers and Other Corporate Combinations, http://www.eia.gov/cneaf/electricity/corp_str/chapter2.html; EIA (2012), State Electricity Profile, p.168, http://www.eia.gov/electricity/state/pdf/sep2010.pdf.

officials, are assumed to be more responsive to public policies (Delmas and Montes-Sancho, 2011). The empirical result shows that RPS is more effective at privatized electric utilities in terms of investment in renewable capacity compared to publicly owned utilities (Delmas and Montes-Sancho, 2011). This can be understood that private utilities are more likely to be motivated by state renewable energy policies and utilize market incentives. In addition, many states exempt publicly owned utilities including municipal utilities and rural cooperatives from renewable energy standards and funds (Deyett, et al. 2003). This study hypothesizes that a state with more private electric utilities is more responsive to renewable energy policies.

3.3 Summary of Literature Review

By reviewing previous studies on renewable energy policies and policy instruments, possible variables and their hypothetical directions toward dependent variable are found. The following table summarizes the explanatory and control variables and their expected relationship with states' renewable electricity generation. This study uses actual net generation of electricity from renewable sources as the measure of dependent variable, renewable energy development. Hypothesized signs in Table 2 are derived from previous empirical studies and also indicate the expected results of this study.

Table 2. Hypothetical Relationship between Explanatory Variables and State Renewable Electricity Generation

Variables	*Hypothesized Signs*	Previous Studies
Command-and-Control Type of Policy Instruments	+	Menz and Vachon (2005); Carley (2009); Delmas and Montes-Sancho (2011); Shrimali and Kniefel (2011)
Market-Based Approach	?	Carley (2009); Delmas and Montes-Sancho (2011); Shrimali and Kniefel (2011)
Information Instruments	+	Delmas and Monte (2011); Shrimali and Kniefel (2011)
Natural Resources	?	Menz and Vachon (2006); Carley (2009); Delmas and Montes-Sancho (2011)
State Wealth	+	Carley (2009)
Industrial Interest Groups - Manufacturing Industry - Fossil Fuel Manufacturing and Mining Industries	 - -	Sapat (2004); Vachon and Menz (2006); Carley (2009); Shrimali and Kniefel (2011)
Political Environment - Legislators' Preference toward Environmental Issues - Democrat governor	 + +	Carley (2009); Delmas and Montes-Sancho (2011)
Social Interest in Environmental Issues	+	Vachon and Menz (2006); Delmas and Montes-Sancho (2011)
Institutional/Administrative Capacity	+	Sapat (2004); Carley (2009);
Natural Gas Price	+	Bird et al. (2005)
Electricity Price	?	Carley (2009); Shrimali and Kniefel (2011)
Privatized Governance of Electric Utilities	+	Delmas and Montes-Sancho (2011)
Export of Electricity	-	Yin and Powers (2010)
Share of other power sources	?	Shrimali and Kniefel (2011)

Notes: (+) denotes positive influence, (-) denotes negative influence, and (?) denotes indeterminate influence.

CHAPTER IV

RESEARCH DESIGN AND METHOD

This study is designed to explore and compare the effectiveness of state governments' renewable energy policies classified according to a tri-fold scheme of policy instruments, including (1) command-and-control instrument, (2) market-based instrument, and (3) information instrument. This section presents the conceptual framework of analysis with which the directional relationship between renewable energy policies is identified in terms of the previously described factors and outcomes. Then, this section specifies the research hypotheses derived from literature review including theoretical arguments on the effectiveness of policy instruments and the prior empirical evaluations of renewable energy policies. Next, I discuss analytical models for time-series cross sectional data analysis in terms of the purpose of this study. This section ends up with operational definitions and data sources of independent and dependent variables.

4.1 Conceptual Framework

This study proposes a conceptual model with which to examine the isolated effectiveness of each renewable energy policy instrument: command-and-control, market-based, and information instruments. It is assumed that at least part of the variation in renewable energy development in states is attributable to the particular set of policy instruments adopted by state governments. This study considers several components of alternative explanatory variables expected to affect states' renewable energy development based on the theoretical foundations of policy instruments and empirical results from prior renewable energy policy studies. This study models that renewable energy development in terms of actual electricity generation using non-hydro renewable sources. This study excludes conventional hydro power from its definition of renewable energy because recent state policies have aimed at supporting solar, wind, or biomass energy technologies while conventional hydroelectric facilities begun considering environmentally unfriendly. In addition, when including hydro power as renewables, the overall trend of renewable electricity generation in the U.S. shows little variation over the past decade because declining interest in conventional hydro power diminished the increasing trend of non-hydro renewable electricity production. The research models of the study represents the variation in total amount and/or share of electricity production from non-hydro renewable sources as a function of states' intervention, specific forms of intervention include various policy instruments designed to encourage renewable energy production and other state specific characteristics such as natural resource, state economic factors, political environment, and the market conditions of electric power industries in states. The conceptual model is

RE_GEN = f (RE_POLICY, RESOURCE, ECONOMY, POLITICS,

ELECTRIC_MARKET) (1)

where RE_GEN represents the amount and share of electricity generated from non-hydro renewable resources within a state;

RE_POLICY represents three policy instrument indices — command-and-control, market incentives, and information instruments that state governments adopt to promote renewable electricity generation;

RESOURCE represents the natural endowment of renewable energy resources;

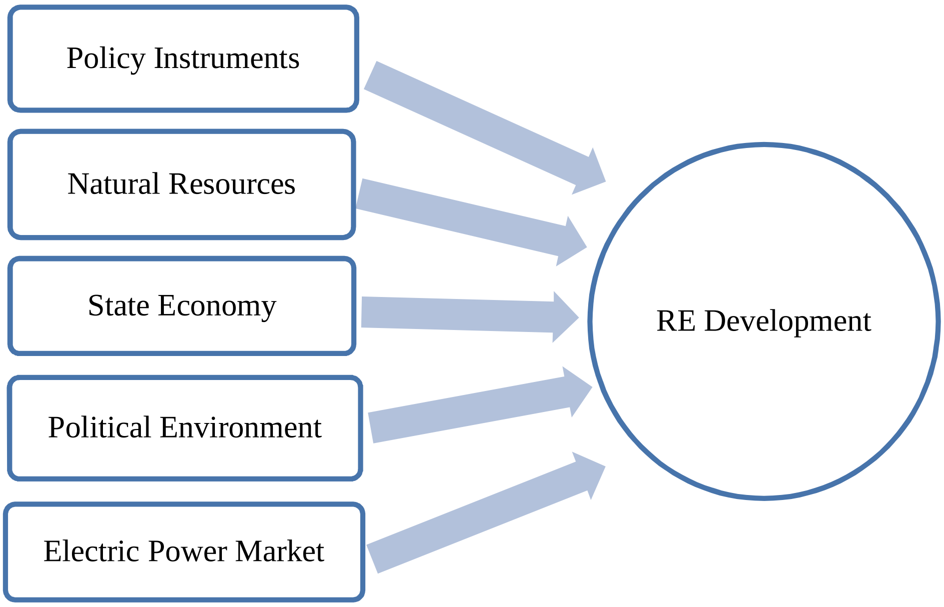
ECONOMY represents the state's economic forces to renewable energy industry;

POLITICS represents the state's political and social preference toward environmental issues and governments' institutional capacity;

ELECTRIC_MARKET represents the characteristics of the electric power market in a state.

Figure 2 illustrates the postulated causal directions of the dependent and independent variables. The primary purpose of this study is to examine and compare the effectiveness of renewable energy policy instruments. It models a directional association of policy instruments and other factors with renewable energy development. The model enables to statistical isolation of the marginal effect of each policy instrument, holding all other factors constant. At the same time, this study stipulates which other control variables are likely to impact renewable energy (RE) development. With the context of this model, once can find the mechanism through which factors induce the electric power industry to produce renewable electricity under the given conditions of states.

Figure 2. Conceptual Framework of Analysis



4.2 Research Hypotheses on the Effectiveness of Policy Instruments

This section introduces research hypotheses of this study. Three primary research hypotheses are built upon aforementioned three types of states renewable energy policy instruments: command-and-control, market-based, and information instruments. Each hypothesis is derived from the theoretical discourse on the effectiveness of respective policy instruments. The empirical evidence of individual renewable energy policy instruments' impact on renewable energy development, discussed in the literature review section, has also contributed to the construction of each hypothesis.

The primary purpose of this study is to discover what type of government activities, shown by states' policy adoption and implementation, work effectively under the given circumstances of renewable energy markets and existing state economic and political environments. We observed that there has been a considerable increase in government intervention in the electric power market for renewable energy development, measured by number of policies and programs. Nevertheless, we have given little attention to neither how state governments got involved in the market, nor what types of government approaches work better than others under the current setting of renewable energy markets. Hence, this study is conducted to first examine the effectiveness of policy approaches that state governments have taken to foster renewable energy markets , then explore the conditions under which the electric power industry deploys renewables.

To do so, this study grouped existing renewable energy policies based on the tri-fold classificatory scheme of policy instruments. The three categories of policy instruments—command-and-control, market-based, and information instruments—enable us to at least partially understand if a state mainly appeals to forceful or coercive policy tools, if it offers financial incentives to the industry, or if the state persuades policy targets by educating and informing market suppliers and consumers. Retrospective examination of the effectiveness of additional adoption of each policy instrument can prospectively suggest the government's future steps regarding better development of renewable energy production. Schneider and Ingram (1990) proposed several reasons why policies may fail to guide people to act to accomplish policy goals: without authority of law, incentives, and/or capacity, people do not comply with or utilize policies. Authority, incentives, and capacity each embodied the behavioral assumption of command-and-control, market-based, and information policy instruments of this study, respectively. Therefore, the existence of positive effect of a certain policy approach/instrument is able to be interpreted that the current mechanism of the renewable energy market needs a governments' policy guide based on the behavioral assumption under the pertaining policy instrument.

Although it is argued that implementation of multiple policy instruments such as a "hybrid" of regulatory standard and financial incentives has been explored and justified (Bennear and Stavins, 2007), examining whether or not adoption of a single type of policy instrument is effective, all else being equal, is expected to give more meaningful guidelines. The first hypothesis deals with the relationship between the states' adoption of command-and-control type policies and the increase of renewable electricity production. Command-and-control type policy instruments, mainly represented by rules, regulations, and standards, are considered to be effective with respect to the accomplishment of policy goals, in general (Campbell, et al., 2004; Harrington, et al., 2004; Weimer and Vinning, 1999).

We observed that state governments also have been increasingly applying command-and-control policy instruments such as RPS to the electric power market for renewable energy deployment. Without a specific policy goal or standard by the Federal government, the states' use of coercion as a policy tool encourage the electric industry's use of renewable electricity is expected to appropriately and effectively increase the production and share of renewable electricity. Moreover, several previous empirical studies on the effectiveness of individual renewable energy policies showed statically positive associations between the number regulatory renewable energy policies like RPS and various measures of renewable energy development (Carley, 2009; Delmas and Montes-Sancho, 2011; Menz and Vachon, 2005; Shrimali and Kniefel, 2011), while a few did not find a significant relationship between those two (Yin and Powers, 2010).

This research perceives that the state governments' intervention in the renewable energy market through the 2000s as an initial phase of public policy innovation and implementation. Hence, it is expected that an introduction of command-and-control policy instruments in the given electric markets will show a significant effectiveness in terms of the increase in the use of renewables for electricity generation. The first research hypothesis of this study is as follows.

H1: *A state that has more command-and-control type of policy instruments is more likely to deploy renewable sources for electricity generation.*

Next hypothesis is about the effectiveness of market-based policy instruments in the renewable electricity market. Since the 1980s, market-based policy tools like economic incentives have been regarded important and innovative because of their relative cost effectiveness pertaining to the flexibility given to policy target people in implementation process (Callan and Thomas, 2004; Hammar, 2006; Harrington et al., 2004). At the same time, however, it is uncertain that market-based policies alone will be effective in altering people's behavior to accomplish policy goals (Bernstein, 1993; Hammar, 2006).

For the development of renewable electric industry, U.S. federal government has offered financial incentives, including feed-in-tariffs and tax expenditures, before state governments began intervening in the electric power industry. So, this study questions the possibility that existing electricity industry's use of renewable sources would significantly increase with additional introduction of economic incentives by state governments. In addition, the analytical results of previous studies support, to some degree, the suspicion this study carries regarding the lack of strong association between economic incentive tools and renewable energy capacity or production in those studies (Carley, 2009; Delmas and Montes-Sancho, 2011; Shrimali and Kniefel, 2011). Based on these conceptual discussion and empirical results, this study builds its second research hypothesis that holding all others variables constant, including pre-existing standards on renewable electricity generation, additional provision of economic incentives would not work effectively in the current electric power market.

H2: *The number of market-based instruments adopted by states will not be associated with the increase of renewable electricity generation.*

The last research hypothesis pertains to the effectiveness of information instruments introduced by state governments. Information instruments, as defined in this study, are relatively new and emerging policy tools, encompassing direct information or knowledge provided by governments through policy tools to inform people about the existence and availability of other related policies (Vedung, 1998). It is argued that information as policy tools increases public awareness about essential policy issues and thus helps both market producers and consumers to be well informed (Stavins, 2003; Stephan, 2002; Weiss, 2002).

For renewable energy development, some state governments have implemented several kinds of information instruments such as information disclosure and green power option programs. Recent empirical studies included these renewable energy programs in the analysis and showed some positive effect of respective programs in the renewable electricity industry (Delmas and Monte, 2011; Shrimali and Kniefel, 2011). This study argues a positive association between a state's adoption of information instruments and the deployment of renewables in the existing electricity industry.

H3: *A state with more information instruments is more likely to generate renewable electricity.*

The following section presents the statistical models, independent and dependent variables, and operational definition of variables and data sources that help test the abovementioned three major research hypotheses.

4.3 Analytical Models

This study examines the effectiveness of renewable energy policy instruments using longitudinal data and cross-sectional time series data. Longitudinal data gives more information and variability, and more degrees of freedom which allows exploration of the more issues than time-series or cross-sectional data (Baltagi, 2001; Kennedy, 2008; Park, 2011). As more longitudinal data have become available, more studies on state level regulation and financial incentives for renewable energy development have employed panel analyses (Carley, 2009; Delmas and Montes-Sancho, 2011; Shrimali and Kneifel, 2011; Yin and Powers, 2010). However, choosing an appropriate panel data model is not only difficult, but also there is no one best modeling suitable to every dataset. This section, therefore, discusses several panel models in terms of their assumptions, for the purpose of helping to identify the appropriate model with which to estimate state-level renewable energy policy effectiveness.

