U.S. STATE CLEAN ENERGY POLICY AND IMPACTS ON INNOVATIVE TECHNOLOGY ADOPTION AND EMPLOYMENT: ANALYZING IMPACTS OF ENERGY-BASED ECONOMIC DEVELOPMENT

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Abstract

U.S. State Clean Energy Policy and Impacts on Innovative Technology Adoption and Employment: Analyzing Impacts of Energy-Based Economic Development

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Nations, states, cities, and towns are increasingly concerned about resilient and sustainable development against climate change. Energy-based economic development (EBED) has become a growing field of practice and research in the United States as well as across the world. EBED, a term recently coined by Carley et al. (2011; 2014), reflects the emerging convergence of two disciplines: energy planning and economic development. EBED captures the integration of policy-driven transformations of energy systems for low-emission and efficient energy generation and regional concerns for economic competitiveness and resilience.

Meanwhile, Hurricanes Sandy and Maria, and other catastrophic blackouts have strengthened the demand to secure energy systems during weather-related or human-induced disruptions. Distributed generation (DG) systems have received renewed interests because of the growing demand for resilient power supplies, low- or zero-carbon energy generation, economic and regulatory environment changes, and advances in DG technology efficiency with declining life-cycle costs (U.S. Department of Energy, 2017). From amidst various technology options for DG, this research focuses on a combined heat and power (CHP) system that is a mature and innovative DG technology promising efficient production of energy on site. However, the CHP deployment is challenged by financial, regulatory, and workforce barriers. To fill the gap between private and public interests, federal, state, and local policymakers have implemented incentive-based and/or regulatory policies, which aim to promote EBED.

This research began from recognizing the lack of theoretical approaches and empirical analyses in current EBED strategies and thus raised the question: *How do clean energy policies affect clean energy use and related job creation?* I assume that consumers are more likely to adopt CHP technologies when the state government provides a number of clean energy policy instruments. To test this hypothesis, this research examines two relationships—1) state governments' activities on clean energy policy entrepreneurship and firms' adoption of CHP technology, and 2) state governments' activities on clean energy policy entrepreneurship and the growth of relevant employment opportunities.

I developed an empirical method to address the influence of state clean energy policies on technology adoption. I first identified types of state policy instruments, and then scored states by the intensity of policy implementations. Using a framework of types of environmental policy instruments defined by Goulder and Parry (2008), I characterized the intensity of state clean energy policies by selective criteria, including the first year of policy enactment and the range of eligible CHP technologies. Second, I investigated regional differentiations of CHP generation by state and by year. The data of new CHP

installations were collected in two forms: number of new CHP units and new installed capacity per GDP (kilowatt/million dollars). Third, I found correlationships in two relationships; the first group examined the aggregated impacts of state clean energy policy on CHP technology adoption, while the second group examined the policy impacts on CHP technology adoption by nine different types of policy tools. Random-effects (RE) regression models were employed to analyze panel data by controlling for all time-invariant differences, such as geographic location, political system, etc. To control for non-policy conditions, time-varying variables were added to the models to explain energy market conditions (electricity generation by fuel and fuel prices) and economic characteristics (personal income per capita and CO_2 emission per capita). A panel data set for the 50 states and Washington, D.C. within a time period from 1980 to 2014 was created for the RE regression analyses.

Last, to strengthen the findings from the RE models, I employed multiple-case studies by selecting four sample states—California as a state having high intensity of clean energy policy entrepreneurship and a high number of new CHP projects, Texas as a state having low policy entrepreneurship but a high number of new CHP projects, Ohio as a state having high policy entrepreneurship but a low number of new CHP projects, and Wyoming as a state having low policy entrepreneurship and a low number of CHP projects. The multiple-case study is conducted by four areas—(1) economic base study by using socio-economic archival and statistical data, (2) industry cluster analysis by using location quotient (LQ) and employment data, (3) energy market analysis by using EIA's state profiles and energy estimates, and (4) CHP supportive policies and

legislations by exploring media, formal policy reports, state governments' documentations, and other website resources created by interest groups and associated stakeholders. The multi-case study of four selected states confirms distinct approaches to CHP policy development and implementation, resulting in different degrees of CHP technology adoption.

I extend the existing literature by developing a theoretical framework to converge two fields—economic development planning and energy planning. Within this framework, I demonstrate how EBED is embedded in reality, how firms act along with clean energy policies, and how energy efficiency and clean energy could be a source of economic development.

Chapter 1 INTRODUCTION AND BACKGROUND

Nations, states, cities, and towns have the challenge and opportunity of crafting their sustainable development to address climate change. Thus, policy makers use the terms "green economy" or "green job growth" widely in current policy-related decisions, particularly in legislation related to renewable energy and energy efficiency. Ever since Meadows (1972) argued that human society must consider "limits to growth," economic growth and environmental conservation have frequently been weighed against each other as trade-offs. However, since the American Recovery and Reinvestment Act of 2009 (ARRA), green job creation has become a central theme because it counters a significant perception of a "jobs vs. environment tradeoff" (Claussen & Peace, 2007; Goodstein, 1999). Policy makers at both the federal and local levels in the United States have focused on green stimulus policies to promote clean-energy production and consumption with the additional intention of creating diverse jobs.

In this context, energy-based economic development (EBED) has become a growing field of practice and research in the United States as well as across the world. EBED, a term recently coined by Carley et al. (2011, 2014), reflects the emerging convergence of two disciplines: energy planning and economic development. EBED captures the integration of policy-driven transformations of energy systems for low-emission and efficient energy generation and regional and national concerns for economic competitiveness and resilience. It includes national and local efforts for job creation, alternative-energy development and deployment, industry development, economic and energy diversification, energy efficiency savings, and greenhouse gas savings (Carley, 2012). Distinct from traditional economic development strategies, this approach adds a focus on clean energy to emerging sustainable economic development practices that care for both people and place by improving standards of living for all and sustaining local employment capacity (Blakely & Leigh, 2009).

However, implemented studies to date provide only limited understanding of EBED. In the United States in particular, key objectives of economic development have been focusing only on net job growth. Recent policy reports have continued to use the perception of green jobs to address positive contributions of clean-energy policy legislation to job creation and sustainable economic development (see for example, Laitner & McKinney, 2008; Pollin et al., 2008). These studies have discussed job market development driven by renewable energy and energy efficiency policies that have been related to innovative clean technology development and technological diffusion. In general, using macroeconomic analysis models such as the input–output (I-O) model, many policy-based studies estimate an expected number of job creations directly and indirectly induced across related industrial sectors.

However, these previous studies uncover many challenges requiring further research. First, the definition of "green economy" remains unclear and lacks a consistent usage across literatures. This represents a significant challenge for future policy implementation because, if many stimulus policies for the clean-energy industry are implemented based on an unclear definition and uncertain data, public investments would run on the wrong track. Second, the mechanisms shaping labor market outcomes seem to be more complex than what is suggested by the evidence in previous studies. Firms' activities would be determined by diverse regional conditions such as governmental policy supports, politics, an embedded historical–geographical environment, and a pattern of innovative technology adoption (Palmer, Oates, & Portney, 1995; Roland-Holst, 2008). Therefore, this suggests a need for a theoretical underpinning to understand what the mechanism of firms' innovation adoption and cross-firm diffusion in the process of new policy implementation is. Third, green economy literatures rarely consider local needs that policies may seek to address. In particular, employment policies might need to focus on the local level outcomes in terms of the quality of jobs and the relationship with the existing labor force. This also requires theoretical approach, explaining why a certain region might be performing better on sustainable economic development than another and what makes the differences. Finally, previous empirical studies on green jobs generally rely on static assumptions. However, the employment market is shaped by interactions between consumers and producers of innovative technologies. For consumers (e.g., commercial and industrial firms, which are the focus of this dissertation), the determinant factors of their innovation adoption and adaptation can be important elements of job generation. For producers, the issues about how to produce technological innovation and what regional bases exist to diffuse can be other important elements to determine the associated jobs creation.

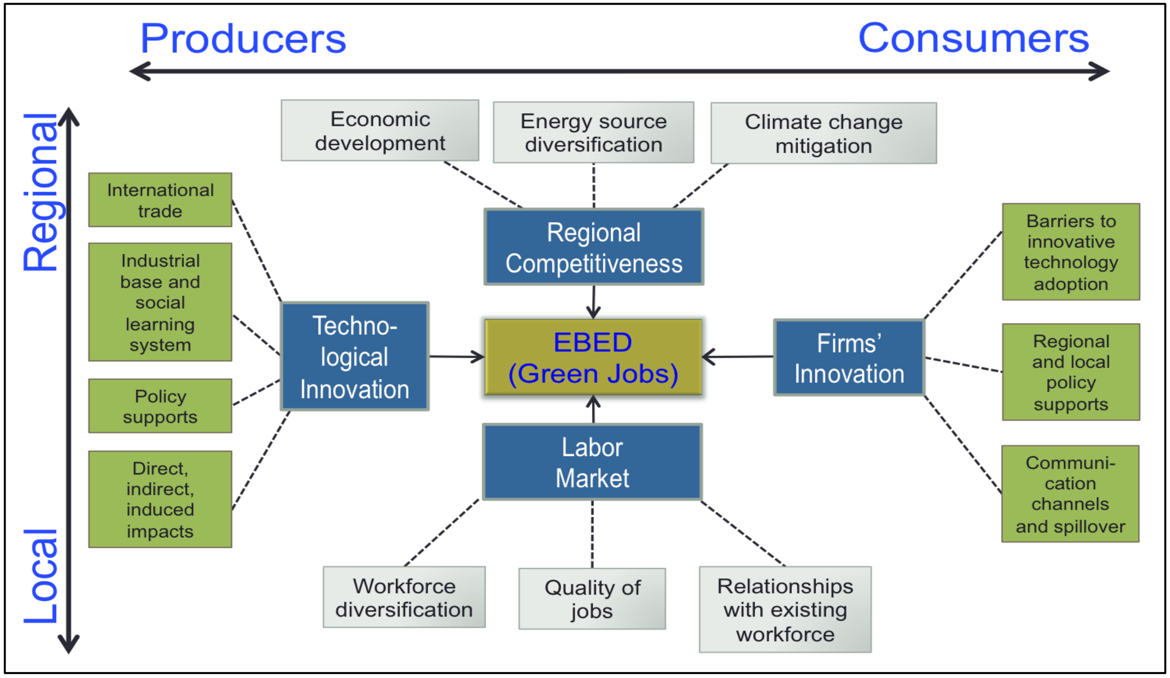
The purpose of this research is to find and fill gaps between existing academic approaches regarding green job estimation and real job market performance. The research design is based on raising major research questions:

- *What actions have the U.S. states taken to promote clean energy?*
- *How do clean energy policies affect clean energy deployment and job creation?*

- *What would a technological shift to clean and efficient energy mean for regional competitiveness?*

Figure 1 depicts a conceptual framework to show compositions of job market development, identifying missing points in previous green job debates. The new framework is organized by vertical and horizontal categories. First, green economy concerns include diverse issues from local to regional, which can be abstracted by the correlation between governmental efforts on clean energy expansion and firms' practical efforts on clean energy adoption, and the regional competiveness matters on the regional scale. Second, job creation can be explained through horizontal interactions between producers and consumers of innovation adoption and diffusion. In my research, I define "consumers" as end users (firms) of energy efficiency and/or renewable energy technologies, and "producers" as primarily manufacturers of these technologies as well as related service sectors.

Figure 1.1 What we are missing in green economy discussions



To answer my research questions, I will develop an empirical method for tracking historical changes on energy generation and examining the relationship between those changes and clean-energy policies. I will then identify regional differentiations of the characteristics of energy generation by state and the content of state policy implementation, and apply them to state-level employment data to find causality. I will conduct a step-by-step analysis: first, from the consumer market; second, from the producer market; and last, from the regional perspective to see the policy–employment relationship.

In addition to investigating the causality among the energy market, clean-energy policies, and the employment market, in this paper I extend the existing literature by developing a theoretical framework to converge two fields—economic development planning and energy planning. Also, I review the innovation diffusion theory to develop my research hypotheses. Within this framework, I demonstrate how EBED is embedded in reality, how firms act along with clean energy policies, and why clean energy could be a source of economic development.

1.1 Research Focus: Distributed Generation (DG) and Combined Heat and Power (CHP) Systems for Energy Efficiency and Resiliency

In the 2000s, the United States expanded and diversified cleaner energy resources, including wind, solar, biomass, and energy efficiency. Unlike traditional and centralized grid systems, these newly emerging energy resources could be characterized as "distributed" or "independently owned" energy. Large and conventional utilities, such as coal fired, gas, nuclear power plants, and hydroelectric dams, have dominated because of their size advantage: "bigger is cheaper." However, in this climate change era, distributed generation systems have received renewed interest because of the growing demand for low- or zero-carbon energy generation, increasing interest in resilient power supplies, the changing economic and regulatory environment, and advances in DG technology efficiency with declining life-cycle costs (Pepermans et al., 2003; U.S. Department of Energy, 2007). Moreover, the California Electricity Crisis in 2000 (Sweeney, 2002), the September 11 attack in 2001, the Northeast Blackout in August 2003, Hurricane Katrina of August 2005, and Hurricane Sandy of 2012 all strengthened the demand to secure energy systems during a catastrophic event. Many people started to consider that DG could be a solution to provide emergency power and resilient energy during a weather-related or human-induced disruption (U.S. Department of Energy, 2007, 2017).

In fact, utilization of DG is not new. The first commercial power plant in the United States, reciprocating steam engines in Thomas Edison's Pearl Street Station, served lower Manhattan with direct-current electricity for both lighting and steam for local manufacturing in 1882 (Hirsh, 2012a). As power generation technologies advanced over the next 100 years, the government supported developing a centralized power system to take advantage of better economies of scale, locations outside of urban centers, efficiency improvement, power dispatch, and resource diversity. Modern distributed generation received attention again when the federal Public Utility Regulatory Policies Act (PURPA) passed in 1978, partly in response to the oil crisis in the 1970s.

PURPA encouraged the use of energy efficient CHP systems and small DG from renewables by requiring central utilities to interconnect with qualified facilities. Section 210 of the PURPA established a class of non-utility generators called "Qualifying Facilities (QFs)," defined as cogeneration and small power producers (Glassman, 2007; Hirsh, 2012c). Under the PURPA, the QFs could enjoy benefits, including the right to sell energy to a utility at the utility's avoided cost[1] or at a negotiated rate, the right to purchase back-up, supplementary, and maintenance power from utilities[2], and relief from certain regulatory burdens[3] (Federal Energy Regulatory Commission, 2015). This package of benefits successfully played a significant role in promoting the development of QFs, which succefully contributed to encourage more efficient and non-fossil fuel DG and cogeneration market in the U.S (Glassman, 2007).

In response to Congress's recognition of the need of more strigent technical requirements for QF industries, the legislation of the Energy Policy Act of 2005 (EPACT)

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[1] Avoided cost is defined as "the incremental cost to an electric utility of electric energy or capacity which, but for the purchase from the QF, such utility would generate itself or purchase from another source (FERC, 2015)."

[2] QFs receive no beneficial rate treatment in purchasing supplementary power as there's no differently situated than other industrial retail customers, but receive beneficial rate treatment for backup and maintenance power purchases (FERC, 2015).

[3] QFs were exempt from state laws and regulations respecting the rates and the financial and organizational regulation of electric utilities, as well as from most provisions of the Federal Power Act (FPA). As a result, under the PURPA, QFs could sell their power at wholesale, issue securities, dispose of their assets with very limited oversight by the FERC, and avoid a variety of onerous FERC filing and reporting requirements (Glassman, 2007).

strengthened the technical requirements and standards for QFs, while it provided a favorable environment by regulating mandatory electric reliability standards; the adoption of standards for net metering, smart metering, and time-based pricing; promoting demand response programs; and establishing financial incentives for DG consumers (Federal Energy Regulatory Commission (FERC), 2015; Glassman, 2007; U.S. Department of Energy, 2007). For example, the provisions under the EPACT raises efficiency standards to achieve new cogeneration QF status by requiring at least 50% of the facility's total annual energy output (including thermal output) should be used for industrial, commercial, residential, or institutional purposes, and not for sale to an electric utility.[4] CHP facilities designed for the primary purpose of selling electricity at wholesale and recycling only a small amount of steam or heat will no longer be certified as the QF. In fact, under the old PURPA rules, it was hardly a CHP as most of the waste heat energy was thrown away (Duvall, 2014). Overall, in the post-EPACT world, the facilities installed DG or CHP systems face a number of challenges, yet significant benefits and opportunities still remain for QFs.

1.1.1 Definition of DG

Identifying the distinct characteristics of DG from conventional utilities helps define DG. DG is different from centralized generation in terms of reliable technology, capacity size, location, and ownership. DG[5] encompasses various technologies, ranging

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[4] The details can be found at 18 C.F.R. 292.205(d), "Criteria for qualifying cogeneration facilities."

[5] DG has been called by different names. Europe and parts of Asia call it "decentralized" generation and the United Kingdom, Canada, and northeastern U.S. often use the term "embedded" generation (Ackermann et al., 2001). The U.S.'s Energy Information Administration (EIA) (2017) uses "distributed" generation for

from solar photovoltaic and wind, which only produce electricity, to CHP systems that produce both thermal energy and electricity at or near the particular load they are intended to serve. To be specific, for example, DG includes rooftop solar panels on homes; a gas turbine for generating electricity and recycling the waste heat for universities, hospitals, or pulp and paper plants; and a micro turbine burning food waste or animal manure to generate electricity for a farm. Thus, the size of DG units varies case by case but, in general, is smaller than centralized generation. According to Ackermann et al. (2001), academic research and government regulations define DG by various ranges of capacity from a few kilowatts to 100 MW.[6] Compared to conventional generation, DG is often defined as small-scale power generation. The location of DG also makes DG different from central utilities, because the installation and operation is connected directly to the transmission and distribution (T&D) grid or connected to the network on the customer's side of the meter. DG ownership is generally independent power producers or the customers themselves. However, it is not limited to independent ownership, as large utility companies often own small DG systems or support their development financially. Nevertheless, DG is often emphasized as "independently owned" generation, so that it can be an important characteristic for the development of DG (Ackermann, Andersson, & Soder, 2001; Kassakian & Schmalensee, 2011; U.S. Department of Energy, 2007).

Reflecting these characteristics, the U.S. Department of Energy (DOE) defines DG as follows:

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facilities "being connected to the electrical grid and intended to directly offset retail sales" and "dispersed" generation for facilities "being off-grid and often used for remote applications where grid-connected electricity is cost-prohibitive" .

[6] According to 2015 data of the U.S. EIA-861 survey (accessed March, 2018), several DG facilities have a capacity larger than 100MW. For example, the capacity of the Florida Power and Light Company is 188 MW, generated by 371 internal combustion engines.

"Electric generation that feeds into the distribution grid, rather than the bulk transmission grid, whether on the utility side of the meter, or on the customer side" (U.S. Department of Energy, 2007 p. xvi).

1.1.2 Potential Benefits and Barriers of DG

In this section, I will explore the strengths and limitations of DG, focusing on industrial use. Responding to the EPACT legislation in 2005, the DOE (2007) analyzed the potential benefits of DG as follows.

First, DG can provide emergency or back-up power when grid-connected power is unavailable. This benefit has been emphasized along with the growing importance of the resiliency of the electricity supply, especially for industries such as telecommunication, food, and chemicals, as well as critical infrastructure such as hospitals, fire stations, transportation systems, drinking water and wastewater treatment plants, which rely on electric system reliability. In particular, after Hurricane Sandy, the Federal Hurricane Sandy Rebuilding Task Force (2013) emphasized the importance of cost-effective investments in distributed and resilient energy generation by the federal, state, and private sector cooperation across regional boundaries. Starting with the Task Force's initiative, the DOE, Environmental Protection Agency (EPA), and Department of Housing and Urban Development (HUD) developed a guidance to promote the use of CHP, other forms of clean DG, and storage technologies by incorporating DG applications in state and local energy resiliency planning (DOE, EPA & HUD, 2013). The lessons learned from the Sandy recovery efforts show that DG can be used to decrease the vulnerability of the electric system to threats from catastrophic blackouts such as weather-related outages and regional blackouts, as well as terrorist attacks.

Second, DG offers potential benefits not only to electricity customers, but also to large utilities, because DG may reduce peak loads, improve the efficiency of the T&D network through DG-generated reactive power, and reduce power quality concerns,[7] particulary by involving energy storage technologies, power electronics, and power conditioning equipment in the DG systems (Dugan, McGranaghan, Santoso, & Beaty, 2004). Therefore, several electric utilities provide financial incentives to DG users to make their electricity available during peak demand hours or other emergency periods (U.S. Department of Energy, 2007).

Finally, since DG sources are much smaller in scale and more widely distributed in location, DG can reduce negative land use effects by reducing its land area required for power generation facilities and the T&D lines. According to the DOE (2007), the land area required for DG facilities is much smaller compared to large-scale power plants, which can mitigate serious issues related to land purchase costs (Table 1.1). In addition, DG can be incorporated into industrial or commercial buildings in an engine room or on a rooftop so that it provides a lower risk of not-in-my-backyard issues and no requirements of open space (Styers & Mitchell, 2012; U.S. Department of Energy, 2007).

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[7] Dugan et al. (2004) defined power quality problem as "any power problem manifested in voltage, current, or frequency deviations that results in failure or misoperation of customer equipment." The power quality problems are generally caused by voltage surges and sags, frequency excursions, harmonics, flicker, and phase imbalances, which are mostly be ultimately a consumer-driven issue, especially with the increasing use of electronic components for appliances and equipment in homes, officies, and factories, and are not often system wide concerns (U.S. DOE, 2007).

Table 1.1 Land Use for Typical Central Power Generation versus Distributed Generation

(Revised from Data Source of U.S. Department of Energy, 2007)

Category	Fuel Type	Average Land Area (sq ft/kW)
Central Power Generation	Coal	7,196
	Natural Gas	869
	Nuclear	42,799
	Wind	1,774
	Biomass	413
Distributed Generation	Diesel Engine	0.265
	Natural Gas Engine	0.325
	Microturbine	0.250
	Building Integrated Photovoltaic Array	180
	Rooftop Photovoltaic	0
	Fuel Cell	0.9

However, this benefit may depend on the resource being used to generate power. For example, DG facilities burning biomass, such as wood residue or animal waste, may cause air and water quality issues, which have to involve land use implications in the processes of construction permit. DG installations must comply with a host of local zoning, environmental, health and safety requirements at the site, such as air and water quality, noise, hazardous waste disposal, and building safty standards (U.S. Environmental Protection Agency CHP Partnership, 2015). This may hamper DG deployment through numbers of interactions with various local agencies and unnecessary project delays .

Despite the above advantages, there are economic and institutional barriers that make developers and electric utilities hesitate to install DG. Here, I briefly introduce some key barriers but later, in the section 1.1.4, will discuss in more detail, focusing on a case of CHP technology. DG allows customers to capture economic incentives because it is very site-specific. This is why electric utilities sometimes hesitate to invest in DG although they can take advantages from DG in terms of voltage support (Dugan et al., 2004). Furthermore, compared to conventional energy generation, consumers are often unfamiliar with DG technologies. This is led by a lack of standard data, analysis tools for evaluating DG, or practical experiences for incorporating DG into electric system planning and operations. All of these circumstances lead to a lot of uncertainty regarding DG installation. A lack of standardized regulation for electric rates, siting and permitting, and grid interconnection also discourages the development of DG and raises DG project costs (Shipley et al., 2008; U.S. Environmental Protection Agency, 2012). Recently, several states established uniform interconnection standards and adopted time-based electricity rates, net metering, and demand response programs, which have helped reduce the rate-related barriers to DG, which I will introduce in Chapter 4.

1.1.3 DG Technology Option: Combined Heat and Power (CHP)

According to the *Annual Energy Outlook 2018* (U.S. EIA, 2018), the industrial sector is the largest consumer of energy, especially natural gas, in the U.S., accounting for 35 percent of natural gas consumption in 2017. In addition, industrial energy consumption is expected to show the largest increase of any sector over the next 30 years.

Therefore, improving energy efficiency in the industrial sector is a critical agenda item for policy makers. The AEO 2018 and a recent DOE's report (U.S. Department of Energy, 2017) addressed that overall energy consumption in the industrial sector could grow slowly than economic growth because of efficiency gains. CHP technologies have been considered as a key player for industrial energy efficiency improvement (M. A. Brown, Jackson, et al., 2010; M. Brown, Cox, & Baer, 2012; Chittum & Kaufman, 2011; Shipley et al., 2008; U.S. EIA, 2018). As my research aims to analyze the role of clean energy policies and public investments to achieve EBED, I will narrow down my research objectives by investigating CHP, a representive technology for DG, to specify target policies.

CHP is a form of distributed generation, as CHP technologies allow end-users to generate electricity on site. The primary CHP technologies (so-called "prime movers") include gas turbines, reciprocating engines, and boiler/steam turbine combinations, which are combined into systems with electrical generators and heat recovery equipment. Such systems are tailored to available fuels, plant operating costs, the difference between the electricity price and fuel costs,[8] and the on-site need for electrical power versus thermal energy (Sentech Inc., 2010). CHP technology is often regarded as a transformational technology with the potential for significantly improving energy efficiency by reusing waste heat productively (Shipley et al., 2008). Also known as cogeneration, CHP is the production of electricity along with economically useful heat, and is used in industrial processes and for heating and cooling buildings. By capturing energy that would

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[8] The estimated operating cost stream is called the "spark spread," which is the theoretical gross margin of a CHP-installed power plant from selling a unit of electricity. The spark spread is calculated as the "price of electricity – [(cost of fuel)*(heat rate)]."

otherwise be wasted, the efficiency of the conversion can be increased from 45 percent in typical thermal power plants to as much as 70 percent in efficient natural gas CHP facilities (U.S. EPA CHP Partnership, 2008). In addition, while the main fuel of CHP systems is natural gas,[9] CHP can often be fueled with industrial waste products or with biomass, further reducing fossil fuel consumption and carbon dioxide emissions.

As a DG system, the deployment of a CHP system reduces electricity purchased through the grid from central utility stations and usually produces power to sell back to the grid. This on-site generation avoids energy losses from electricity transmission, and it can increase overall system resilience, as has been shown in the development of locational marginal pricing for distributed generation of all types (Lewis, 2010). These characteristics make CHP especially attractive for industrial users who want to enjoy the benefits of site-specific, strategic energy production to supply their electricity and thermal energy needs.

CHP provides environmental advantages as well. A study by the American Council for an Energy-Efficient Economy (ACEEE) found that CHP deployment across all states could save more than 68 million MWh of energy in 2030, which could offset the need for about 36 power plants and cut carbon dioxide emissions (Hayes et al., 2014). The EPA recognized this potential of air pollution mitigation by energy efficient technology deployment and, in August 2015, announced *Clean Power Plan* that sets state-by-state goals of CO_2 emission reductions from existing power plants and outlines paths (called “building blocks”) for states.[10] The plan included end-use energy efficiency

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[9] Approximately two-thirds of industrial CHP systems in the U.S. are fueled by natural gas (DOE CHP Installation Database assessed on 11/2018).

[10] For more details, see Section 2.1.1 and 2.1.3.

as a means of compliance as EPA assumed energy savings from energy efficiency could displace emitting generation.

In addition to offering energy and environmental benefits, CHP is a well-established technology that is widely used at industrial facilities, hospitals, and universities to reduce operating costs and ensure reliability. As seen in Figure 1.2, during the 1980s, new CHP installation began to increase mainly for industrial and commercial purposes,[11] relying on coal, natural gas, and industrial waste, in terms of capacity. In the 2000s, more than 100 facilities built new natural gas-fired CHP systems every year. In terms of a number of facilities, many other facilities started to use biomass for the small size CHP units. These distributed CHP systems, which are smaller than 100MW in capacity size, currently supply 4% of installed U.S. electric generating capacity in 2014, but has the potential to achieve much more (U.S. Energy Information Administration, 2018).