First of all, if the model used to analyze the panel data utilized in this study does not produce heterogeneity or individual effects, ordinary least squares (OLS) estimation or pooled OLS regression is appropriate and provides consistent and efficient parameter estimates. However, OLS models applied to panel data usually violate this assumption (due to unobserved variables fixed in sectional units or time periods) (Baltagi, 2008; Born and Breitung, 2010). Moreover, even when OLS models are used with a dataset that meets this assumption, use of OLS estimation still should be done with great care. This is because pooled OLS regression assumes a constant slope and intercept regardless of state and year, and it relies on the implicit assumption that between-year and between-state comparisons are valid and of interest (Brüderl, 2005; Park, 2011). However, since the purpose of this study is to estimate the effectiveness of governmental intervention using different types of policy instruments, under the various state-level conditions pertaining to renewable energy development, within-state estimates are the matter of interest.

When cross-sectional time series data have heterogeneity issues, panel data models should be considered. Here we compare random-effects and fixed-effects models in terms of their assumptions and strength and limitations. Random-effect models assume that individual specific characteristics (heterogeneity) are not associated with any independent variables; that is, the variation across state is random. Also, random-effect models assume a constant intercept and constant slopes across states (Brüderl, 2005; Park, 2011; Wooldridge, 2012). Experimental research designs would in principle allow the investigator to appropriately estimate the effects of treatment using random-effects estimation. However, in practice, the independent variables are likely to be associated with state specific characteristics. Random-effects estimation is based on assumptions about between comparisons; therefore insofar as this study focuses on the impact of differences across states in terms of the dependent variable, random-effects estimation is useful. To meet the assumption of the random-effects model, a research model has to specify state-specific characteristics that may influence the independent variables (Green, 2008; Torres-Reyna, 2012). In reality, however, there is usually omitted variable bias in the model due to unavailable variables (Baltagi, 2001; Park, 2011; Wooldrige, 2012).

Fixed-effects estimation, on the other hand, assumes state-specific characteristics may affect the predictor and/or outcome variables. In other words, it assumes there are time-invariant characteristics unique to the states. Hence, fixed-effects estimation allows assessing the net effect of regressors or independent variables by removing or demeaning the effect of time-invariant, state-specific characteristics (Baltagi, 2001; Wooldridge, 2012). Different from random-effects estimation, therefore, fixed-effects models do not affect biased due to omitted time-invariant and state-specific variables (Kohler and Kreuter, 2009). Rather, fixed-effects models explore the cause of changes within an entity. Any changes in the values of a dependent variable can be explained due to variation in predictors other than space-fixed characteristics (Stock and Watson, 2003; Wooldridge, 2012).

Based on the assumptions of pooled OLS, random-effects, and fixed-effects models, fixed-effects estimation is most suitable to the analysis of this study for many reasons. Because fixed-effects models allow an investigator to study the causes of changes in outcome variables within an entity, fixed-effects estimate is useful for policy analysis and program evaluation (Wooldridge, 2012). For analyzing the effectiveness of renewable energy policy instruments, therefore, this study will employ a fixed-effects model to answer the research question on whether the increase of renewable electricity generation is attributable to variation in policy instruments adopted within state, ceteris paribus.

A fixed-effects model is advisable in respect to considerations about its assumption in terms of the existence of heterogeneity or individual specific effects as well. In practice, states have many entity-fixed variables related to the adoption of policy instruments and also to the energy production using renewable sources. For instance, the size of land area varies between states, and this is expected to in part determine the levels of investment and installation of renewable energy equipment. Also, under the guidelines set by state legislation, the deployment of renewable energy is left to electric power industries as well as the policy designs of municipal authorities. There are a variety of player-initiated non-legislative initiatives in the energy market, such like green pricing and self-obligations. For instance, the state of Florida does not have a mandatory renewable portfolio standard enacted by governmental authority; but a municipal utility, JEA (formally Jacksonville Electric Authority), signed a memorandum with the Sierra Club and the American Lung Association of Florida giving testimony to its commitment of at least 7.5% of electric capacity from renewable energy sources by 2015.[35] Also, there are a variety of rebate and loan programs offered by corporations, municipalities, or utilities to their members and consumers.

Model 1 shows the statistical models of this study using fixed-effects estimate. This model allows us to explore the effectiveness of each type of policy instrument on states' renewable energy deployment; also to compare the relative explanatory power between policy instruments.

$$R_{it} = \alpha_0 + \beta * I_{it} + \delta * C_{it} + \gamma S_i + \theta T_t + \varepsilon_{it} \qquad \text{Model 1}$$

where "i" denotes a state, and "t" denotes a year of the observation; α denotes intercepts; R_{it} denotes the total renewable electricity generation; I_{it} denotes the policy instruments indices (command-and-control, market-based, and information instruments) existing in a state (*i*) in a certain year (*t*); C_{it} denotes other control variables; S_i denotes the vector of state dummy variables; T_t denotes the vector of year dummy variables; and ε_{it} denotes the error term.

[35] Database of State Incentives for Renewables & Efficiency, Accessed July 26, 2013, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=FL10R&re=1&ee=0.

Later, the analysis results section introduces the statistical and technical processes for evaluating goodness-of-fit, comparing pooled OLS, random-effects, and fixed-effects models. Throughout the process, the study remains focused upon verifying and implementing the most appropriate analytical model for the panel data of this study.

4.4 Variables and Data

This study analyzes state-level observations as a unit of analysis. For the analysis, historical state level data, from 2001 to 2010, were collected. Analyses with time series cross sectional data or panel data were deemed most suitable for this study because panel data allows an investigator to study on time-ordering of events and individual dynamics of states with more informative data (Brüderl, 2005). Using pooled state-specific panel data, therefore, increases the power of the models and improves the validity of statistical conclusion of this study (Shadish, Cook, Campbell, 2002). This study looks at 48 states, excluding Alaska and Hawaii, and D.C. for the time span between 2001 and 2010. This following section presents dependent and independent variables with their operational definitions and data sources.

4.4.1 Dependent Variables

To measure the outcomes of renewable energy policies, this study employs non-hydro renewable electricity generation, which is measured as the MWh of electricity generated from renewable resources excluding hydropower within a state. The Energy Information Administration (EIA) defines the non-hydro renewable resources as "other renewables," which include "biogenic municipal solid waste, wood, black liquor, other wood waste, landfill gas, sludge waste, agriculture byproducts, other biomass, geothermal, solar thermal, photovoltaic energy, and wind". [36]

According to the hypotheses and analytic models, this study uses two separate dependent variables. The first dependent variable is total amount of annual renewable electricity excluding non-hydropower. The second dependent variable is share of renewable electricity to total electricity generation. This second variable is calculated by dividing a state's annual amount of electricity generation from non-hydro renewable sources by total amount of electricity generated from all sources. Data for each state's electricity generation are available, by energy source, between 2001 and 2010 in EIA's report, *State Electricity Profiles* (EIA, 2012b).[37]

4.4.2 Renewable Energy Policy Instruments

This study reviews 18 state level policies and programs supporting renewable energy development across 48 states between 2001 and 2010. The major data sources of renewable energy policies discussed in this study are the Database of State Incentives for Renewable Energy (DSIRE), operated by the North Carolina Solar Center, the National Renewable Energy Laboratory (NREL), and the Energy Efficiency and Renewable Energy (EERE) at the U.S. Department of Energy (DOE). DSIRE provides regulations, policies and financial incentives related to renewable energy development.[38]

The purpose of this study is to examine states' renewable energy development derived attributable to policy instruments utilized by state governments. This study,

[36] State Electricity Profiles 2009. EIA (http://www.eia.gov/cneaf/electricity/st_profiles/sep2009.pdf)
[37] http://205.254.135.7/electricity/state/
[38] The historical data between 2001 and 2007 on state regulations, programs and financial incentives for renewable energy were collected through personal contact of person in the North Carolina Solar Center.

therefore, classifies and measures current state level renewable energy policies to reveal between-state-variation in policy instruments through which states favor to implement for renewable energy development. State level policies and programs supporting renewable energy development were classified into three types of policy instruments based on the coerciveness and behavioral assumption that each policy or program involves. Three categories of policy instruments are command-and-control, market-oriented, and information policy instruments.

This study creates indices of renewable energy policy instruments. First, this study constructs a dummy variable for each policy or program adoption, equal to one if a state has a renewable energy policy, and equal to zero if the state does not have a program in a given year (Carley, 2009; Delmas and Montes-Sancho, 2011). Each individual renewable energy program or policy is equally weighted and assigned into a group of policy instruments among three types. The command-and-control instrument includes five renewable energy programs and its index ranges from zero to five. Eleven renewable energy programs and incentives are assigned in the market approach instrument, ranging from zero to eleven. The information instrument contains two programs.[39]

[39] For measuring policy instruments, this study had adopted a relative frequency count calculated as the number of programs or incentives in each policy instrument adopted by each state divided by the maximum number of programs. A relative frequency count is used as a useful measure to compare the variations of policy adoption in different states (Meier, 1987; Ciocirlan, 2008). However, there was no difference between absolute numbers vs. relative frequency count measures in the level of significance explaining dependent variables.

4.4.3 Control Variables

Natural resources

This study includes variables regarding the availability of each state's renewable resources such as wind, solar, and biomass potentials. Wind and solar potentials are used as control variables affecting states' renewable electricity generation. Previous studies (Carley, 2009; Delmas and Montes-Sancho 2011; Menz and Vachon, 2006) employing technical potential of wind and/or solar energy of each state were estimated by the Union of Concerned Scientists (Deyette et al., 2003) based on earlier work by Elliott, Wendell, and Gower (1991) and Doherty (1995). These are, however, based upon time-invariant data and are therefore not applicable in terms of fixed effect panel analysis. Therefore, instead of using given data such as 10-year average, this paper uses real time data provided by National Aeronautics and Space Administration (NASA). NASA's POWER web site[40] provides daily radiation and meteorological data from 1983 through near-real time. For measuring each state's solar and wind parameters, average annual daily measure is computed for each parameter applying average latitude and longitude[41] of states. This paper uses Average Insolation Incident on A Horizontal Surface, measured as $kWh/m^2/day$, to represent each state's solar energy potential and employ Wind Speed at 10 m Above The Surface Of The Earth (m/s) for wind potential.[42]

In the final models, however, solar potential is not included due to the fact that it accounts for too small of a share of the total solar energy generated and thus may not be appropriate to use as a part of the explanation for the observed overall changes in non-

[40] The data are obtained from NASA's SSE and POWER, http://eosweb.larc.nasa.gov/sse/.
[41] http://www.maxmind.com/app/state_latlon
[42] http://power.larc.nasa.gov/cgi-bin/cgiwrap/solar/timeseries.cgi?email=daily@larc.nasa.gov

hydro renewable energy (EIA, 2012a, p.75). A state's given solar potential, measured by annual average insolation incident on a horizontal surface (kWh/m^2/day), varies little over time, even though there are significant differences between states. In addition, solar energy accounts for a very small proportion even among the electricity generated from non-hydro renewable sources. As of 2010, 1,212 thousand megawatt hour of electricity is generated from solar thermal and solar PV. It grew by 123% compared to the amount of electricity generated from solar energy in 2001, 543 thousand megawatt hour, but it accounts less than 1% of non-hydro renewable electricity (EIA, 2012b).[43]

State economic characteristics

This study hypothesizes a positive association between state wealth and amount and proportion of a state's electricity generation from renewable sources. This study measures state wealth by per capita gross state product (GSP). Per capita real GSP data, converted into constant 2005 dollar, are available at Bureau of Economic Analysis across 48 for the time span of this study, from 2001 to 2010.

The strength of fossil fuel based interest groups is expected to be negatively associated with a state's renewable energy deployment. This is measured by the percentage of gross state product (GSP) attributable to the petroleum and coal product manufacturing and mining industries out of total GSP of the state respectively. U.S. Bureau of Economic Analysis (BEA) provides the gross domestic product by state by industry available for the time period of this study.

[43] http://www.eia.gov/electricity/data.cfm#generation

Political environment

This study hypothesizes that state legislators' preference toward environmental issues positively affect the renewable energy deployment of the state. In line with previous studies (Carley, 2009; Delmas and Montes-Sancho, 2011; Shrimali and Kneifel, 2011), this study will use the scorecards offered by League of Conservation Voters (LCV). Among various scores, the average score of states' House of Representatives on environmental issues of each state will be used to measure the preference of a state's governing body vis-a-vis renewable energy deployment. LCV scores are available on an annual basis in the *National Environmental Scorecard*, provided by League of Conservation Voters[44].

The political affiliation of governors is also considered to be a factor in renewable energy production. This study measures the presence of Democratic governors with dummy variables as 1 if the political affiliation of governor in a state in a given year is a democrat; as 0 if governor is Republican or Independent. The National Governors Association provides the political affiliation of the governors of the 50 states.

Another political environment variable that this study considers is the capacity of administrative institution. To measure states' administrative capacity affecting renewable energy implementation, this study uses the number of employees working for natural resources in state and local governments (Carley, 2009). Historical statistics on government employment are available from *the Annual Survey of Public Employment and Payroll*[45] at the Bureau of Census. Government employment data are provided by

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[44] http://scorecard.lcv.org/scorecard/archive
[45] http://www.census.gov/govs/apes/historical_data.html

states, by government function. This study looks at the number of state and local governments' employees assigned to the government function of natural resources. This study counts full-time equivalent (FTE) employees of state and local governments according to each state. A state's administrative capacity for natural resources is measured as number of FTE public employees for natural resources per million people.[46]

This study includes social interest in environmental issues among the factors used to explain the renewable energy deployment of states. This study hypothesizes that a state with a higher level of citizen participation in environmental groups is likely to be more supportive of the state legislation and policy implementation for renewable energy development. This study measures Sierra Club chapter membership per 1,000 people in each state as the degree of social interest in environmental issues. The historical statistics of Sierra Club membership by chapter was obtained through Sierra Club Member Services.[47]

Electricity market conditions

This study expects that higher fossil fuel prices, natural gas in particular, will stimulate more electric suppliers to shift to renewable energy sources. For the analysis this study considers only the natural gas consumed for electricity generation. In the *State Electricity Profile*, EIA provides information on the fuel prices at which each state's electric power sector purchases its resources by fuel type such as natural gas, coal, and

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46 2006 Mississippi has missing value in state and local governments' FTE employment for natural resource. Estimate is calculated as the average of 2005 and 2007 employees. LA 2006 state and local governments' FTE employment for natural resource is missing.