Regarding energy and environmental benefits, on August 30, 2012, an executive order under Obama administration has set a national goal of 40 GW of new industrial CHP by 2020, targeting a broad set of stakeholders including states, manufacturers, and utilities (The White House, 2012). Baer et al. (2015) estimates that national CHP capacity in industrial sector could reach 50 GW in 2020 and 80 GW in 2035 in a business-as-usual case, which would meet only 47% of the 2012 executive goal by 2020. However, policy supports, such as an expanded financial subsidies on CHP equipment costs, would

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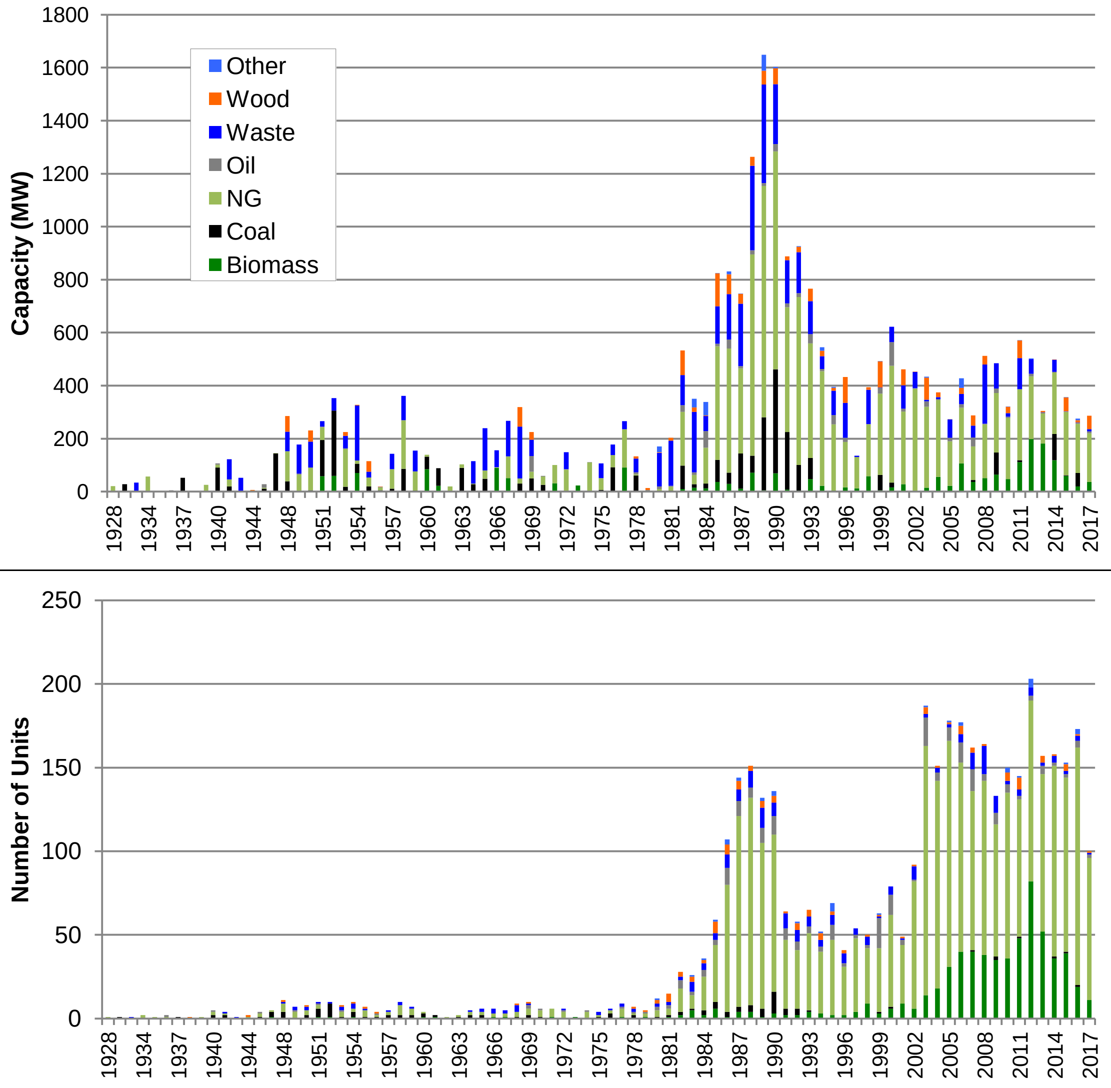
[11] According to the same data source of Figure 1.2 (DOE CHP Insstallation database, 2016), in terms of capacity, industrial plants, such as chemicals, refining, and pulp and paper manufacturing facillities, have been major users of CHP systems, which account for more than 70 percent of new CHP projects. On the other hand, in terms of number of facilities, many numbers of commercial facilities, such as universities, schools, hospitals, and hotels, also have installed smaller-scale CHP that account for more than 40 percent of numbers of new built CHP facilities. In addition, there are other users, for example, wastewater treatment, utilities, and military facilities.

encourage the use of industrial CHP. For example, Baer et al. (2015) estimated impacts of policy cases of expanded investment tax credit, and suggested that a 30% ITC policy would help industrial sector closer to achieve the executive goal, meeting 70% of the goal by 2020.

Figure 1.2 New CHP (<100MW)* Built by Year and by Fuel
(Top: capacity, Below: number of facilities)
(Data source: DOE CHP Installation Database, accessed 11/2018)



* Note: To be consistent with the definition of distributed generation, this chart represents CHP systems in all sectors but only smaller than 100 MW, which are 4,273 facilities (96%) among a total of 4,454 facilities in 2018. These small CHP systems possess 27 GW (34%) in capacity among a total 81 GW of the total CHP capacity in the U.S.

(Fuel Code)

- OTHER: Fuel Cell, Unknown
- WOOD: Wood, Wood Waste
- WASTE: Waste, Waste Heat, Municipal Solid Waste, Black Liquor, Blast Furnace Gas, Petroleum Coke, Process Gas
- OIL: Oil, Distillate Fuel Oil, Jet Fuel, Kerosene, RFO
- NG: Natural Gas, Propane
- COAL: Coal
- BIOMASS: Biomass, LFG, Digester Gas, Bagassee

1.1.4 Barriers to CHP Deployment

Despite the economic and environmental attractiveness of CHP, decision makers in the industrial sector face financial, regulatory, informational, and workforce barriers to what are generally considered to be cost-saving investments. First of all, for decision-making about new CHP installation, industrial companies are challenged by a greater financial risk because new CHP technologies often require high upfront costs and have longer payback periods compared to traditional equipment. On the other hand, the benefits of energy bill savings can hardly be captured in a short period of time, and are not usually considered as economic benefits in evaluating CHP investments. In particular, the economic downturn or uncertainty has caused companies to become conservative, with even greater aversion to longer payback periods and difficulties in securing financing (Chittum & Kaufman, 2011).

Second, utility monopoly power and utility rate structures also distort CHP economics. Many utilities discourage CHP facilities from acting as independent distributed generators who can sell excess power to nearby customers at retail or negotiated rates. In some states, utilities own and manage the transmission and distribution infrastructure and they discourage CHP users from selling their excess power back to the grid at a wholesale rate. Furthermore, utilities impose additional charges for private wire usage and for standby or back-up service (Chittum & Kaufman, 2011; Sciortino et al., 2011). These electricity rate structures reduce the money-saving potential of on-site generation.

Third, the enforcement of interconnection standards and environmental regulations can be substantial barriers to CHP investments, especially for smaller CHP projects that must predict the costs and requirements for the project development and future operation (Kalam et al., 2012; Shipley et al., 2008). Although many states have developed interconnection standards that ensure stable interconnection with the grid, the lack of uniformity in application processes and fees has caused unnecessary project delays and has generated high transaction costs (Shipley et al., 2008; U.S. Environmental Protection Agency, 2012). In addition to the costs of dealing with interconnection standards, various permits and regulations—such as input-based emission standards—can also increase upfront project costs. Satisfying the conventional emission regulations based on heat input (lb/MMBtu) or exhaust concentration (parts per million) can be challenging to CHP deployment at the beginning of a project's lifespan. CHP generally increases the on-site emissions, but due to its high efficiency, reduces the overall emissions of all pollutants in a given region as well as overall fuel consumption (Chittum & Kaufman, 2011). Many CHP studies argue that the transformation from current input-based emission standards to output-based emission standards (OBES) can capture the total regional emissions benefits of CHP development (Shipley et al., 2008; Cox, Brown, and Jackson, 2011; Sciortino et al., 2011).

Last, as CHP has been utilized in quite varied sectors, the difficulty of effectively sharing lessons and information across industries can impede the process of diffusion and modernization of CHP projects (Brown et al., 2012; The Committee on Climate Change Science and Technology Integration, 2009). Given the uncertainties about the benefits and risks of CHP technology over a project's whole lifespan, the information incompleteness can be a substantial barrier to expensive capital investments. Subsidies that encourage the market penetration of CHP systems and continuing technology development may mitigate these information barriers.

While clean energy policies play a role in jumpstarting the diffusion of new energy efficiency technologies, consumers are the real stakeholders that cause the technologies' market demand to expand. Despite the economic and environmental attractiveness of energy efficient technologies, however, decision makers in industrial sectors seem to face regulatory, financial, informational, and workforce barriers, as I reviewed above. Policy interventions would support the marketability of CHP use.

Many studies have asserted that an “energy-efficiency gap (EEG)” exists (Brown et al., 2010). The EEG refers to a gap between the optimal and actual level of energy consumption when households, businesses, manufacturers, and government agencies all fail to take full advantage of cost-effective, energy-conserving opportunities (Dietz, 2010; Hirst & Brown, 1990; Jaffe & Stavins, 1994). The concept of EEG refers to numerous market failures and barriers that inhibit the growth of energy efficient technology installation. To improve the marketability of innovative energy technology, it is important to investigate the potential of closing the EEG. In this context, raising a research question will highlight the role of state policy intervention in EEG abatement and energy resource diversification.