47 Sierra Club website, http://www.sierraclub.org/contact/

petroleum.[48] This study uses the natural gas prices measured as cents per million Btu (British thermal unit).

Another market factor which is expected to explain the variation in renewable energy deployment is electricity price. However, it is hard to predict the direction toward which electricity price affect states' investment in renewable energy technologies. Previous studies did not show a consistent result for the relationship between electricity price and renewable electricity generation and/or capacity (Carley, 2009; Shrimali and Kniefel, 2011). This study will use the states' average annual retail electricity price, measured in cents per kilowatt-hour. EIA provides the historical electricity price data by state, between 1990 and 2010.[49]

This study assumes that a state's experience of electricity import incentivizes the state to develop renewable energy. Yi and Feiock (2012) used the net import of electricity from other states, in million Btu, in their study of the determinants of states' renewable portfolio standards adoption. Measures of variation in states' electricity import/export tendencies, however, should consider the relative size of the energy industries within the respective states. Yi and Powers' study (2010) measured states' import ratio of electricity by computing the net difference between electricity sales and generation divided by total electricity sales within a state. They modeled a year lagged impact of states' experience in increase or decrease of electricity import ratio on renewable energy development.[50] However, their measure is not only complicated to interpret, but also generates negative

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[48] Missing data for some states were estimated by the average natural gas prices of neighboring states according to NERC.
[49] EIA (2011). Electric Power Annual. http://205.254.135.7/electricity/data.cfm#sales
[50] $IMPORTRAIO_{it} = (SALES_{i,t-1} – GENERATION_{i,\ t-1}) / (SALES_{i,\ t-1})$

values which do not allow possible data transformation, e.g. log transformation, for appropriate and efficient statistical analysis.

The EIA provides states' net interstate trade of electricity[51] and net trade index of electricity in its annual report of State Electricity Profiles.[52] The net trade index is the ratio of a state's total supply, including electricity generation and import from other countries, to state total use of electricity, sum of in-state consumption and international exports. [53] EIA's net trade index is useful in terms of looking at the overall size and trends of states' import and export of electricity. However, EIA's net trade index would be a misleading measure of states' self-sufficiency ratio for electricity, because it considers import from other countries as a part of states' electricity supply.

Based on the aforementioned two indices, this study measures a state's electricity import/export ratio by the net generation of electricity in a state over total electricity sales within the state. The underlying assumption is that a state exports whatever portion of its electricity production exceeds total demand in the state. An electricity export index bigger than unify indicates a positive net export of electricity of a state; export index smaller than 1 refers positive net import of electricity from other states. Data for the MWh of net generation and sales of electricity by state are provided by the Energy Information Administration.

The type of governance of electric utility industry is measured by the ownership of electric utilities. The ownership of utilities is expected to influence the utilization of

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[51] Net Interstate Trade = Total Supply - (Total Electric Industry Retail Sales + Direct Use + Total International Exports (if applies) + Estimated Losses).
[52] EIA, http://www.eia.gov/electricity/state/.
[53] Net Trade Index is the sum of Total Supply / (Total Disposition - Net Interstate Trade).

state governments' financial incentives, subsidies, and tax expenditures. Energy Information Administration issues Electric Sales, Revenue, and Average Price data by state and utility.[54] This includes class of ownership – public, cooperative, and investor-owned – state location, number of consumers, revenue, sales (MWh), etc. Data are available from 1994 to 2010. This study measures the share of private utility by the percent of the sales sold by investor-owned utilities to total electric utility sales in each state.

The final control variables are year dummies. To control the heterogeneity attached to years, year dummies with 2001 reference are measured. There are some variables which must have influenced the renewable energy industry, but which are hard to allocate to states, such as federal efforts for renewable energy development under ARRA 2009 or the recent downturn and recovery in the US economy. This study is especially interested in the year effects of 2009 and 2010 when the Federal government awarded cash grants to renewable electricity developers under ARRA. Significant year effects in 2009 and 2010, in particular, could give us some evidence of the effectiveness of Federal effort to develop renewable industries through the stimulus package.

Table 3 presents the operational definitions and data sources of all dependent and independent variables used in the final models.

[54] EIA, http://www.eia.gov/electricity/sales_revenue_price/index.cfm

Table 3. Variable definitions and data sources

Variable	Definition	Data Source
Total renewable electricity	Total amount of electricity in MWh generated from non-hydro renewable (other renewables)	U.S. Energy Information Administration (EIA)
Share of renewable electricity	Percentage of renewable electricity out of total net electricity generation	EIA
Command-and-control policy index	Number of existing renewable energy policy instruments classified as command-and-control type instrument in a state each year, range 0-5	Database of State Incentives for Renewables & Efficiency (DSIRE) and by author
Market-based approach index	Number of existing renewable energy policy instruments classified as market approach in a state each year, range 0-11	DSIRE and by author
Information instrument index	Number of existing renewable energy policy instruments classified as information instrument in a state each year, range 0-2	DSIRE and by author
Wind potential	Annual average daily measure of wind speed at 10 m above the surface of the earth in m/s for average latitude and longitude of each state	NASA
Per capita GSP	Annual gross state product per capita, inflation adjusted to 2010 dollar value	U.S. Bureau of Economic Analysis (BEA)
Share of fossil fuel manufacturing	Percentage of the product in the petroleum and coal manufacturing industry out of total GSP	BEA
Share of mining industry	Percentage of the product in the mining industry out of total GSP	BEA
Sierra membership	Number of the Sierra Club chapter membership per 1,000 state population	Sierra Club HQ
Democrat Governor	If governor's political affiliation is democrat, 1; republican or independent, 0.	National Governors Association
House score	Average voting scores on environmental issues of House of representatives, range 0-100	League of Conservation Voters
State and local NR employment	Number of full-time equivalent employees working for natural resources in state and local governments per million people within a state	Census
Total electricity sales	Total amount of residential, commercial, and industrial electricity sales within each state, MWh	EIA
Natural gas price	Annual average natural gas price purchased by electric power industry in cents per million Btu, inflation adjusted to 2010 dollar value	EIA
Electricity price	States' average annual retail electricity price	EIA
Share of nuclear	Percentage of nuclear power generation out of total electricity generation	EIA
Share of hydro	Percentage of hydro conventional electricity generation over total amount of electricity generation	EIA
Share of IOU	Percentage of electricity sales of investor-owned-utilities over total electricity sales	EIA
Electricity export ratio	The amount of electricity generation divided by total sales in Mwh within states.	EIA

Note: Data are retrieved for 48 states and the time period of years between 2001 and 2010.

CHAPTER V

RESULTS

This section presents the results of statistical analyses which test the hypotheses discussed in the previous section. This study is mainly to examine and compare the effectiveness of three different types of policy instrument on states' renewable energy development, all other things being equal. This study measures renewable energy development within each state and observes state level renewable energy policy instruments and all other independent variables across 48 states, excluding Alaska, Hawaii, and D.C., over the time period between 2001 and 2010. This section first covers the trends in renewable energy development and variation in states' policy design for developing renewable energy in the United States, focusing on 48 states over the past decade. A descriptive analysis of all other independent variables is following. Then, this section presents results from statistical models which tests the hypotheses of this study. The conclusion highlights how the effectiveness of renewable energy policies varies depending on the types of policy instruments and what other variables explain the states renewable energy development. It also compares the estimations from different model specifications.

5.1 Trends in Renewable Electricity Generation

In order to examine the relationships between renewable energy policies and their effects, it is important to observe variation in states' policy designs and renewable electricity generation among states over years. Overall trends in the electricity industry of the 48 states, in terms of electricity generation by sources, are shown in Table 4. In 2010, 48 states generated a total of 4,107 TWh electricity, which grew by 10.4% compared to the total electricity generation in 2001. Of a 388 TWh growth in electricity generation, 84% increased between 2001 and 2006. The economic recession that the United States experienced in 2008 and 2009 can account for a weakening in the growth in the overall electricity market.

Meanwhile however, for electricity generation, the 48 states increased their use of non-hydro renewable technologies by 139% between 2001 and 2010. From 2006 to 2010, the energy industry generated 70 TWh of electricity from non-hydro renewable sources, accounting for 73% of total change since 2001. The electricity industry had a rapid increase in the share of non-hydro renewable sources in electricity generation. In 2001, non-hydro renewable technologies were used for 1.9% of total electricity generation, but in 2010 electricity suppliers generated 4% of electricity from non-hydro renewable sources (see Table 5).

Table 4 shows the averages of 48 states' total electricity, non-hydro renewable electricity generation, and percentages of non-hydro renewable electricity, and the results of analysis of variance (ANOVA) that compare changes of those three measures over years. Since 2001, 48 states' average total electricity increased from 77.5 TWh to 85.6 TWh, but there was no statistically significant increase (F=.17, *p*=.84) between years considering the variance among states. During the same period, however, electricity generation using non-hydro renewable technologies increased statistically significantly (F=3.09, *p*=.048) at 95% confidence level. Average non-hydro renewable electricity of the 48 states increased from 1,463 GWh in 2001 to 3,466 GWh in 2010. Therefore, the percentage of non-hydro renewable electricity also significantly changed over years (F=5.88, p<.00).

Table 4. Electricity Generation by Year (MWh, %)

	Year	N	Mean	S.D.	Minimum	Maximum	F	*p*
Total Electricity	2001	48	77,482,157	67,779,197	5,480,614	372,580,002	.17	.84
	2006	48	84,299,737	73,991,627	5,967,725	400,582,878		
	2010	48	85,568,009	74,894,552	5,627,645	411,695,046		
Non-hydro Renewable Electricity	2001	48	1,463,368	3,164,466	0	21,600,000	3.09	.048
	2006	48	1,997,604	3,548,012	417	23,900,000		
	2010	48	3,465,679	5,248,432	138,197	27,700,000		
Percent Non-hydro Renewable	2001	48	2.19	3.36	0.00	19.55	5.88	.00
	2006	48	2.81	3.65	0.01	23.59		
	2010	48	4.85	4.78	0.29	24.40		

There appear differences in the size of electricity supply and energy sources between states. Table 5 shows total electricity generation, non-hydro renewable electricity, and percentage of non-hydro renewable electricity by states over the years of 2001-2010. In 2010, Texas was ranked first in total electricity generation with 411.7 TWh, accounting for 10% of total electricity generated in the 48states. Pennsylvania, Florida, California, and Illinois have large electrical generating industries that produced more than 200 TWh of electriciy in 2010. Of these states, Texas and California were ranked first and second in use of non-hydro renewable technologies for electricity generation. Each state generated more than 25 TWh electricity from renewable sources, and their total accounted for 32% of U.S. total renewable electricity generation in 2010. When looking at the percentage of electricity generated from non-hydro renewable sources, Maine was ranked first with 24.4%; and Iowa (16.3%), South Dakota (13.7%), California (12.5%), Minnesota (12.4), and North Dakota (11.8) are following in 2010 (see Table 5).

Table 5. Electricity Generation by State (MWh, %)

Area	Total Electricity			Non-Hydro Renewables			Percent Renewables		
	2001	2006	2010	2001	2006	2010	2001	2006	2010
Alabama	125,345,113	140,895,441	152,150,512	4,189,364	3,884,462	2,376,986	3.34	2.76	1.56
Arizona	89,911,272	104,392,528	111,750,957	39,437	53,567	318,907	.04	.05	.29
Arkansas	47,192,035	52,168,703	61,000,185	1,511,997	1,722,805	1,623,943	3.20	3.30	2.66
California	198,596,075	216,798,688	204,125,596	21,600,000	23,900,000	25,400,000	10.89	11.03	12.47
Colorado	46,876,002	50,698,353	50,720,792	112,843	896,228	3,554,533	.24	1.77	7.01
Connecticut	30,490,646	34,681,736	33,349,623	908,924	763,320	739,660	2.98	2.20	2.22
Delaware	6,807,684	7,182,179	5,627,645	0	417	138,197	.00	.01	2.46
Florida	190,945,344	223,751,621	229,095,935	3,789,757	4,330,690	4,486,723	1.99	1.94	1.96
Georgia	118,316,789	138,010,208	137,576,941	3,002,754	3,418,918	3,180,563	2.54	2.48	2.31
Idaho	9,346,941	13,386,085	12,024,564	533,335	689,957	1,014,010	5.71	5.15	8.43
Illinois	179,249,285	192,426,958	201,351,872	678,569	848,832	5,138,159	.38	.44	2.55
Indiana	122,569,673	130,489,788	125,180,739	114,580	220,212	3,245,666	.09	.17	2.59
Iowa	40,658,512	45,483,462	57,508,721	591,612	2,454,717	9,360,483	1.46	5.40	16.28
Kansas	44,748,523	45,523,736	47,923,762	39,832	991,890	3,459,351	.09	2.18	7.22
Kentucky	95,417,626	98,792,014	98,217,658	9,553	458,798	439,875	.01	.46	.45
Louisiana	87,894,377	90,921,829	102,884,940	2,704,289	2,962,363	2,467,776	3.08	3.26	2.40
Maine	19,564,821	16,816,173	17,018,660	3,825,725	3,967,651	4,152,283	19.55	23.59	24.40
Maryland	49,062,340	48,956,880	43,607,264	373,015	626,161	573,665	.76	1.28	1.32
Massachusetts	38,478,434	45,597,775	42,804,824	1,312,787	1,278,829	1,273,734	3.41	2.81	2.98
Michigan	111,845,610	112,556,739	111,551,371	2,361,663	2,442,559	2,832,452	2.11	2.17	2.54
Minnesota	48,523,226	53,237,789	53,670,227	1,977,113	3,058,884	6,639,633	4.08	5.75	12.37
Mississippi	53,446,452	46,228,847	54,487,260	1,432,117	1,541,082	1,504,270	2.68	3.33	2.76
Missouri	79,544,873	91,686,343	92,312,989	8,798	23,971	987,597	.01	.03	1.07
Montana	24,232,485	28,243,536	29,791,181	65,425	530,385	1,027,157	.27	1.88	3.45
Nebraska	30,485,212	31,669,969	36,630,006	19,293	313,261	493,153	.06	.99	1.35
Nevada	33,875,966	31,860,022	35,146,248	1,199,873	1,343,711	2,286,647	3.54	4.22	6.51
New Hampshire	15,074,624	22,063,695	22,195,912	1,025,621	746,380	1,232,218	6.80	3.38	5.55
New Jersey	59,421,260	60,700,139	65,682,494	843,632	916,783	850,054	1.42	1.51	1.29
New Mexico	33,611,643	37,265,625	36,251,542	18,652	1,277,321	1,854,792	.06	3.43	5.12
New York	143,914,559	142,265,432	136,961,654	1,801,072	2,596,641	4,814,548	1.25	1.83	3.52
North Carolina	117,495,850	125,214,784	128,678,483	1,751,290	1,828,305	2,083,142	1.49	1.46	1.62
North Dakota	30,332,072	30,881,137	34,739,542	7,665	373,029	4,108,028	.03	1.21	11.83
Ohio	142,261,807	155,434,075	143,598,337	430,961	458,615	700,089	.30	.30	.49
Oklahoma	55,249,450	70,614,880	72,250,733	230,696	2,009,724	4,159,956	.42	2.85	5.76
Oregon	45,051,906	53,340,695	55,126,999	839,528	1,828,988	4,756,880	1.86	3.43	8.63
Pennsylvania	196,576,591	218,811,595	229,752,306	1,896,196	2,472,946	4,245,175	.97	1.13	1.85
Rhode Island	7,501,892	5,967,725	7,738,719	103,616	148,913	140,073	1.38	2.50	1.81
South Carolina	89,158,987	99,267,606	104,153,133	894,154	1,910,437	1,873,064	1.00	1.93	1.80
South Dakota	7,400,743	7,132,243	10,049,636	871	148,965	1,371,750	.01	2.09	13.65
Tennessee	96,221,976	93,911,102	82,348,625	822,025	810,599	987,550	.85	.86	1.20
Texas	372,580,002	400,582,878	411,695,046	2,180,945	7,818,260	27,700,000	.59	1.95	6.73
Utah	35,853,750	41,263,324	42,249,355	158,238	205,476	780,967	.44	.50	1.85
Vermont	5,480,614	7,084,344	6,619,990	382,541	449,910	482,339	6.98	6.35	7.29
Virginia	74,104,750	73,069,537	72,966,456	1,747,072	2,458,450	2,219,649	2.36	3.37	3.04
Washington	83,048,669	108,203,155	103,472,729	1,221,331	2,502,854	6,616,963	1.47	2.31	6.40
West Virginia	81,836,725	93,815,804	80,788,947	15,527	174,053	939,172	.02	.19	1.16
Wisconsin	58,763,431	61,639,843	64,314,067	1,102,210	1,265,623	2,473,956	1.88	2.05	3.85
Wyoming	44,776,938	45,400,370	48,119,254	365,159	759,061	3,246,793	.82	1.67	6.75
Total	3,719,143,555	4,046,387,390	4,107,264,431	70,241,657	95,885,003	166,352,581	1.89%	2.37%	4.05%

5.2 Innovative Policy Designs for Renewable Energy Development

Between 2001 and 2010, the 48 states developed new renewable energy policy designs. Overall, states have implemented an increasing number of programs and policies and also diversified their approaches to electricity markets so as to increase the use of renewable energy technologies. Table 6 shows the average number of renewable energy policies utilized by 48 states, reflecting the years 2001, 2006 and 2010. As mentioned before, 18 state level policies and programs supporting renewable energy development were equally weighted and classified into three types of policy instruments. The command-and-control instrument index ranges from zero to five; the market-based instrument ranges from zero to eleven; and the information instrument ranges zero to two. The sum of the three policy instruments is presented as "Total" in the table.

Overall, state governments have significantly increased their intervention in renewable energy industries. Mean values of Table 6 show the average number of total renewable energy policy instruments that each 48 states adopted in each year. It is evident that state governments have introduced more policy instruments to the renewable energy market ($F=17.58$, $p<.00$) (Table 6). The number of policy instruments adopted by 48 state governments was almost doubled between 2001 and 2010. The 48 state governments had adopted only one command-and-control type policy instrument, on average, for motivating renewable energy producers in 2001, but in 2010 states utilized on average two kinds of command-and-control instruments. A huge increase is seen in market-based instruments used by state governments. State governments offered, on average, six types of market-based incentives for the power producers to deploy more renewable energy technologies in 2010. Information instruments were also introduced and increased to use at state level.

Table 6. Number of Policies for Renewable Energy Development by Year

Policy Instruments	Year	N	Mean	Std. Deviation	Std. Error	F	*p*
Command-and-control (0-5)	2001	48	1.1	1.057	0.153	7.305	0.001
	2006	48	1.6	1.267	0.183		
	2010	48	2.04	1.271	0.183		
Market-Based (0-11)	2001	48	3.17	1.993	0.288	20.017	0.000
	2006	48	4.29	2.343	0.338		
	2010	48	5.98	2.226	0.321		
Information (0-2)	2001	48	0.33	0.476	0.069	3.764	0.026
	2006	48	0.63	0.64	0.092		
	2010	48	0.65	0.729	0.105		
Total (0-18)	2001	48	4.6	2.819	0.407	17.58	0.000
	2006	48	6.52	3.632	0.524		
	2010	48	8.67	3.563	0.514		

There are variations between states and years in regards to the existence of renewable energy policy instruments. In 2001, 48 states adopted 4.6 renewable energy policies or programs out of 18 programs on average. New York adopted the greatest number of renewable energy policies in 2001: three regulations, seven market incentives, but no information instruments. California, Connecticut, Minnesota, and Oregon had nine policy instruments and Arizona, Massachusetts, Montana, and Rhode Island had adopted eight programs to encourage renewable energy development. On the other hand, however, until 2001, 18 states had not adopted any kind of regulatory instrument and only 10 states introduced an informative/voluntary policy instrument to their energy industry. Three states, Louisiana, South Carolina, and West Virginia, did not have legislative activities to force or incentivize their electricity industry to deploy renewables, in respect to the 18 policies or programs in which this is interested. Interestingly, 13 states such as Indiana, North Carolina, and Tennessee supported the use of renewable energy technologies through market instruments, but did not introduce any regulatory nor informative policy instruments (see Table 7).

As of 2010, there were, on average, 8.6 legislated policies or programs for renewable energy development per state in the 48 states. Massachusetts and Oregon had implemented 16 renewable energy programs and incentives. Massachusetts had introduced all 11 types of market instruments, including market regulations and financial incentives. New York and New Jersey had 15 and 13 renewable energy policies/programs respectively. Also eleven states[55] had more than 11 policies supporting renewable energy development. As of 2010, every state had adopted at least one policy instrument supporting renewable energy technologies. Six states—Idaho, North Dakota, Tennessee, Oklahoma, Alabama, and Mississippi—had not yet adopted regulatory or informative policy instruments, but had introduced market instruments. Half the 48 states had introduced at least one information instrument into their electricity industry to encourage energy suppliers to voluntarily employ renewable energy technologies (Table 7).

[55] Connecticut, Maine, Iowa, Maryland, Minnesota, Ohio, Vermont, Wisconsin (12), California, Montana, Rhode Island (11) in 2010.

Table 7. Number of Renewable Energy Policy Instrument by State, Year

State	2001				2006				2010				Total change 2001-2010
	Command-and-control	Market-based	Information	All RE Policies	Command-and-control	Market-based	Information	All RE Policies	Command-and-control	Market-based	Information	All RE Policies	
Alabama	0	2	0	2	0	3	0	3	0	3	0	3	1
Arizona	2	5	1	8	2	3	1	6	3	6	0	9	1
Arkansas	2	3	0	5	1	1	0	2	1	1	0	2	-3
California	3	5	1	9	4	7	1	12	4	6	1	11	2
Colorado	0	3	1	4	2	2	1	5	2	6	2	10	6
Connecticut	3	5	1	9	4	5	1	10	4	7	1	12	3
Delaware	2	1	0	3	3	3	1	7	3	4	2	9	6
Florida	1	3	1	5	1	2	1	4	2	6	1	9	4
Georgia	1	1	0	2	1	2	0	3	1	6	0	7	5
Idaho	0	4	0	4	0	5	0	5	0	5	0	5	1
Illinois	1	2	1	4	2	2	1	5	3	6	1	10	6
Indiana	0	4	0	4	1	3	0	4	1	6	0	7	3
Iowa	1	6	0	7	2	8	2	12	2	8	2	12	5
Kansas	0	3	0	3	0	3	0	3	2	5	0	7	4
Kentucky	0	1	0	1	1	2	0	3	1	7	0	8	7
Louisiana	0	0	0	0	1	3	0	4	1	5	0	6	6
Maine	3	2	1	6	2	4	1	7	4	6	2	12	6
Maryland	1	6	0	7	2	8	1	11	2	9	1	12	5
Massachusetts	2	5	1	8	3	10	1	14	4	11	1	16	8
Michigan	1	0	1	2	2	4	1	7	4	5	1	10	8
Minnesota	2	7	0	9	3	7	2	12	3	8	1	12	3
Mississippi	0	1	0	1	0	1	0	1	0	1	0	1	0
Missouri	0	2	0	2	0	4	0	4	2	4	0	6	4
Montana	2	5	1	8	3	6	2	11	3	7	1	11	3
Nebraska	0	2	0	2	0	2	0	2	1	4	0	5	3
Nevada	2	4	1	7	3	5	1	9	3	6	1	10	3

Table 7. Number of Renewable Energy Policy Instrument by State, Year

(Continued)

State	2001				2006				2010				Total change 2001-2010
	Command-and-control	Market-based	Information	All RE Policies	Command-and-control	Market-based	Information	All RE Policies	Command-and-control	Market-based	Information	All RE Policies	
New Hampshire	1	3	1	5	1	3	0	4	2	5	0	7	2
New Jersey	3	3	1	7	4	7	1	12	3	9	1	13	6
New Mexico	2	2	0	4	1	6	1	8	2	7	1	10	6
New York	3	7	0	10	4	10	1	15	4	10	1	15	5
North Carolina	0	4	0	4	0	5	0	5	2	8	0	10	6
North Dakota	0	4	0	4	0	6	0	6	0	5	0	5	1
Ohio	2	5	0	7	2	8	1	11	3	8	1	12	5
Oklahoma	0	1	0	1	0	3	0	3	0	4	0	4	3
Oregon	2	7	0	9	2	8	1	11	4	10	2	16	7
Pennsylvania	1	2	1	4	4	3	1	8	3	6	1	10	6
Rhode Island	2	6	0	8	2	5	1	8	2	8	1	11	3
South Carolina	0	0	0	0	1	1	0	2	1	5	0	6	6
South Dakota	0	1	0	1	0	1	0	1	1	2	0	3	2
Tennessee	0	2	0	2	0	3	0	3	0	5	0	5	3
Texas	1	5	1	7	2	4	1	7	2	5	1	8	1
Utah	1	1	0	2	2	5	0	7	2	6	0	8	6
Vermont	1	2	0	3	2	3	1	6	2	10	0	12	9
Virginia	1	4	0	5	1	4	1	6	1	6	2	9	4
Washington	0	5	1	6	1	5	2	8	2	5	2	9	3
West Virginia	0	0	0	0	1	2	0	3	1	4	0	5	5
Wisconsin	3	4	0	7	3	6	0	9	4	8	0	12	5
Wyoming	1	2	0	3	1	3	0	4	1	3	0	4	1
Average	1.10	3.17	.33	4.60	1.60	4.29	.63	6.52	2.04	5.98	.65	8.67	4.06
Total	53.00	152.00	16.00	221.00	77.00	206.00	30.00	313.00	98.00	287.00	31.00	416.00	195.00

Diversity and Coerciveness of Policy Instruments

To answer the questions whether state governments have diversified their policy instruments for supporting the deployment of renewable energy, a detailed investigation on is made on the states' use of renewable energy policies. The renewable energy policies and programs that were most frequently adopted and implemented by state governments in 2001 were economic regulations, and as such these were classified as market instruments in this study. 31 states applied net-metering systems to their electricity markets and introduced access laws to recognize and protect accessibility to solar or wind as a property right. In 2010, about a quarter of the states gave various tax benefits for the investment and installation of renewable energy technologies: corporate tax (10 states), personal tax (11 states), property tax (16 states), and sales tax (12 states) credits. However, some programs or incentives such as green power purchasing programs, production incentives, or required green power options were rarely used by states' renewable energy policy designs back in 2001.

Overall states introduced a larger number of programs and policies in their renewable energy policy portfolios between 2001 and 2010. Policy instruments also became more diversified in the sense that new policy instruments—green power purchasing, production incentives, green power option—were introduced and adopted during the period. Forty one states implemented net-metering programs as of 2010. Interconnection standards have been adopted and applied in 41 state and 25 states adopted them since 2001. Thirty five states have adopted solar or wind access laws with voluntary easements. Twenty eight states of the 48 states have implemented renewable portfolio standards.

In the beginning of governmental intervention into renewable electricity markets, back in the early 2000s, the most popular approaches were net-metering and access laws. These are economic regulations that reduce market barriers and provide assurance of property rights for solar and wind access. State governments began setting up electric power markets favorable to renewable energy developers by using policy instruments characterized by medium level coerciveness, rather than highly coercive command-and-control instruments. During and after the period of electricity restructuring, however, very coercive command-and-control instruments—RPS, interconnection and PBFs—have been adopted in many states; also information disclosure of power industries has been mandated in many states during the time period. Financial incentives including various tax expenditures, and governmental subsidies and grants have increasingly been adopted as states' policy instruments supporting renewable energy development. For recent years, new policy instruments such as performance-based or production incentives and green power options have been introduced and adopted at the state level.