The DOE published CHP technical potential that is estimated based on electric and thermal needs from existing industrial facilities and commercial buildings (U.S. Department of Energy, 2016). The CHP potential is relatively higher in states with energy-intensive industries and dense population leading concentrations of commercial buildings. Table 1.2 presents state-by-state comparisons between DOE's estimates of

CHP on-site potential and existing CHP capacity in 2016. It shows the 149 GW potential of additional CHP capacity for on-site installation, which is almost double of existing CHP capacity by 2016. This confirms that there is a significant energy-efficiency gap for CHP technology use across the United States. Texas, California, Illinois, Pennsylvania, Ohio, Florida, New York, Georgia, Louisiana, and North Carolina are the top ten states remaining more than about 5 GW of technical potential that could be installed on site. Some states such as Texas, Louisiana, and California have already adopted CHP as much as the potential remained. However, in some states such as Ohio, Illinois, and Georgia, the current use of CHP is much less than the potential.

Here, research questions are raised what the drivers and barriers of CHP technology use in each state are? What types of clean energy policies have engaged to promote CHP system adoptions? How those policies influence on consumers' innovative technology adoption to close EEG? How different by state? To answer the questions, I employed panel data analyses by using the annual CHP capacity by state as a dependent variable and the state performance of energy efficiency policies as main independent variables. Other variables of fuel mix and energy prices are also included as independent variables to reflect regional energy market characteristics, which affect to CHP technology adoption. In Section 5, I will explain the details of methodology and results.

Table 1.2 Energy Efficiency Gap in CHP Technology Use : CHP On-Site Potential versus Existing CHP Capacity in 2016

State	CHP Capacity (MW) 1)	CHP On-site Potential (MW) 2)	% of Existing CHP	State	CHP Capacity (MW) 1)	CHP On-site Potential (MW) 2)	% of Existing CHP
Texas	17,445	13,675	128%	Arkansas	569	1,795	32%
California	8,631	11,542	75%	Colorado	565	1,665	34%
Louisiana	5,975	4,903	122%	Mississippi	529	1,833	29%
New York	5,738	6,908	83%	Ohio	510	7,005	7%
Michigan	3,425	4,291	80%	Alaska	465	408	114%
Florida	3,379	6,917	49%	Delaware	368	747	49%
Alabama	3,282	2,777	118%	Nevada	368	1,254	29%
New Jersey	2,979	3,761	79%	West Virginia	354	929	38%
Pennsylvania	2,881	7,025	41%	Hawaii	349	563	62%
Indiana	2,319	4,145	56%	New Mexico	273	1,140	24%
Oregon	2,077	1,337	155%	Missouri	234	2,882	8%
Virginia	1,689	4,308	39%	Utah	227	1,119	20%
Massachusetts	1,631	3,028	54%	Idaho	212	659	32%
Wisconsin	1,592	3,187	50%	Kansas	193	1,909	10%
North Carolina	1,546	4,352	36%	Wyoming	169	847	20%
South Carolina	1,394	3,063	46%	North Dakota	165	445	37%
Georgia	1,339	5,110	26%	Kentucky	136	2,721	5%
Illinois	1,237	7,161	17%	Rhode Island	127	616	21%
Washington	1,061	2,387	44%	Nebraska	104	984	11%
Minnesota	937	3,260	29%	Arizona	99	2,320	4%
Maine	936	494	190%	Montana	73	377	19%
Iowa	736	1,993	37%	New Hampshire	47	447	10%
Connecticut	727	1,214	60%	South Dakota	24	378	6%
Maryland	652	2,282	29%	District of Columbia	23	762	3%
Tennessee	584	3,981	15%	Vermont	20	228	9%
Oklahoma	572	1,805	32%	Total U.S.	80,969	148,936	54%

Data Source: 1) CHP Installation Database, accessed 10/2016, U.S. DOE; 2) U.S. DOE CHP Technical Potential in the United States, 2016

Note: 1) States ordered by the size of CHP capacity. 2) The top ten states of CHP on-site potential are shaded.

1.2 Policy Focus: State Clean Energy Policy Instruments for DG and CHP

CHP deployment can be encouraged by appropriate policy intervention. Table 1.3 provides types of state energy policy options that support CHP and DG deployment—called "clean energy policies" throughout this dissertation. The nine categories of policy options are selected for the policy analysis aim to:

- Directly promote end-use energy savings
- Encourage the diversification of energy resources, including renewables, EE and DG
- Establish mandatory performance standards
- Reduce financial, regulatory, and informational barriers to EE and RE
- Provide favorable emissions treatment for energy efficiency
- Accelerate the expansion of DG technologies

I follow the framework of types of pollution policy instruments defined by Goulder and Parry (2008). They identified environmental policy instruments to address pollution in two groups: incentive-based instruments and direct regulatory instruments. Incentive-based instruments include carbon tax, cap-and-trade systems, subsidy for pollution abatement, and tax credits on inputs or goods associated with emissions reductions. Direct regulatory instruments include performance standards (e.g., boiler standards for generators), interconnection standards, net metering, and technology mandates (e.g., renewable portfolio standard (RPS)). Moreover, I added information policies as a new category, following Brown et al.'s (2014) framework of energy efficiency policy options because I assume that programs and policies, which allow industrial firms expose to a certain channel of information sharing, can encourage energy efficiency efforts. Using these categories, as shown in Table 1.3, I characterize clean energy policies that are currently implemented by state to promote clean DG and CHP deployment.

Based on the metrics of selective clean energy policies in Table 1.3, I will define the “intensity of clean energy policies” by scoring states on the characteristics of policy implementation. It includes the first year of policy enactment, the number of regulation requirements, the range of eligible CHP technologies, system size, and fuel.

Current policy implementations affecting DG technologies expansion, greenhouse gas emission reduction, and green job market dynamics are taking place to different extents in different states. According to the Database of State Incentives for Renewables and Efficiency’s (DSIRE) inventory[12], for example, only 26 states offer tax incentives that support the renewable energy industry and 30 states have RPS (in some of these RPS state, CHP can be used to contribute to the goal) (Brown et al., 2014). Some states are more aggressive in clean energy policies, while others are less aggressive. However, many state and local energy strategies are attempts to “be first movers” to gain an early market share and to reap advantages from future energy development (Rabe, 2008). In this context, I’ll score states policy entrepreneurship by giving a credit 1 from the initial year of each policy implementation.

Table 1.3 Types of Clean Energy Policy Instruments for DG and CHP

Category	Type	Description
Incentive-Based Instruments	Tax credits for renewables	States provide corporate, personal, or both tax exemptions for each kW installed or kWh

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[12] Retrieved from www.dsireusa.org, accessed March, 2018.

		produced from qualified renewables. The eligible renewable resources or technologies vary by state.
	Tax credits for energy efficiency	States provide corporate, personal, or both tax deductions or exemptions for qualifying energy efficiency project costs.
	Utility rate policies	Utilities offer decoupling, time-of-use rates, and discounts or exemptions of fees for customers with on-site power generation.
	Financing assistances	Low-interest loan programs, loan guarantees, property assessed clean energy (PACE) financing, rebates, tax credits, grants, and bonds are all supportive tools that states implement to make CHP systems financially attractive.
	Other types of incentives	Grant programs, and deductions are adopted by states to incentivize CHP deployment or renewable energy. The leading states have mixtures of multiple types of incentives.
Direct Regulatory Instruments	Renewable Portfolio Standard (RPS)	States set goals for future years, generally a percentage of total electricity sold that must be derived from renewable energy or energy efficiency.
	Energy Efficiency Resource Standards (EERS)	
	Interconnection policies	Multiple levels of interconnection exist to encourage distributed generation deployment

		because smaller systems can be offered a faster path toward interconnection. System capacity limits vary by state and by customer type. Higher size limits are preferable.
	Net metering policies	States have adopted state net metering policies or voluntary utility programs. States indicate the different sizes of individual system capacity limits in kW.
	Output-based emission regulations	While many states employ emission regulations for generators by calculating levels of pollutants based upon the system's fuel input, some other states take the useful energy output of CHP systems into consideration when quantifying a system's criteria pollutant emissions.
Information Policies	Energy and Climate Change Plans	States provide broad and long-term roadmaps and information by assessing current and future energy supply and demand, examining existing policies, and identifying energy and climate change challenges and opportunities.
	Other supportive policies	States provide a variety type of programs, including technical assistance programs, education campaigns, or other incentives that support CHP. When states created a goal of energy efficiency savings or renewable energy capacity, they also establish a communication channel for tracking customers' performances in a regular base.

Chapter 2 Literature Review

To understand the emerging discipline of EBED, I will explore the evolution of U.S. energy policy and economic development policies in this section. This will continue and expand into a literature review on green economy and green jobs. Last, I will review the innovation diffusion theory to construct the logic of my research hypotheses.