Table 8. Number of States with Renewable Energy Policies

Policy Instruments	Illustrative Tools	Renewable Energy Policies and Programs	2001	2006	2010
Command -and- Control	Obligations	Green Power Purchasing	2	7	3
		RPS	11	20	28
		PBF	14	15	17
	License/process standard	Contractor License	10	7	9
		Interconnection	16	28	41
Market-Based	Market systems	Net-Metering	31	35	41
		Access Laws	31	30	35
	Subsidies and Grants	Rebates	9	17	22
		Grants	10	17	23
		Loans	13	21	35
		Production Incentives	1	6	9
	Tax Expenditures	Corporate Tax Credit	10	15	22
		Personal Tax Credit	11	15	21
		Property Tax Credit	16	26	32
		Sales Tax Credit	12	17	27
		Industry Support	8	7	20
Information	Information	Disclosure	16	25	22
		Required Green Power Option	0	5	9

5.3 Regression Results

5.3.1 Estimation Issues

In order to find out an appropriate statistical analysis model for the time-series cross sectional data, this study performed and compared three different models: pooled OLS regression analysis, random-effects, and fixed-effects estimates analyses. Analyses were performed on 480 observations: 48 states for the time period from year 2001 through 2010. The fixed-effects and pooled OLS regression models are based on the assumption of a linear relationship between variables, while random-effects models are based on feasible generalized least squares. This study transformed the dependent and independent variables to build a base model which meets the assumptions of ordinary least square regression best. This section describes the process through which the final panel model was decided.

First of all, the research examined the skewness of the distribution of dependent and independent variables, and transformed whichever ones needed to be transformed to achieve a normal or symmetric distribution. The outcome variables of this study, MWh of electricity generated from renewable sources and the share of renewable electricity, both had right-skewed distributions. Among various methods used for handling asymmetric distributions of measures, this study used a natural log transformation. This is a popular means to normalize univariate data (See Appendix C). The natural log transformation resulted in a distribution more nearly symmetric and closer to a normal distribution for both variables. Also, the measures of most of independent variables were skewed to the right. For normally distributed measures of independent variables, a natural log transformation was used. Those variables are electricity price, natural gas price, shares of nuclear and hydro power, electricity export ratio, per capita GSP, shares of fossil fuel manufacturing and mining industry, number of Sierra Club membership per 1,000 capita, state and local governmental employees, and wind energy potential. Renewable energy policy instrument indices and the average congressional House voting scores on environmental issues were nearly normally distributed.

Next, this study compared three different panel regressions—pooled OLS, random-effects, and fixed-effects regressions—to verify the appropriateness of the analytical modeling done in this study. In a previous section, the researcher discussed the assumptions and purposes of three panel regression models for the study. The logical conclusion was that a fixed-effects model is conceptually most appropriate for the purpose of the analysis as well as the virtue of the panel data used in this study. The fixed-effects model is also attractive when a study intends to investigate the causes of changes within an entity. With adjustment for heteroskedasticity, a fixed-effects estimate usually provides a valid inference (Wooldridge, 2011).

The following paragraphs introduce the step-by-step process of statistical model selection this study. Park (2011)'s guidelines suggest to begin with pooled OLS regression model, and to examine whether or not there is observed or unobserved heterogeneity, that is, cross-sectional or time-series effects. This study thus started with a pooled OLS without fixed and/or random effects as a base model. Then, this base model was compared to a least square dummy variable (LSDV) model with year dummy variables for year specific effects as well as to a LSDV with state dummy variables, in order to examine the existence of state fixed effects.

As expected on the basis of the literature review and research design sections, the results found evidence of time effect. Unobserved year fixed effects existed in two respective models. The first was on in which the dependent variable was log transformed MWh of electricity generated from non-hydro renewable sources. The second was on in which the dependent variable was log transformed share of renewable electricity. For both models, LSDV with year dummy variables fitted the data better than the pooled OLS. The R square increased; F statistic increased; while sum of squares due to residual (SSE) decreased.

The results of the LSDV models with state dummy variables showed strong evidence of the unobserved heterogeneity of individual (or state) effects. State dummy variables significantly improved the goodness-of-fit of models: R-squared increased; the model F statistic increased; and sum of squared errors (SSE) decreased in both models with two different outcome measures.

Given the substantial evidence of unobserved heterogeneity due to state-specific and/or year-specific effects, the researcher then employed a Breusch-Pagan Lagrange multiplier (LM) test. The LM test is usually conducted to decide between a pooled OLS and random-effects regression. The null hypothesis of the LM test was that state-specific or year-specific error variance components were zero (homoscedasticity). That is, the null hypothesis was that there was no significant difference across states over years (Breusch and Pagan, 1980). Test results rejected the null hypothesis. Therefore it was determined that a random effects model is appropriate as compared to an OLS regression for both models with different dependent variables (See Appendix D.1 and D.2).

Next, a Hausman test was conducted to decide between fixed-effects and random-effects estimates for the base regression model with year dummy variables. The basic idea of Hausman test is to test whether there is heterogeneity or unique errors correlated with the regressors (Hausman, 1978; Wooldridge, 2012). The null hypothesis of the Hausman test was that the random-effects and fixed-effects estimates are not different. In general, a fixed effect model is favorable when the null hypothesis is rejected (Hausman, 1978; Wooldridge, 2012). Even though many prior scholars (Baltagi, 2001; Wooldridge, 2012) proved that the fixed-effects estimate is more convincing model for the purpose of policy analysis, a formal test for a statistically significant difference between random- and fixed-effects models is also common (Wooldridge, 2012). In this research, Hausman tests on the two different dependent variables both rejected the null hypothesis (See Appendix D.1 and D.2). This means that there exist state-fixed unique errors in the panel data of this study. The researcher, therefore, decided to employ fixed-effects regression models for the analysis.

Given the decision to use fixed-effect estimate models, this study conducted several post-estimate diagnostics tests for cross-sectional dependence, heteroskedasticity, and serial correlation of residual. Because the fixed-effects regression applies the OLS estimators, the classical assumptions of OLS regression on residuals/error be considered: independent and identical (or homoscedastic) distribution of errors.

The presence of special correlation of residuals can bias the analysis results. Cross-sectional dependence is more problematic in macro panels with long time-series (over 20-30 years) than in micro panels according to Baltagi (2001). Although this study has 10 years of time-series, a residual diagnostic test for contemporaneous correlation was conducted. To test whether the residuals resulted from a fixed-effect regression are correlated across states, Pasaran cross-sectional dependence (CD) test was used. The null hypothesis of the test is uncorrelated residuals. Test results for both regressions—with amount of electricity generated from renewable resources and with share of renewable electricity—did not find statistically significant cross-sectional dependence of residuals (See Appendix D.1 and D.2).

A test for the OLS assumption of homoskedastic distribution of residuals was also conducted. Non-constant variance of errors does not lead to biased parameter estimates, but p-values are unreliable. A modified Wald test for groupwise heteroskedasticity in fixed-effect regression was conducted (Greene, 2000; Baum, 2001). The null hypothesis of the test is constant variance of residuals for all cross-sectional units. The test results rejected the null hypothesis, so the presence of heteroskedastic residuals was detected for both models.

Serially correlated residuals of cross-sectional time series regression based on OLS estimates can bias the standard errors and make the results less efficient (Drukker, 2003). Baltagi (2008) argues that the residuals of linear panel data regression are likely to be serially correlated because a dynamic effect of shocks is usually distributed over years. This study used the test suggested by Wooldridge (2003) for diagnostic of autocorrelation of residuals. Woodridge's test uses the residuals from a first-difference regression, which removed the effects of time-invariant covariates and constant (Drukker, 2003). The null hypothesis is no serial correlation of residuals. Wooldridge's tests showed that there are statistically significant first-order autocorrelation in the residuals of fixed-effects models of the panel data.

Although tests for heteroskedasticity and serial correlation of residuals in panel regressions have become routinely (Born and Breitung, 2010; Yin and Powers, 2010; Chrimali and Kniefel, 2011), some previous studies on the effects of renewable energy policies did not take seriously account of the violation of these assumptions (Carley, 2009). Diagnostic test results showed that the panel data of this study has heteroskedastic and serially correlated residuals with fixed-effects regressions with year-fixed dummy variables (See Appendix D.1 and D.2). In order to adjust for heteroskedasticity and autocorrelation of residuals, this study employed the "cluster-robust" or consistent (HAC) standard errors suggested by Wooldridge (2003) and Druckker (2003).

5.3.2 Regression results

The fixed-effects estimates with cluster-robust standard errors including year-fixed dummy variables proved to be the best suitable analytical model for the longitudinal data of this study in terms of the statistical diagnostics test results as well as the policy analysis purpose of the study.

Table 9 presents the result from the fixed-effects estimates with a dependent variable equal to the total amount of electricity generation from non-hydro renewable sources. Cluster-robust standard errors, errors clustered by states, are used to account for the heteroskedasticity and serial autocorrelation found in the model (Drukker, 2003; Wooldridge, 2003). The primary independent variables of interest are three policy instrument indices for renewable energy developments.

The result demonstrates that the number of command-and-control type of policy instruments adopted by a state government has a positive and significant association with the amount of electricity generated from non-hydro renewable sources (t=2.73, p=.009), all else being equal. In other words, the increase of states' electricity generated from non-hydro renewable sources over the past decade can be significantly attributed at least in part to the use of more diversified command-and-control type of policies that state governments have adopted to enforce electric power suppliers to use more renewable energy technologies.

On the other hand, the market approach index (t=-1.27, p=.211) and information instrument index (t= 1.19, p=.238) do not have statistically significant associations with the amount of renewable electricity generation in states. States' introduction of additional policy instruments based on economic incentives to date has not shown to be effective in affecting the increase of electricity generation using non-hydro renewable sources in states, all else being equal. Also, the increase of renewable electricity generation in recent years is not statistically significantly explained by the adoption of information disclosure or green power options program, with which state governments mandate electric power suppliers to provide customers such information on the sources of electricity generation of companies and to offer customers to choose electricity generated using renewables.

The fixed-effects estimates result in Table 9 shows significant predictors of the amount of renewable electricity generation. This study hypothesized that states' characteristics of natural endowment, economy, political environment, and electric market conditions together with governmental intervention determine the electricity producers' behavior on renewable electricity generation. The result shows that states' natural endowment measured by wind energy potential has a statistically significant and positive association (t=3.08, p=.003) with net electricity generation using non-hydro renewable sources. It demonstrates that wind speed in a state influences the generation of renewable electricity, all else being equal.

Among the state economic factors expected to affect the power industry's electricity generation using renewable sources, state wealth is a significant predictor of renewable electricity generation in states. This study measures state wealth as per capita gross state product (GSP) and the analytic results show a statistically significant and positive association ($t=2.39$, $p=.021$) between a state's per capita GSP and the amount of renewable electricity generated in the state. This can be understood that wealthier states deploy more renewable energy technologies to produce electricity. Other economic factors representing industrial structure of mining industry and fossil fuel interest groups however are not statistically significant in the model.

The result demonstrates that citizen's interest and preference toward environmental issues are related to states' renewable electricity generation. Table 5.7 shows that the number of Sierra Club membership per thousand state population has a highly significant and positive association ($t=2.79$, $p=.008$) with the amount of renewable electricity generation within a state.

Other two variables indicating states' political environment, democrat governorship and the degree of state legislators' preference for environmental issues, were also assumed to affect states' decision on renewable energy policy adoption and implementation. The political affiliation of governors to the democrat party shows a positive sign ($t=1.41$, $p=.165$), but is not statistically significant with cluster-robust standard errors. State legislators' preference favorable to environmental issues also does not show a significant influence on the increase of electricity generation using non-hydro renewable energy technologies. This can be understood that once renewable energy policies have decided policy decision makers such as governors or legislators are unable to affect the use of renewable energy technologies in the electric power industry.

The electricity demand and the cost of electricity resource in states are significant predictors of states' net generation of renewable electricity. Table 9 shows that the coefficient of electricity demand in a state, measured by total MWh of electricity sales within the state, is highly significant and positive (t=2.4, p=0.02). This means that the amount of renewable electricity is accordingly determined by the size of electricity markets in a state. The wholesale price of natural gas purchased by electric power industries in a state shows a significant and positive association at marginal level (t=1.92, p=0.061) with the net generation of renewable electricity within the state. This means that electric power producers are more likely to invest in or to deploy renewable energy technologies when natural gas prices, a portion of the cost of production, rises for seeking alternative cost competitive energy sources. However, the average retail price of electricity, the proportions of nuclear and conventional hydro power generation, the share of investor-owned utilities in total MWh of electricity sales, and the export/import ratio of electricity in states are not statistically significant predictors of the amount of renewable electricity production.

Table 9. Regression results for logged total MWh of renewable electricity generation from non-hydro renewable sources

Variables	Fixed Effects	
Command-and-control	0.156	(0.057)***
Market-Based Approach	-0.033	(0.026)
Information Instruments	0.139	(0.116)
Wind potential (ln)	0.559	(0.182)***
Per capita GSP (ln)	1.955	(0.819)**
% Fossil Fuel Manufacturing (ln)	0.042	(0.07)
% Mining (ln)	0.05	(0.049)
Sierra Membership (per 1,000) (ln)	1.116	(0.4)**
Democrat Governor	0.128	(0.09)
LCV House Score	0.001	(0.002)
State&Local NR Emp (per million) (ln)	-0.123	(0.226)
Total Electricity Sales (ln)	3.322	(1.382)**
Natural Gas Price (ln)	0.589	(0.307)*
Electricity Price (ln)	-0.048	(0.188)
% Nuclear Power (ln)	0.289	(0.546)
% Hydro Power (ln)	0.043	(0.088)
% IOU (ln)	0.393	(0.357)
Electricity Export Ratio (ln)	0.201	(0.171)
Year 2002[a]	0.002	(0.091)
Year 2003	-0.113	(0.088)
Year 2004	-0.1	(0.182)
Year 2005	-0.224	(0.209)
Year 2006	-0.067	(0.214)
Year 2007	-0.097	(0.243)
Year 2008	0.037	(0.197)
Year 2009	0.678	(0.219)***
Year 2010	0.677	(0.247)***
Constant	-73.530	(23.220)
R-squred	.61	
Adjusted R-squared	.59	
Observations	480	
Number of state fixed effects	48	
F-test (model)	7.05***	
Model degrees of freedom (with 48 clusters)	26	

Note: Cluster-robust standard error in parenthesis; *p<.10, **p<.05, ***p<.01.
[a] Omitted category: Year 2001

Table 10 displays the results of fixed-effects estimates for the logged share of non-hydro renewable electricity generation. The dependent variable in this model is the percentage of non-hydro renewable electricity that measures the relative use of non-hydro renewable energy technologies and resources of the electric power industry in states. The variation in the share of non-hydro renewables electricity generated in states' electric power industry indicates how policy instruments and other factors influence electricity suppliers alter their decision and behavior on renewable electricity generation. Table 10 presents the coefficients and cluster-robust standard errors of variables, including year dummies. This study corrected the standard errors which are heteroskedastic and auto correlated, by applying cluster-robust standards errors clustered on states (Wooldridge 2003).

This study hypothesized that the more command-and-control type of policy instrument state governments adopt the more renewable electricity is generated in the electric power market. The command-and-control policy instrument index is positive and significant at 95 percent confidence level (t=2.01, p=.05), all else being equal. This model also demonstrates that additional adoption of command-and-control type of policy instruments increase the proportion of renewable sources used for electricity production in states. In other words, when state governments adopt and implement more diversified command-and-control instruments, one observes a significant replacement of electric power sources from other conventional sources to non-hydro renewable sources.[56]

[56] According to an EIA's report, *Electric Power Monthly* (2013), between 2001 and 2011, the share of electricity generated from non-hydro renewable sources increased from 1.9% to 5.4%, while the proportion of coal power declined from 51% to 37.4%, natural gas increased from 17% to 30.5%; and petroleum liquid usage in electricity generation dropped from 3% to 0.3% in the United States. Retrieved from http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_1, on March 27, 2013.

Information instruments index has a statistically significant and positive association (t=1.79, p=.08) with the share of renewable electricity at 90 percent confidence level. Although the effect is for all practical purposes a marginal one, states' intervention into the electric power market using informative and voluntary policy instruments such as information disclosure or green power options seemed to affect power suppliers to alter their source of energy production from others to non-hydro renewables, all else being equal.

Among the three categories of policy instruments, market-based policy instruments appear to be the least effective in the renewable energy market. The result demonstrates that additional adoption of market-based instruments by a state is not a statistically significant determinant of an increase of the share of renewable electricity in the state (t=-1.21, p=.231).

In addition to the effects of the three categories of policy instruments that state governments implement, this model explained the increase of renewable share of electricity generation with wind potential, state economic and political environments, and electricity market conditions in states. Wind energy potential is also significant and positive (t=3.34, p=.002). All else being equal, the variation of the share of renewable sources in electricity generation is partially but significantly attributable to annual average wind speed in states.

States' economic wealth explains the proportion of non-hydro renewables in electricity generation of the states. All else being equal, per capita gross product in states has a statistically significant and positive association (t=2.44, p=.018) with the share of renewable electricity in states. This can be understood to mean that when a state economically grows, the state is likely to seek alternative energy sources that possibly replace the conventional source of energy, which is today fossil fuels.

The size of the total electricity demand in a state does not statistically significantly explain the relative use of renewable sources in electricity generation in the state (t=1.19, p=.241). As seen in the first model (Table 9), the amount of renewable electricity generation increases as the electricity demand/consumption in a state grows. However, increasing demand for electricity does not affect electric power producers' choice between conventional and renewable sources.

Instead, interestingly enough, the ratio of net electricity generation (MWh) to total electricity sales (MWh) in a state is strongly related to the proportion of the use of renewable sources in power production in the state. The ratio of electricity generation to sales in a state measures whether the state exports or imports electricity. The assumption is that if a state's net generation of electricity exceeds the total electricity sales in MWh within the state, the state will export its excess to other states and vice versa. The analysis result shows that states' electricity export ratio or generation to sales ratio has a statistically significant and negative association (t=-2.67, p=.01) with the share of renewable electricity generation. In other word, a state that imports electricity from outside uses more renewable energy technologies in electricity production within the state.

The wholesale price of natural gas in states is positive and statically significant (t=2.1, p=.041), all else being equal. This analytic result demonstrates that the price of conventional power sources, natural gas in particular, affects the decision of power producers on the source of electricity generation. When natural gas prices increase, states increase either/or their investment in or operation of renewable energy technologies, probably due to the relative competitiveness of renewables.

Citizen's interest in environmental issues is also evidently a significant determinant of the relative use of non-hydro renewables for power generation under given policy designs and electric market conditions. Table 10 shows a positive and statistically significant association between the relative size of a state's Sierra Club membership and the share of renewable resource in electricity generation in that state ($t=2.34$, $p=.024$), all else being equal. This means that the more people become interested in and get involved in environmental issues, the larger proportion of electricity is produced using renewable energy technologies in states.

Other variables measured for states' political and legislative preference toward environmental issues are not statistically significant in the analysis with the share of renewable electricity (Table 10). Coefficients of both political affiliation of governor ($t=1.53$, $p=.133$) and average house voting score for environmental issues ($t=.94$, $p=.354$) have positive signs with the proportion of renewables in net electricity generation, but neither of them are statistically significant.

Table 10. Regression results for logged share of renewable electricity generation

Variables	Fixed Effects	
Command-and-control	0.102	(0.051)**
Market-Based Approach	-0.031	(0.025)
Information Instruments	0.204	(0.114)*
Wind potential (ln)	0.577	(0.173)***
Per capita GSP (ln)	2.035	(0.834)**
% Fossil Fuel Manufacturing (ln)	0.054	(0.064)
% Mining (ln)	0.040	(0.046)
Sierra Membership (per 1,000) (ln)	0.950	(0.407)**
Democrat Governor	0.121	(0.079)
LCV House Score	0.003	(0.003)
State&Local NR Emp (per million) (ln)	-0.014	(0.252)
Total Electricity Sales (ln)	1.545	(1.300)
Natural Gas Price (ln)	0.605	(0.288)**
Electricity Price (ln)	-0.079	(0.212)
% Nuclear Power (ln)	0.086	(0.522)
% Hydro Power (ln)	-0.007	(0.068)
% IOU (ln)	0.207	(0.334)
Electricity Export Ratio (ln)	-0.452	(0.169)***
Year 2002	-0.014	(0.080)
Year 2003	-0.125	(0.079)
Year 2004	-0.166	(0.153)
Year 2005	-0.279	(0.178)
Year 2006	-0.139	(0.182)
Year 2007	-0.154	(0.210)
Year 2008	0.009	(0.193)
Year 2009	0.617	(0.207)***
Year 2010	0.619	(0.236)**
Constant	-54.738	(22.119)
R-squared	.58	
Adjusted R-squared	.56	
Observations	480	
Number of state fixed effects	48	
F-test (model)	5.00***	
Model degrees of freedom (with 48 clusters)	26	

Note: Cluster-robust standard error in parenthesis; *p<.10, **p<.05, ***p<.01.
[a] Omitted category: Year 2001

5.4 Findings

The fixed-effects models of this study, using two separate operational definitions of renewable energy development showed very consistent results. The analytic results supported the primary research hypotheses of this study on the effectiveness of three types of policy instruments. Also, this study found meaningful results regarding other control variables. Those variables significantly associated with the increase of renewable electricity production supported the hypothetical relationship that this study derived from the literature review.

Hypothesis 1 was about the implementation of command-and-control types of renewable energy policy instruments and the deployment of renewable energy technologies in electricity production. This study hypothesized that a state with more command-and-control type of policy instruments will deploy more renewable energy. The results of both fixed-effects models demonstrated the significant and positive associations of command-and-control policy instrument index with the net generation of renewable electricity as well as with the share of non-hydro renewables in electricity production in states.

The second research hypothesis was that the diversification of market-based policy instruments is not associated with an increase in renewable energy generation in states. The fixed-effects models failed to reject the null hypothesis that there is no significant relationship between the number of market-based instruments and both the amount of electricity generation from renewables and the proportion of renewable electricity, all else being equal.

Hypothesis 3 was about the effectiveness of the additional adoption of informative policy instruments. The fixed-effects model with the amount of electricity generation from non-hydro renewable sources failed to reject null hypothesis. Therefore, the increase of the amount of renewable electricity generation was evidently not attributable to the number of information instruments adopted by states. However, the analysis with dependent variable measured by relative use (%) of non-hydro renewables in electric power production supported the hypothesis. The more a state diversified information instruments, the larger share of electricity generated from renewable sources. More detailed interpretation and policy implications will be discussed in the following section regarding inconsistent analytical results on hypothesis 3.

Regarding other variables, not all variables show significant associations with the increase of renewable electricity generation, but all five components of factors—natural resource, economic, political, and market circumstances and state policies—were found to affect deployment of non-hydro renewables. More details are discussed in the discussion section.

CHAPTER VI

DISCUSSION

6.1 Conclusion

The primary purpose of this study was to examine the effectiveness of three different types of policy instruments implemented by state governments to support renewable energy development. This was accomplished by first analyzing currently adopted states' legislative renewable energy programs and incentives, then by classifying them into three categories of policy approaches: command-and-control, market-based, and information instruments.

There was a significant increase in the overall number of policy instruments that state governments introduced for renewable energy development between 2001 and 2010. Popular policy instruments have changed with time. In the very beginning of governmental intervention, the role of governments was to set foundational rules for renewable energy suppliers. Afterward, command-and-control instruments, represented by renewable portfolio standards, have been adopted in many states. State governments began using authoritative and coercive policy tools to alter the behavior of electricity producers to use more renewable sources. With Federal support for the renewable energy industry, state governments have also provided a variety of financial incentives to renewable energy developers. To date, states have continued to develop new policy instruments including information instruments and financial incentives.

This study then analyzed the effectiveness of the policy instruments which have been diversified over time. The researcher expected that additional adoption of command-and-control or information instruments would positively affect electricity production from renewable sources, holding other factors constant. Diversification of market-based instruments, however, was suspected to have significant impact on the increase of renewable power generation. For the most part, the analysis results supported the primary research hypotheses.

The increase in the amount and share of renewable electricity both were attributed by adoption of more command-and-control instruments. This implies that the diversification of authoritative and coercive approaches of state governments' intervention in electric power industries has effectively altered the power suppliers' choice of energy sources from conventional to non-hydro renewables. Even though regulatory approaches have been criticized with respect to cost-effectiveness and flexibility, authoritative and coercive governance tools have been effective in achieving policy goals at the early stage of governmental intervention. Moreover they have been effective specifically in the area where market systems do not generate socially appropriate goods and services (Harrington et al., 2004).

Regarding market-based instruments, results did not find significant evidence of effectiveness. The results verified the theoretical arguments that market-based policy instruments or economic incentives do not guarantee the achievement of policy goals (Hammar, 2006; Harrington, et al., 2004). The results are also consistent with prior empirical studies that examined the influence of financial incentives on renewable energy capacity or production (Delmas and Montes, 2011).

Over the past decade and a half, states have developed and adopted a variety of market-based policy instruments for the purpose of increasing electricity production using renewable sources. However, the analytic results show some evidence that the use of diverse market-based instruments does not always result in policy effectiveness. A possible explanation is that these market-based instruments, adopted by states, failed to incentivize or motivate people to use renewable energy technologies in electricity production. While market players in the electric power industry benefited from using given market-based instruments, the renewable energy outcome did not meet state governments' expectations (Hammar, 2006). In either case, the states' market-based policy designs do not seem appropriate or effective as a catalyst for renewable energy production.

Especially, financial incentives including tax expenditures and subsidies or loans may mislead the energy market. Electricity producers may enjoy the financial benefits from purchasing and installing renewable energy equipment offered by the governments to reduce their cost of electricity generation from renewable sources. However, at the same time, electricity producers may want to invest more, as much as they save from governmental support for renewables, in purchasing their conventional sources of electricity such as coal or natural gas. If this is the case, financial incentives can hardly be expected to show the expected short-term outcomes in terms of proportion of renewables of total electricity generation.

This study showed results consistent with prior empirical studies (Yin and Power, 2009, Shrimali and Kniefel, 2011, Delmas and Montes-Sancho, 2011) that estimated the effects of individual informative programs. They found a positive and significant impact of green power options on renewable energy capacity. This study showed that the number of information instruments did not explain the amount of electricity generation from renewable sources, but helped to explain the share of renewables in electricity production. A possible explanation is that information given to consumers does not necessarily translate to new investment in renewable energy systems. Instead, the availability of information influences electric power producers to choose to alter the power sources from conventional to renewable sources. This story is moreover supported by positive and significant influence of citizen interest in environmental issues on the amount and share of renewable electricity in states.

The political environment has been expected to affect policy adoption and innovation (Yi and Feiock, 2012). However, once policy designs have developed, achievement of policy goals depends on policy implementation rather than on state legislators or governors' preference or citizen preference and involvement (represented by Sierra Club membership). Put it another way, although different governments may intervene in the power market with similar type of policy instruments, market incentives in particular, people may or may not be motivated to alter their behavior depending on their pre-existing interest and preference toward the environment and green energy.

Citizens with favorable preferences toward environmental issues could either be consumers or producers of electricity, or both. As consumers, they could exercise their pressure on electric power utilities to use clean energy sources. Or, they also can generate renewable electricity as independent power producers, or produce combined heat and power produced using renewable energy equipment.

As seen in the results, state wealth measured by per capita GSP was the single most important factor accounting for variation in the increase in electricity production using renewable sources. Such results suggest that wealthy states have more interest and capacity to invest in environmentally friendly projects (Ringquist, 1994; Sapat, 2004), which is consistent results what previous empirical studies found (Carley, 2009; Shrimali and Kniefel, 2011; Delmas and Monte-Sancho, 2010). Even though this study examined the impact of state wealth on renewable electricity production, it is possible that the state wealth induces investment in clean energy industry either from inside or outside state developers.

Pre-existing conditions of the electricity market also significantly affect the actual use of renewable source for electricity production in a given year. As the U.S. experienced in the early 1990s and 2000s, natural gas price inversely correlates with investment in renewable energy technologies. A huge decline in natural gas prices in the early 90s hindered the growth rate of renewable energy as industry stagnated; the Energy Crisis in California in early 2000s motivated Western states to invest more in alternative power sources.

Interestingly, the average retail price of electricity does not seem significant in both models, while natural gas price consistently seem to serve as a significant factor. This implies that electricity suppliers care about the cost-effectiveness or efficiency and consider non-hydro renewables as their alternative resources to reduce the cost of production. On the other hand, the sales price or retail price at which consumers purchase electricity does not seem to influence power suppliers' choice of power sources in any ways.