2.1 Energy-Based Economic Development: The Convergence of Two Fields—Energy Planning and Economic Development

2.1.1 Energy Planning To Date

The history of the U.S. energy policy and planning began with the New Deal and was spurred on by rapid industrialization after World War II (Carley et al., 2011; Luke, 2009). Building new centralized power plants grew to meet the rapidly increasing electricity demand. Most of these power plants, which were built before the 1973 oil shock, generate electricity by burning fossil fuels, such as bituminous coal and residual fuel oil (Figure 2.1). In the 1970s, nuclear and natural gas power grew as the environmentalists argued the advantages of air pollution reduction, although they were concerned about nuclear proliferation and radioactive waste disposal (J. S. Walker, 2004). However, the Three Mile Island accident in 1979 led to the cancellation of plans for new nuclear plant construction.[13] In addition, another oil shock in 1979 changed and expanded

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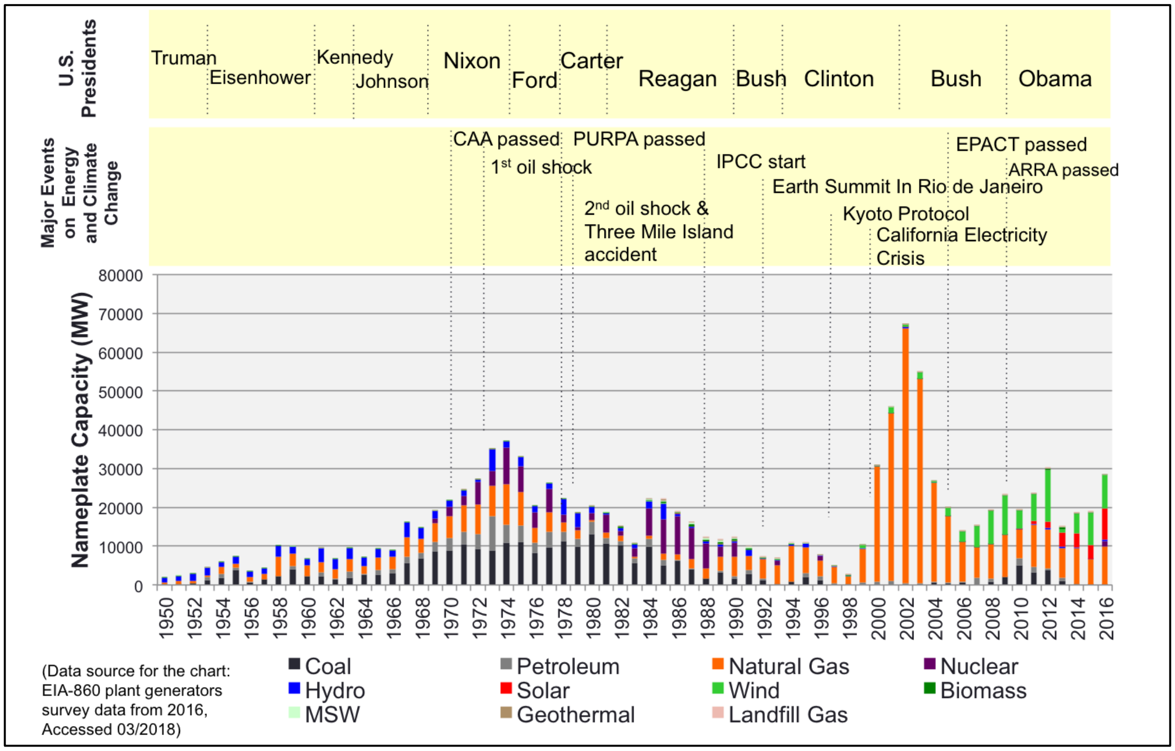
[13] According to *Outlook for New U.S. Reactors* (Parker & Holt, 2007), no reactor had been ordered in the U.S. since 1978 and more than 120 reactor orders were ultimately cancelled. In 2012, the Nuclear Regulatory Commission approved the first construction of new reactors since the Three Mile Island accident (Rascoe, 2012).

energy policies. In order to respond to the 1973 and 1979 energy crises, PURPA was passed as part of the National Energy Act in 1978. PURPA encouraged energy conservation and increased energy efficiency, especially by cogeneration, equitable retail rates, and greater use of domestic energy and renewable energy (Glassman, 2007; U.S. Department of Energy, 2007). It enabled cogeneration facilities to produce electricity in an efficient way and to sell excess power back to the grid. Even though it was not enough to create a competitive market for non-utility-owned generation against the central utilities the law is regarded as having "broke[n] the stranglehold on power companies' previous monopoly in the generation function" (Hirsh, 2012b).

Figure 2.1 Footprints of U.S. Energy Production and Fuel Sources, 1950-2016

(Data source for the chart: EIA-860 plant generators survey data, Accessed 03/2018)



(Data source for the chart: EIA-860 plant generators survey data from 2016, Accessed 03/2018)

In the 1980s, the concept of least-cost energy services emerged, which led many state utility commissions to mandate that utilities create integrated resource planning (IRP). The goal of IRP is to identify the least-cost resource mix for the utility and consumers. To do so, IRP forecasts future energy demand, identifies supply- and demand-side resource options, optimizes the resource mix, and facilitates demand-side management efforts (Hirst & Goldman, 1991; Hoog & Hobbs, 1993). Hirst and Goldman (1991) compared distinctive characteristics between traditional utility planning and IRP. First, IRP focuses on diverse resources, including utility-owned plants, small power producers, purchased electricity from other producers, energy efficiency, T&D improvements, and pricing, while traditional planning considers only central-station power generation owned by utility. In particular, demand-side management (DSM) plays a significant role in involving energy efficiency and distributed generation as the potential resources for cost-effective savings (Hirst & Goldman, 1991; Wilson & Biewald, 2013). Second, IRP involves a wider range of participants: public utility commissions, non-utility energy experts, and even customers. In contrast, traditional planning was established within utility departments. Third, IRP developed diverse evaluation criteria, including electricity prices, energy-service costs, utility financial condition, risk reduction, technology diversity, environmental quality, and economic development, while traditional planning primarily focus on electricity price minimization and system reliability (Hirst & Goldman, 1991; Jonghe, Delarue, Belmans, & D’haeseleer, 2011).

Since the middle of the 1990s, in the U.S., the focus on energy policy has started to converge with global warming and climate change worries (see for example, Gore, 1992, 2006; Hertsgaard, 1999), which was first raised by international awareness.

International discussions on global warming have emerged to claim human responsibility for climate change, and combined with the movements of international collaborative actions. In 1972, climate change became a public agenda in the first United Nations (UN) environmental conference in Stockholm. Academic research has provided scientific evidence of what people are doing to cause climate change and how climate change happens, such as ozone depletion, carbon dioxide emission, melting glaciers, and rising sea levels. The Montreal Protocol, in 1978, was an agreement among nations to restrict chemicals that damage the ozone layer, which raised the need for international collaboration on greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC), which formed in 1988, started producing evidence on climate change, beginning with the First Assessment Report in 1990 and followed by updates in 1995, 2001, 2007, and 2013. Right after the first IPCC report, in 1992, at the Earth Summit in Rio de Janeiro, developed nations agreed to the UN's Framework Convention on Climate Change, which was an agreement to return their emissions to 1990 levels. These efforts were specified in the 1997 Kyoto Protocol. Developed nations agreed to set targets for their individual countries to reduce emissions by an average of 5 percent by the period between 2008 and 2012. The U.S. Senate did not ratify the treaty at that time and the George W. Bush administration removed the U.S. from the Kyoto process in 2001. However, the world continues to build efforts aimed at establishing a global treaty on climate change—discussions have been held at the UN summits in Bali (2007), Copenhagen (2009), and Mexico (2010).

In the U.S., the Obama administration began and pledged vigorous engagement on climate change in 2008. A key policy to combat climate change was the *Clean Power*

Plan (CPP), which was first proposed by EPA on June 2014 and announced its final version on August 2015. This first-ever national plan set achievable goals to reduce carbon dioxide emissions from power plants by 32 percent from 2005 levels by 2030 (U.S.Environmental Protection Agency, 2015). It enables states to create programs to meet the goal. Before the Obama administration, American climate policy had been led by state policy leadership through multistate collaboration, with a prolonged federal inability to construct policy (Rabe, 2008). Under the CPP, EPA is charged with providing electricity decarbonization guidelines for states, based on their determination of the Best System of Emission Reduction, including more efficient coal-fired plants by heat rate improvements, more use of natural gas, and lower carbon intensity by building renewable energy power. However, it is challenged by the current Trump administration, which signed an executive order on March 28, 2017 identifying the CPP as "burden" safe and efficient developments or use of domestic energy resources[14] and mandating the EPA to review the plan (The White House, 2017). The EPA under that Trump administration announced the regulatory procedures to change emission rules and repeal the plan on October 10, 2017.

2.1.2 Economic Development Planning To Date

With increasing concerns about energy security, energy price volatility, and climate change, energy policy and economic development policy start to converge more

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[14] The Executive Order defines *burden* as "to unnecessarily obstruct, delay, curtail, or otherwise impose significant costs on the siting, permitting, production, utilization, transmission, or delivery of energy resources.“ The domestic energy resources particularly mean oil, natural gas, coal, and nuclear energy resourecs.

concretely. EBED reflects this convergence and provides a transformational system of economic development practice.

Economic development planning and practice has evolved along with socioeconomic transformation. Leigh and Blakely (2017) identified five phases of economic development practice.[15] The traditional system of economic development planning and practice during the 1930s-1980s basically sought to create wealth for people's well-being and to establish a good business climate through tax abatement, financial incentives, and infrastructure and land development. In this first phase of U.S. economic development practice, state governments were competing for industrial recruitment and jobs, which resulted in "smokestack chasing" across the nation (Atkinson, 1993; Boothroyd & Davis, 1993; Bradshaw & Blakely, 1999). As growth progressed, given the mobility of industry, businesses learned to weigh one place against other places according to their economic interests. For example, when industries would lose economic profit because of environmental pollution responsibility, they could move to a "pollution haven," which refers to the race to the bottom where states compete to be lax their environmental standards in order to attract and retain industries (Revesz, 1992; Stewart, 1977). By the middle of the 1990s, these traditional economic development approaches earned criticism, which provided the initiative to enter phase 2 (Leigh & Blakely, 2017). Politicians and academics claimed that these job creation efforts were not successful because competitive job creation was zero-sum by transferring jobs from one place to the other. These critiques resulted in a shift of economic development strategies from supply-

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[15] Earlier regional economic development scholars identified three waves of U.S. economic development policy for the period of 1930s – 2000s. (Cohen & Levinthal, 1990; David, 2005; Dosi et al., 1995; Freeman, 1994; John S. Metcalfe, 1994; Mokyr, 1990; Nelson, 1993)

side industrial attraction to demand-side approaches, such as supporting local, small, and entrepreneurial businesses and developing a global market for locally made products and services (Eisinger, 1995).