States' experience of importing electricity is also an important determinant of the relative use of renewable sources for electricity generation. The more a state imports electricity from other states, the larger the share of renewable electricity. This study assumed that those states with export of a greater proportion of electricity are less likely to replace their conventional sources of electricity production with non-hydro renewables. Conversely, those states where import more electricity from other states for their in-state consumption are likely to use relatively more renewable sources to produce electricity. It is also possible that a state may increase its import of electricity from other states by intention of exporting carbon emissions generated from coal-fired power production, while promoting renewable energy technologies within the state.

The results showed that the coefficients of year dummies 2009 and 2010 in both models are consistently significant and positive compared to year 2001. It was originally expected that the economic recession between 2008 and 2010 would slow the increase in energy sector, also tempering with the growing renewable industry. However, at least partially due to the heavy investment offered by the Federal Stimulus Package--cash grant in lieu of tax credit to renewable energy project developers under ARRA of 2009--

renewable electricity has increasingly generated during the period of economic recession. In fact, between 2008 and 2010 average annual growth rate of the total amount of renewable electricity, from non-hydro renewable sources, was 16.7%, more than twice the average annual growth rate of the previous three years (8.2%) in the U.S.[57] The results of this study with significant year dummies 2009 and 2010 give us evidence of the effectiveness of Federal stimulus package under ARRA of 2009. In other words, Federal government's active supports for renewable energy projects, in addition to state specific economic and political characteristics and state government led policy designs, influenced the overall growth of the renewable electricity industry since 2009.

6.2 Policy Implications

There was significant variation in renewable energy policy designs among states over time. However, some commonalities among these policy instruments also emerged. Without a well-designed policy evaluation, it is hard to say if states have developed and used the policy instruments due to the effectiveness or policy diffusion effects across neighboring states.

To date, command-and-control types of policy instruments such as renewable portfolio standards have been regarded as the dominant and effective tools in the electric power markets for an increase of renewable electricity production. However, it is too early to assume that the authoritative and coercive policy approach is the best instrument. It is only in the recent years that the government has intervened in the electricity market

[57] Calculation of the average annual growth is done by the author. Electricity data is from the Energy Information Administration.

using the command-and-control instruments, which have the possibility to achieve policy goals at a faster rate than other instruments (Harrington et al. 2004).

Similarly the insignificant effects of market-based instruments revealed by the analysis results do not mean that state governments need to stop financial supports for renewable energy developers. The market-approach may take a longer time to affect the electric power industry. We may need to wait until the investment in renewable energy technologies and equipment are effectively operating. Another issue is the possibility that Federal support for renewable energy industries, under the ARRA of 2010, diminished the impact of states-setting incentive systems for the renewable energy market. In that case, continuing experiments and evaluation of market-based policy instruments are necessary for improvement of policy designs.

Over the long history of the federal government's support for electric power sectors using fossil fuel and nuclear power, renewable electricity has been at a competitive disadvantage. As long as fossil fuel or nuclear-based electricity is being incentivized, renewable energy policies, especially financial incentives will experience difficulties in taking immediate effects.

In addition, increased availability of oil and gas achieved by recently permitted shale drilling in the U.S. may put a brake on the recent trend of increasing deployment of renewable energy technologies. As oil and gas extraction businesses boom, the market equilibrium of supply and demand would move the natural gas price downward, which affects electric power producers' choice of power sources, consistent with the analysis results. Therefore, policy makers must have a comprehensive consideration when they make policy designs for renewable energy development.

Analytical results showed that both informative/voluntary instruments and social interest in environment are important. Together with citizen “Go Green programs,” sermons to the electric industry become important. Under given circumstances, financial and institutional capacity, one of the possible and effective ways that state and local governments can approach deployment of renewable electricity is to educate and enlighten both suppliers and consumers of electricity. Innovative policy instruments such as information, education, voluntary agreements, etc. are highly recommended to be designed.

6.3 Strength, limitation, and future direction

This study has several strengths. First of all, this study makes a contribution to policy instrument studies through the practice of classifying policies empirically into groups and examining the effectiveness of additional adoption of policy instruments: command-and-control, market-based, and information instruments. Previous studies (Vedung, 1998; Schneider and Ingram, 1990) conceptually discussed the appropriate categorization of policy instruments, while others classified existing policies related to renewable energy development into their chosen groups of policy instruments (Enzensberger, et al., 2002; Menz, 2005; Beck and Martinot, 2004; Jonstone, et al., 2008). However, they rarely applied their classification of policy instruments to an empirical analysis of policy evaluation, which relates policy instruments to policy effects.

Through the empirical classification of policy instruments, this study found several lessons which would help us better understand of policy instruments classification. With applying the tri-fold categories of policy instruments—command-and-control, market-based, and information—, rather than the degree of coerciveness, the behavioral assumption under each policy tool serves as a more helpful and useful criterion for the classification. Many previous studies (Vedung, 1998; Salamon, 2002) conceptually categorized policy instruments or tools based on the level of coerciveness. This study, however, mainly applied the behavioral assumption of policy tools that Schneider and Ingram (1990) discussed, with more or less consideration of the degree of government authority or coerciveness inherent in policies.

Because the subject public policies and programs dealt in the research are all state legislative policies and many of them mandate energy suppliers a certain types of obligations, using the coerciveness criterion was not sufficient to distinguish renewable energy policies into three groups of policy instruments. Hence, this study adopted three behavioral assumptions through which governments intend to alter policy targets' behavior toward accomplishing policy goals: coercion, use of material resources, and intellectual/moral appeals. For instance, generation/environmental disclosure programs are requirement set by state legislation for electric utilities to provide customers information. This program may appear like a command-and-control type policy instrument from the respect of coerciveness because it requires activities of policy targets. However, the information disclosure itself does not directly coerce electricity suppliers to accomplish a certain goal, rather it can appeal to electricity suppliers' conscience as well as consumer's intellectual decision making, indirectly influencing electricity generators' choice of energy sources. Therefore, based on the policy instrument's behavioral assumption, this study assigned the disclosure program in the group of information instrument.

Another lesson is that the market-based instrument defined by this study included somewhat too broad range of policies and programs, 11 of 18 renewable energy policies, to be considered homogeneous within a group. Net-metering programs and renewable energy access laws, in particular, were classified as market-based policy instruments under the tri-fold classificatory scheme. However, these two instruments are somewhat different in nature from other policies under the group of market-based instrument. Other nine market-based policies are all financial incentives directly offered to renewable energy suppliers such as tax expenditures, loans, and subsidies, whereas net-metering and access laws are adopted to arrange electric market systems preferable to initiating and developing renewable electricity generation and distribution. In the future studies, especially in the area that has pre-existing market, researchers may want to divide market-based policy instruments into more than two groups: one is about financial incentives given by governments which change the production cost or market prices of goods and services in principle; and the other is about market systems which shift demand and/or supply.

Second possible contribution of this research is building a database of comprehensive and historical information on states' renewable energy policies. Such database would enable the measurement of variance of policy instruments utilized by states over time. Furthermore, a time-variant measure of policy instrument indices would allow policy analysts and policy makers to determine whether the implementation of diverse policy instruments, classified by regulatory, incentive-based and informative policy instruments, is effective in terms of renewable electricity production within a state.

In addition, this study also has done some to advance a study on the determinants and mechanism of the development of renewable energy industries. Results found that the amount and share of renewable electricity production in a state is merely affected by economic variables such as economy of scale or price of substitutes, but also affected by political environments including related policies.

Although this study contributes to policy instrument studies in terms of exercising a tri-fold scheme of policy instruments, it is not without limitation. One limitation concerns the intervention of subjectivity in classification of renewable energy policy instruments. Renewable energy policies were classified based on theoretical and logical classificatory criteria discussed in previous literature. However, due to limited time and resources, the classification was conducted by the author, and the inter-subjective reliability of the classification has not been tested. I expect that a survey of experts can practically adjust and enhance the classificatory schemes in the future.

Another limitation deals with the measure of policy instrument indices. This study has not considered the degree of relative coerciveness/strictness of policy tools or the importance of individual renewable energy policies. Instead, the researcher weighed each renewable energy policy or program equally and measured the existence of individual renewable energy policies in a state with dummy variables.

As an extension of my dissertation, I propose to examine the effects of policy instruments mixes and to find the appropriate form of policy mix for the multi-level, state-and-local, governance of renewable energy development. Since the 1990s, interest in "policy mixes," has increased (OECD, 2001; Persson, 2006). Combined policy instruments were considered to complement and reinforce each other to enhance the overall effectiveness and efficiency of policy implementation compared to a single instrument (Rist, 1998). In addition, governments implemented multiple types of policy tools to solve complex policy issues (Gunningham and Sinclair, 1999; Lafferty and Meadowcroft, 1996). Therefore, selecting the most appropriate combination of instruments comprises a crucial component of a policy design that would maximize the goal achievement and minimize political economic costs (Peters, 2002).

A very simple methodological approach to look at the effect of policy instrument mix will be analyzing the interaction effect coefficients between three policy instruments. In addition, I also propose to categorize types of policy instrument mix depending on the diversity and magnitude of governments' policy adoptions. Possible policy mix scenarios that I expect include: a state with a full set of command-and-control instruments that uses least number of market-based instruments; a state with least use of all instruments; a state with a full set of market-based instruments and half of others, etc. Then, I would classify observations (states) based on their form of policy instrument mix into 3 or 4 groups and those groups will be considered as explanatory variable.

I also propose to find the determinants of multi-level policy instrument adoption for renewable energy development. Applying the types of policy instruments, it is expected to discover the mechanism under which local and state governments prefer certain types of policy tools or mixes. There are considerable studies on determinants of policy innovation and adoption. Before 1990, state government innovation study was dominated by testing internal determinants, national interaction, or diffusion models (Balla, 2001; Berry and Berry, 1990; Gray, 1973; Mintrom, 1997; Walker, 1969, etc.). Recently, however, alternative forms of diffusion such as vertical influence between federal, state, and local governments were suggested (Allen, Pettus, and Haider-Markel, 2004). Some claim that the motivation for policy diffusion includes both policy learning and competition (Boehmke and Witmer, 2004). Some previous studies employed both internal determinants and diffusion effects to analyze determinants of renewable energy policy or climate protection policy adoption of local governments (Krause, 2010; Matisoff, 2008; Yi and Feiock, 2012).

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APPENDIX A - E

Appendix A. Descriptive Analysis of Dependent and Independent Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Non-hydro Renewable Electricity	480	2,151,752	3,909,227	0.001	27,700,000
Percentage Non-hydro Renewable	480	3.01	3.83	0.0001	26.08
Ln Non-hydro Renewable Electricity	480	13.94	1.17	11.57	17.14
Ln Percentage Non-hydro Renewables	480	0.78	0.93	-1.06	3.27
Command-and-control	480	1.61	1.31	0	5
Market-Based Approach	480	4.48	2.34	0	11
Information Instruments	480	0.59	0.65	0	2
Total Electricity Sales (ln)	480	17.72	0.97	15.49	19.7
Natural Gas Price (ln)	480	7.25	0.14	6.79	7.55
Electricity Price (ln)	480	18.18	0.67	16.83	19.87
% Nuclear Power (ln)	480	3.1	0.69	2.27	4.5
% Hydro Power (ln)	480	0.89	1.77	-2.41	4.5
% IOU (ln)	480	5.08	0.21	4.81	5.41
Electricity Export Ratio (ln)	480	-0.21	0.52	-2.08	1.15
Per capita GSP (ln)	480	10.22	0.27	9.48	10.93
% Fossil Fuel Manufacturing (ln)	480	-1.25	1.52	-5.08	2.93
% Mining (ln)	480	-0.86	1.93	-4.36	3.55
Sierra Membership (per 1,000, ln)	480	0.56	0.56	-0.83	1.82
Democrat Governor	480	0.49	0.5	0	1
LCV House Score	480	48.74	26.62	0	100
State&Local NR Emp (per million, ln)	480	6.43	0.62	4.75	8.02
Wind potential (ln)	480	0.86	0.28	0.11	1.51

Appendix B. Correlation Analysis of Variables (Pearson r, n=480)

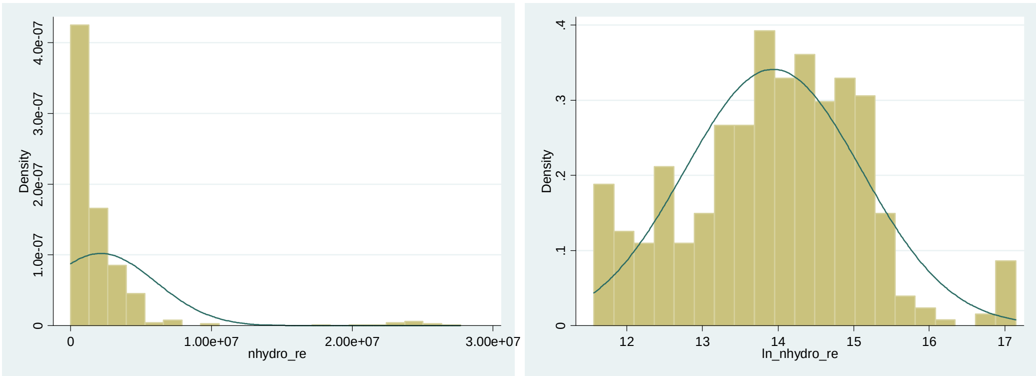
	1	2	3	4	5	6	7	8	9	10
1. Non-hydro Renewable Electricity (ln)	1.00									
2. Percentage Non-hydro Renewable (ln)	0.74	1.00								
3. All Renewable Energy Policies	0.25	0.26	1.00							
4. Command-and-control	0.27	0.24	0.80	1.00						
5. Market-Based Approach	0.16	0.19	0.92	0.52	1.00					
6. Information Instruments	0.28	0.26	0.63	0.51	0.41	1.00				
7. Wind potential (ln)	-0.16	-0.02	0.12	0.11	0.10	0.10	1.00			
8. Per capita GSP (ln)	0.12	0.11	0.45	0.46	0.32	0.37	0.31	1.00		
9. % Fossil Fuel Manufacturing (ln)	0.04	0.08	0.21	0.13	0.21	0.13	0.10	0.21	1.00	
10. % Mining (ln)	0.03	-0.13	-0.32	-0.34	-0.24	-0.21	0.00	-0.36	-0.10	1.00
11. Sierra Membership (per 1,000) (ln)	0.07	0.26	0.56	0.50	0.43	0.57	0.10	0.43	0.18	-0.37
12. LCV House Score	0.11	0.32	0.49	0.51	0.38	0.31	0.00	0.33	0.09	-0.59
13. State&Local NR Emp (per 1,000) (ln)	-0.16	0.02	-0.41	-0.46	-0.32	-0.21	0.07	-0.42	-0.11	0.47
14. Total Electricity Sales (ln)	0.54	-0.10	0.14	0.14	0.09	0.13	-0.26	0.07	-0.08	0.05
15. Natural Gas Price (ln)	0.00	-0.02	0.06	0.09	0.03	0.02	-0.02	0.07	0.04	-0.18
16. Electricity Price (ln)	0.27	0.35	0.52	0.60	0.36	0.33	0.03	0.39	-0.07	-0.53
17. % Nuclear Power (ln)	0.27	0.10	0.06	0.16	-0.01	0.01	-0.24	0.13	0.10	-0.37
18. % Hydro Power (ln)	0.11	0.31	0.11	-0.03	0.17	0.08	-0.20	-0.12	0.16	0.03
19. % IOU (ln)	0.02	0.05	0.05	0.05	0.05	-0.02	-0.04	-0.12	-0.05	0.01
20. Electricity Export Ratio (ln)	-0.06	-0.17	-0.21	-0.16	-0.19	-0.16	0.05	-0.31	0.10	0.46