Beginning around the 1990s, the U.S. and other international countries had experienced the emergence of the New Economy, characterized by a global, digital economy that was flourishing, and a knowledge-job dependent, entrepreneurial, and innovation-driven market (Atkinson & Wu, 2017). Atkinson's *State New Economy Index* has been updated in 1999, 2002, 2007, 2008, 2010, 2012, and 2014. Through these long-term observations, the authors argued that "in the New Economy, innovative capacity (derived through universities, R&D investments, scientists and engineers, highly skilled workers, and entrepreneurial capacities) is increasingly the driver of competitive success" (Atkinson & Stewart, 2012, p. 17). In this context, the third phase of economic development practice started, with additional strategies, summarized as: 1) entrepreneurial strategies, including high-tech industry support, international trade promotion, venture capital funds (Eisinger, 1995), and creative class attraction (Florida, 2002); 2) equity strategies promoting place-based redistribution and wider stakeholder participation (e.g., civic groups, neighborhood organizations, labor unions, and non-governmental organizations); and 3) regional resource utilization by building specified industrial clusters and by strengthening local capacity through networks between universities and industries, especially for local workforce development.

The fourth phase of economic development practice emphasizes sustainable economic development. As many scholars have argued the importance of sustainability for the next generation, sustainable economic development practice tries to realize social, economic, and environmental benefits by balancing development with the ecosystem, having a self-sufficient economy, and growing fairly across people or across places (Campbell, 1996; Newby, 1999; Norton, 2005). This view addresses the idea that economic development ultimately depends on the resources of the earth's ecosystem, which are finite and often require extended periods of time and substantial resources to recover. In this phase, energy has become a more prominent issue for sustainable economic development in response to greater desires for an independent and resilient energy supply(U.S. Department of Energy, 2017). Sustainable economic development basically contrasts with the mainstream growth models (S. Carley, Brown, & Lawrence, 2012; Sanya Carley & Lawrence, 2014), where energy was considered to be an element of three inputs of production: capital, labor, and energy (Stern, 2011).

Many states have now developed third and/or fourth initiatives based on increasing their competitive advantages in the political economy (Leigh and Blakely, 2017). These shifts are occurring simultaneously, although not with equal force across nations. States are in a policy learning process. EBED is one of the emerging outcomes in this policy learning process. State governments play a leading role in developing a set of technologies and skills that promote renewable energy, energy conservation, and expertise to foster a low-carbon economy. In the past 20 to 30 years, federal and state legislations have increasingly paid attention to energy policies that encourage the diversification of new energy resources or the development of efficient ways of using existing energy resources. Indeed, virtually every governor has now developed various policy tools embraced the notion of developing "homegrown" energy sources, at least in part, in order to foster existing and future economic development (S. Carley et al., 2012; Rabe, 2008, 2010). DG technologies have received increasing attention in this context.

Globalization has also contributed to the adoption of EBED practices. Developing countries have considered energy planning and economic development together to reduce poverty by building equal energy access for all individuals (United Nations Development Programme, 2005). For developed countries, the energy policies turned out to be a tool, promoting technology innovation and supplying efficient and cleaner energy sources while preventing the volatility of electricity prices and reducing overall energy intensity across these nations (Brown & Sovacool, 2011). Policy makers have developed diverse tools to enforce the development of alternative energy sources and the installation of energy efficient technologies, which ultimately led to positive macroeconomic development, not only by affecting the industrial sectors within a nation but also by multiplying the effects across nations. According to the Organisation for Economic Co-operation and Development (OECD)'s aid statistics (2014), development assistance committee countries have donated to developing countries for energy development and poverty reduction, and these donations have doubled, from $5.2 billion on average in 2004-2006 to $12.4 billion on average in 2010-2012. In 2012, the aid focused on the development of electrical transmission and distribution, energy policy and administrative management, and renewable energy generation.

Overall, EBED has embraced activities that share the goals and objectives of energy policy and economic development disciplines. Carley and Lawrence (2014), in their recently published book, defined EBED as: "focuses on advanced, efficient, or low-emission energy sources and technologies; advances joint energy and economic development goals; builds on the varying scale and distributed nature of low-emission energy; provides a framework that aligns goals in a unified approach; and recognizes the role of governance, leadership, and stakeholder models in shaping outcomes." (Carley & Lawrence, 2014, p.15)

2.1.3 U.S. Legislation on EBED

In the U.S., energy-related legislation provides specific regulations and standards that reflect EBED efforts of linking energy, climate change, and economic development. With President Carter's mindset making energy matters a top priority, the PURPA seems to have been the first legislation that provided public tools to manage energy supply and demand by encouraging energy efficiency and exploiting alternative energy resources (Hirsh, 2012c). Since its first legislation in 1978, PURPA had been amended by incremental proceedings, as discussed above. In 2005, Senator Jim Jeffords proposed an amendment to PURPA, named the Energy Policy Act of 2005, to add a RPS program and to regulate electric utilities meeting the capacity requirement.[16] In 2009, Representatives Henry A. Waxman of California and Edward J. Markey of Massachusetts proposed House Bill 2454, which is the other amendment to PURPA, to add a cap and trade system, and a combined energy efficiency and renewable electricity standard.[17] Following Waxman and Markey's prior settlement with a broader purpose of climate change actions, on September, 2010, Senate Bill 3813, named the Renewable Electricity Promotion Act

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[16] S. 427 (2005) Renewable Energy Investment Act of 2005 (source: govtrack.us)

[17] H.R.2454 (2009) American Clean Energy and Security Act of 2009 (source: govtrack.us)

of 2010, was introduced by Jeff Bingaman, a Senator from New Mexico.[18] The purpose of this bill was to establish a national Renewable Electricity Standard, amending the PURPA of 1978. To promote clean and domestic sources of electricity, the legislation requires sellers of electric utilities to obtain 15 percent of their electric supply from renewable energy resources by 2021.

To establish public tools for direct EBED investments during the great recession starting in early 2008, the Obama administration and the 111th Congress enacted the ARRA in February 2009, which was introduced by Rep. Dave Obey. ARRA's long title stated its purpose as "making supplemental appropriations for job preservation and creation, infrastructure investment, energy efficiency and science, assistance to the unemployed, and State and local fiscal stabilization, for the fiscal year ending September 30, 2009, and for other purposes."

The ARRA was launched as an economic stimulus package, but its primary objectives included investments in energy infrastructure and research and investments in energy efficiency and renewable energy. From 2009 to 2013, the ARRA devoted $816.3 billion out of $840 billion to U.S. economy, widely supporting Medicaid/Medicare, unemployment insurance programs, education, health, family services, transportation, infrastructure, housing, research and development, and job training (Recovery.gov 2014).[19] $62.5 billion, which accounts for 8 percent of the total funds, was distributed for energy innovation and environmental improvement. As shown in Appendix I, these funds

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[18] S. 3813 (2010) Renewable Electricity Promotion Act of 2010 (source: govtrack.us)

[19] Recovery.gov, the official U.S. government website for the Recovery Accountability and Transparency Board, provided and updated information about the distribution and spending of the ARRA stimulus funds. The data was accessed on 10/01/2014. Since Trump administration has opened, the ARRA website has been closed.

focused on tax incentives for energy efficient and renewable energy equipment, electrical grid development, and specified energy property grants.

On August 30, 2012, the Obama administration released an executive order to accelerate investments in industrial energy efficiency by setting a national goal of 40 GW of new, cost-effective industrial CHP by the end of 2020. The order targets a broad set of stakeholders that include states, manufacturers, and utilities (The White House, 2012).

In terms of carbon emission reduction efforts, the EPA, under President Obama's *Clean Power Plan*, proposed a comprehensive rule on June 2, 2014, and announced its final rule on August 3, 2015 to limit carbon dioxide emissions from existing fossil fuel-based power plants (U.S. EPA, 2014; 2015). This rule will help cut CO_2 emissions by 32 percent from 2005 levels by 2030. It contains state-specific goals in a rate term, which is CO_2 emissions divided by state electricity generation (pounds of CO_2 per MWh), to guide not only the mass-based CO_2 reductions but also the improved generation systems, such as demand-side energy efficiency, improved power plant operations, and reliance on low-carbon energy. Also, the rule identified the "best system of emission reduction" and provided four sets of measures, called "building blocks," that allow states flexibility to set reduction plans according to their particular circumstances and policy objectives. The four building blocks include more efficient fossil fuel power plants (e.g., heat rate improvement), lower-emitting power sources (e.g., re-dispatch from coal to existing natural gas combined cycle), increased zero- or lower-emitting power sources (e.g., nuclear and renewables), and increased demand-side energy efficiency. The rule aims to achieve meaningful emission reductions and create jobs by driving clean energy investment in existing power plants and reducing energy waste.

However, the ambitious rule has been stayed by the U.S. Supreme Court first since February 2016. On March 28, 2017, the Trump administration announced an executive order on Energy Independence (E.O. 13783) directing a review of the CPP. On October 10, 2017, the EPA under Trump administration proposed to repeal the CPP (U.S. EPA, 2017).