	11	13	14	15	16	17	18	19	20	21
1. Non-hydro Renewable Electricity (ln)										
2. Percentage Non-hydro Renewable (ln)										
3. All Renewable Energy Policies										
4. Command-and-control										
5. Market-Based Approach										
6. Information Instruments										
7. Wind potential (ln)										
8. Per capita GSP (ln)										
9. % Fossil Fuel Manufacturing (ln)										
10. % Mining (ln)										
11. Sierra Membership (per 1,000) (ln)	1.00									
12. LCV House Score	0.48	1.00								
13. State&Local NR Emp (per 1,000) (ln)	-0.24	-0.39	1.00							
14. Total Electricity Sales (ln)	-0.14	-0.13	-0.39	1.00						
15. Natural Gas Price (ln)	0.01	0.12	-0.10	0.09	1.00					
16. Electricity Price (ln)	0.37	0.62	-0.59	0.07	0.14	1.00				
17. % Nuclear Power (ln)	0.04	0.19	-0.43	0.37	0.11	0.40	1.00			
18. % Hydro Power (ln)	0.28	0.02	0.26	-0.20	-0.06	-0.12	-0.13	1.00		
19. % IOU (ln)	0.03	0.11	-0.09	-0.03	-0.42	0.09	0.01	-0.06	1.00	
20. Electricity Export Ratio (ln)	-0.15	-0.19	0.30	-0.19	-0.12	-0.25	-0.15	0.02	-0.02	1.00

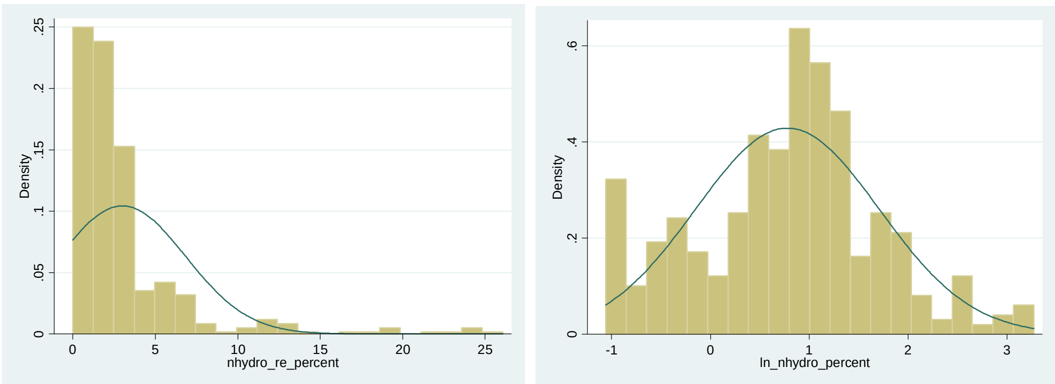
Appendix C. Transformation of variables

Dependent Variables:

MWh of electricity generated from non-hydro renewable sources vs. Ln RE generation



Share of non-hydro renewable electricity vs. Ln RE share



Appendix D.1 Estimation Issues and Process with Dependent Variable: Ln MWh of Renewable Electricity Generation

Pooled OLS vs. random-effects models

```
Breusch and Pagan Lagrangian multiplier test for random effects

        ln_nhydro_re[fips,t] = Xb + u[fips] + e[fips,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                ln_nhyd~e |    1.36683       1.169115
                        e |   .1267048       .3559562
                        u |   .6225506       .7890187

        Test:   Var(u) = 0
                             chi2(1) =   997.39
                         Prob > chi2 =     0.0000
```

Fixed- vs. Random-fixed effects: Hausman test

```
Test:  Ho:  difference in coefficients not systematic

             chi2(27) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =       85.41
            Prob>chi2 =      0.0000
            (V_b-V_B is not positive definite)
```

Cross-sectional correlation test (after fixed-effects regression): xtcsd, pesaran abs

```
Pesaran's test of cross sectional independence =    -0.817, Pr = 0.4137

Average absolute value of the off-diagonal elements =     0.427
```

Heteroskedasticity test: xttest3

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (48)  =    1564.07
Prob>chi2 =      0.0000
```

Serial correlation test: xtserial

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      47) =     95.082
           Prob > F =      0.0000
```

Cluster-robust standard error: cluster(fips)

Appendix D.2 Estimation Issues and Process with Dependent Variable: Ln Share of Renewable Electricity Generation

Pooled OLS vs. random-effects models: xttest0

```
Breusch and Pagan Lagrangian multiplier test for random effects

        ln_nhydro_percent[fips,t] = Xb + u[fips] + e[fips,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                ln_nhyd~t |   .8662296       .9307146
                        e |   .1154657       .3398025
                        u |   .4674381       .6836945

        Test:   Var(u) = 0
                             chi2(1) =   879.80
                         Prob > chi2 =     0.0000
```

Fixed- vs. Random-fixed effects: Hausman test

```
Test:  Ho:  difference in coefficients not systematic

             chi2(27) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =       85.79
            Prob>chi2 =      0.0000
            (V_b-V_B is not positive definite)
```

Cross-sectional correlation test (after fixed-effects regression): xtcsd, pesaran abs

```
Pesaran's test of cross sectional independence =    -0.481, Pr = 0.6305

Average absolute value of the off-diagonal elements =     0.441
```

Heteroskedasticity test: xttest3

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (48)  =    2040.87
Prob>chi2 =      0.0000
```

Serial correlation test: xtserial

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      47) =    115.887
           Prob > F =      0.0000
```

Cluster-robust standard error: cluster(fips)

Appendix E.1Regression Results of Total Amount of Renewable Electricity Generation: OLS, RE, FE, and FE with cluster-robust S.E.

MWh Renewable Electricity Generation (Ln)	OLS		RE		FE		FE w. Cluster-robust S.E.	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	Cluster-robust S.E.
Command-and-control	-0.027	0.044	0.106	0.035***	0.156	0.035***	0.156	0.057***
Market-Based Approach	-0.060	0.021***	-0.053	0.016***	-0.033	0.016**	-0.033	0.026
Information Instruments	0.235	0.078***	0.107	0.061*	0.139	0.061**	0.139	0.116
Wind potential (ln)	0.046	0.159	0.509	0.108***	0.559	0.106***	0.559	0.182***
Per capita GSP (ln)	0.118	0.190	1.301	0.272***	1.955	0.325***	1.955	0.819**
% Fossil Fuel Manufacturing (ln)	0.068	0.028**	0.011	0.043	0.042	0.048	0.042	0.070
% Mining (ln)	0.047	0.031	0.101	0.038***	0.050	0.043	0.050	0.049
Sierra Membership/1,000 (ln)	-0.023	0.119	0.502	0.184***	1.116	0.252***	1.116	0.400***
Democrat Governor	0.044	0.079	0.117	0.050**	0.128	0.049***	0.128	0.090
LCV House Score	0.004	0.002	0.001	0.002	0.001	0.002	0.001	0.002
State&Local NR Emp/million (ln)	0.579	0.095***	0.122	0.136	-0.123	0.160	-0.123	0.226
Total Electricity Sales (ln)	1.071	0.070***	1.032	0.177***	3.322	0.818***	3.322	1.382**
Natural Gas Price (ln)	-1.589	0.534***	0.474	0.312	0.589	0.302*	0.589	0.307*
Electricity Price (ln)	0.820	0.113***	-0.126	0.113	-0.048	0.123	-0.048	0.188
% Nuclear Power (ln)	0.096	0.071	0.184	0.180	0.289	0.415	0.289	0.546
% Hydro Power (ln)	0.149	0.026***	0.105	0.055*	0.043	0.082	0.043	0.088
% IOU (ln)	1.081	0.394***	0.511	0.256**	0.393	0.254	0.393	0.357
Electricity Export Ratio (ln)	0.066	0.088	0.134	0.137	0.201	0.165	0.201	0.171
Year 2002	-0.039	0.175	0.077	0.085	0.002	0.084	0.002	0.091
Year 2003	0.312	0.169*	0.056	0.085	-0.113	0.087	-0.113	0.088
Year 2004	0.899	0.241***	0.224	0.141	-0.100	0.147	-0.100	0.182
Year 2005	1.118	0.273***	0.166	0.160	-0.224	0.170	-0.224	0.209
Year 2006	1.018	0.244***	0.337	0.147**	-0.067	0.162	-0.067	0.214
Year 2007	1.051	0.246***	0.367	0.154**	-0.097	0.179	-0.097	0.243
Year 2008	0.982	0.210***	0.403	0.131***	0.037	0.150	0.037	0.197
Year 2009	0.716	0.189***	0.880	0.119***	0.678	0.134***	0.678	0.219***
Year 2010	0.925	0.189***	1.011	0.128***	0.677	0.156***	0.677	0.247***
Constant	-6.368	5.242	-26.321	5.260***	-73.530	14.807	-73.530	23.220
R square	0.5585		0.3414		0.6103		0.6103	
Adjusted R square	0.5322				0.5390		0.5390	
Number of observations	480		480		480		480	
F or Wald chi2	21.28		575.34		23.49		7.05	
p-value	0.000		0.000		0.000		0.000	
Df	27		27		74		26	

Appendix E.2 Regression Results of Share of Renewable Electricity Generation: OLS, RE, FE, and FE with cluster-robust S.E.

Share of Renewable Electricity Generation (Ln)	OLS		RE		FE		FE w. Cluster-robust S.E.	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	Cluster-robust S.E.
Command-and-control	-0.059	0.040	0.051	0.033	0.102	0.034***	0.102	0.051**
Market-Based Approach	-0.047	0.019**	-0.049	0.015***	-0.031	0.015**	-0.031	0.025
Information Instruments	0.183	0.070***	0.167	0.058***	0.204	0.058***	0.204	0.114*
Wind potential (ln)	0.111	0.142	0.515	0.104***	0.577	0.101***	0.577	0.173***
Per capita GSP (ln)	-0.246	0.170	1.142	0.255***	2.035	0.311***	2.035	0.834**
% Fossil Fuel Manufacturing (ln)	0.059	0.025**	0.023	0.040	0.054	0.046	0.054	0.064
% Mining (ln)	0.049	0.028*	0.091	0.036**	0.040	0.041	0.040	0.046
Sierra Membership/1,000 (ln)	0.136	0.107	0.408	0.171**	0.950	0.240***	0.950	0.407**
Democrat Governor	0.000	0.071	0.115	0.048**	0.121	0.046***	0.121	0.079
LCV House Score	0.004	0.002**	0.003	0.002	0.003	0.002	0.003	0.003
State&Local NR Emp/million (ln)	0.480	0.085***	0.196	0.128	-0.014	0.153	-0.014	0.252
Total Electricity Sales (ln)	0.046	0.063	-0.016	0.157	1.545	0.781**	1.545	1.300
Natural Gas Price (ln)	-1.413	0.477***	0.445	0.299	0.605	0.288**	0.605	0.288**
Electricity Price (ln)	0.773	0.101***	-0.097	0.107	-0.079	0.118	-0.079	0.212
% Nuclear Power (ln)	0.125	0.064*	0.217	0.160	0.086	0.396	0.086	0.522
% Hydro Power (ln)	0.146	0.023***	0.101	0.051**	-0.007	0.079	-0.007	0.068
% IOU (ln)	0.933	0.352***	0.304	0.245	0.207	0.242	0.207	0.334
Electricity Export Ratio (ln)	-0.376	0.079***	-0.413	0.128***	-0.452	0.157***	-0.452	0.169***
Year 2002	-0.033	0.156	0.049	0.082	-0.014	0.080	-0.014	0.080
Year 2003	0.296	0.151*	0.040	0.082	-0.125	0.083	-0.125	0.079
Year 2004	0.827	0.215***	0.142	0.134	-0.166	0.141	-0.166	0.153
Year 2005	1.052	0.244***	0.099	0.153	-0.279	0.163*	-0.279	0.178
Year 2006	0.974	0.218***	0.249	0.140*	-0.139	0.155	-0.139	0.182
Year 2007	1.046	0.220***	0.290	0.147**	-0.154	0.171	-0.154	0.210
Year 2008	0.966	0.188***	0.356	0.124***	0.009	0.144	0.009	0.193
Year 2009	0.729	0.169***	0.792	0.113***	0.617	0.128***	0.617	0.207***
Year 2010	0.922	0.169***	0.912	0.121***	0.619	0.149***	0.619	0.236***
Constant	2.515	4.687	-18.386	4.887	-54.738	14.135	-54.738	22.119
R square	0.4431		0.1153		0.5810		0.5810	
Adjusted R square	0.4098				0.5045		0.5045	
Number of observations	480		480		480		480	
F or Wald chi2	13.32		479.43		20.80		5.00	
p-value	0.000		0.000		0.000		0.000	
Df	27		27		74		26	