2.2 Green Job Creation and Energy-Based Economic Development

The term, “green jobs,” which was a mainstream agenda of Barack Obama’s U.S. presidential election campaign, represents the strategies and practices of EBED. It achieved increased salience in public discussion starting at around 2005. The idea of solving peak oil, the financial crisis, and environmental problems sustains “green statism,” leading many to think about organizing a Green New Deal (GND) (Friedman, 2007; Luke, 2009). This emerged from the thoughts of many others, such as Hertsgarrd’s (2009) *global green deal* and Jones’s (2008) *green collar economy*. They advocated the necessity of “working together” for climate change mitigation as well as for economic recovery with a “low-tech, on the ground, local level, and direct action undertaking” (Luke 2009, p.17). In the economic recession from 2007 to 2009, the GND had great traction in the U.S., following the historical remembrance of the New Deal as a collective policy experiment in the Great Depression of the 1930s. The GND advocates sought a governmental leadership that would stimulate the national economy in a sustainable way as well as a collective political movement for “the new red, white, and blue” (Friedman 2007).

The early definition of “green jobs” was provided by a global organization. The United Nations Environment Program (UNEP), International Labor Organization (ILO), and International Trade Union Confederation (ITUC) joined the green efforts, creating a Green Jobs Initiative (GJI) to assemble international information about the green employment market. Their definition of a green job is:

> “Positions in agricultural, manufacturing, R&D, administrative, and service activities aimed at alleviating the myriad environmental threats faced by humanity. Specifically, but not exclusively, this includes jobs that help to protect and restore ecosystems and biodiversity, reduce energy, materials, and water consumption through high-efficiency and avoidance strategies, de-carbonize the economy, and minimize or altogether avoid generation of all forms of waste and pollution” (United Nations Environment Program, 2008, p.35).

As this definition indicates, job opportunities across diverse economic sectors, green economic growth will result in complex effects in the transition of energy dependency from fossil fuels to clean energy. In addition, GJI addressed the important role of environmentally friendly investments, which generate direct and indirect job creation, preserve existing jobs, and promote “induced jobs” that lead to increases in employment opportunities from daily consumer spending.

At the national level, Van Jones (2008) explored the overall economic effects when the U.S. turned away from the fossil fuel-oriented economy. He defined a “green-collar” job as “a family-supporting, career-track job that directly contributes to preserving or enhancing environmental quality” (p. 12). He predicted that the future U.S. job market will flourish in five subsystems of sustainability: energy, food, waste, water, and transportation.

Soon after the 2008 presidential election, the Obama administration took action on the GND through the ARRA legislation. Following that, the Bureau of Labor Statistics (BLS) measured the number of “green jobs” and trends over time in their growth (The Bureau of Labor Statistics, 2014), formally linking the discourse of the presidential campaign to ARRA investments (Mulvaney, 2014). While the definition of a green job is vague and different studies use the term in different ways, in 2010, the BLS introduced the following definitions:

> A. Jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources.
>
> B. Jobs in which workers’ duties involve making their establishment’s production processes more environmentally friendly or use fewer natural resources.

BLS also identified 333 industries where green goods and services exist. Green goods and services fall into five groups: 1) renewable energy, 2) energy efficiency, 3) pollution reduction and recycling, 4) natural resource conservation, and 5) environmental compliance, education and training, and public awareness. BLS published green jobs data for 2010 and 2011. They found that, in 2010, the private and public sectors had about 3.2 million jobs in “green goods and services (GGS)” (definition A) and about 850,000 workers who worked more than half time on “green technologies and practices” (definition B). The GGS jobs increased to 3.4 million the next year. GGS employment accounted for 2.2 percent of total employment in 2010 and 2.3 percent in 2011.

However, these definitions still leave a lot of ambiguity. Recently, many studies of green jobs have provided regional or state analyses of the employment and income effects of clean energy programs with different scopes of green jobs. Therefore, the definitions of job growth or losses that are affected by selective policies vary widely. As policy makers have conducted these studies to predict the potential outcomes of new legislation, all of these studies generally point in the same direction—that improved energy and resource efficiency can strengthen local employment and income opportunities. Not surprisingly, the increased jobs are green jobs.

Without the use of the term “green jobs”, the U.S. DOE has continuously published the *U.S. Energy and Employment Report* (USEER) to provide and update a set of direct energy jobs data (National Association of State Energy Officials (NASEO) & Energy Futures Initiatives (EFI), 2018). The USEER was published in 2016, 2017, and 2018, upon recommendation of the 2015 *Quadrennial Energy Review*, which was initiated by the Obama’s *Presidential Memorandum* on January 2014, “to reform existing data collection systems to provide consistent and complete definitions and quantification of energy jobs across all sectors of the economy (U.S. DOE, 2015, p. 8-10).” The 2018 USEER (NASEO & EFI, 2018) developed a supplemental survey of business establishments based on the NAICS industry code used by BLS’s Green Goods and Services (GGS) survey. The energy jobs in the USEER are identified by major four sectors—(1) electric power generation and fuels, (2) transmission, distribution and storages, (3) energy efficiency, and (4) motor vehicles. The 2018 USEER estimated that the employment of electric power generation and fuels sector employed more than 1.9 million workers in 2017, which is consisted of 1.1 million of employees in traditional coal, oil, and gas sectors, and 0.8 million of employees in low-carbon emission generation technologies, including renewables, nuclear, and advanced natural gas. In particular, the 2018 USEER addressed that the bioenergy and CHP generation sectors were the fastest growing sources, “increasing employment by over 4,000 and 9,000 each or 55 percent and 51 percent (p.13)”, and natural gas jobs in electric power generation also increased by over 19,000, while solar energy employment declined by 6 percent or 24,000 jobs in 2017. Overall, the 2018 USEER concluded that the energy and energy efficiency sectors in 2017 hired approximately 6.5 million out of a national workforce of approximately 145 million, which was grown by more than 2 percent from 2016, adding 133,000 net new jobs.

A wide range of academic and consulting studies have used different kinds of models to estimate the direct/indirect/induced employment effects of clean energy policies, including I-O models and computable general equilibrium (CGE) models (Wei, Patadia, & Kammen, 2010). The early I-O analysis associated with energy policies was introduced in the late 1970s. In 1992, Geller et al. (1992) described a set of job sectors that had direct, indirect, and induced economic impacts of the high efficiency energy policies. In their study, the I-O model estimated induced employment and income growth from changes in the spending patterns of related industries. They had not yet considered the green economy sector. On the other hand, they estimated that most industry sectors would generate jobs, while a few sectors, such as refining, coal mining, gas utilities, and oil extraction, would lose jobs. They concluded that the energy efficiency scenario could lead to about 293,000 new jobs by 1995 and 471,000 new jobs by 2000 (Geller et al., 1992).

Some state governments active in energy management have also conducted statewide policy analyses. In California, Roland-Holst (2008) studied the statewide economic impacts of energy policies and climate adaptation, and found that about 1.5

million full time jobs with a total payroll of $45 billion were created. This research posited that California's economic sustainability and stability could be achieved through innovation and technological neutrality. In other words, technological change in favor of energy efficiency can make an essential contribution to energy use intensities, productivity, and other innovative features that have been an important component of economic growth and employment stimulus to the state economy.

The job estimates in these studies are not fully comparable due to geographical and sectoral differences. In addition, even where similar methods were used, model projections vary widely, since they are dependent on baseline assumptions and model parameterizations. Nevertheless, Laitner and McKinney (2008), Carley et al. (2011), and Wei et al. (2010) compared the job estimates of previous studies and provided the average employment over the lifetime of a facility (e.g., job-years/GWh) for each energy efficient technology.

In terms of energy efficiency and jobs, three studies provide examples of empirical analyses on associated job creation. First, Laitner and McKinney (2008), in reviewing 48 reports from 1992 to 2008, concluded that a 20-30 percent energy efficiency gain within the U.S. economy might lead to a net growth of 0.5 to 1.5 million jobs by 2030; the average among all studies reviewed was a net benefit of 49 job-years per TBtu of savings (Laitner & McKinney, 2008). Second, Brown et al. (2010) also estimated employment impacts, focusing on nine energy-efficiency policies[20] that are

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[20] The team proposed nine energy-efficiency policies for the South. It includes: for residential building, four policies—appliance incentives and standards, residential retrofit and equipment standards, expanded weatherization assistance program, and building codes with third-party verification, for commercial buildings, two policies—aggressive commercial appliance standards and commericial retrofit incentives, and for industries, three policies—process improvement, assessments of plant utility upgrade, and CHP

assumed to be adopted throughout the South census region. By using I-O model developed by the ACEEE, they addressed that the nine aggressive energy-efficiency policies could create 0.38 million jobs by 2020 and 0.52 million jobs by 2030 for the Southern economy while saving costs on electricity and natural gas consumptions through improved energy effiency. Third, the most recent study by Baer, Brown, and Kim (2015) evaluated more diverse employment impacts associated with industrial CHP expansion, by adding a concept of second-order impacts that indicate new jobs created by the redirection of energy-bill savings from the lower electricity prices that result from increased end-users' reliance on energy-efficient CHP system[21] (Baer, Brown, & Kim, 2015). They argued that 0.036 million jobs will be created on average between 2030 and 2035 if 30% ITC policy is implemented for industrial CHP technology users. This includes job growths in the first-order from new construction and installation (0.08 jobs/GWh), operation and maintenance (0.09 jobs/GWh), increased natural gas demand (0.26 jobs/GWh), and second-order jobs from residential and commercial respending (0.33 jobs/GWh), but also includes job losses from reductions of centralized utility generation (-0.45 jobs/GWh).

One more study by Pollin et al. (2009) examined broader economic impacts of the ARRA stimulus program. Their results of job estimation suggested that roughly 2.5 million new jobs would be created throughout the nation by spending 150 billion dollar a year from goverment and private-sector clean energy investments over the decade, even

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incentives—were proposed. They estimated the amount of spending for these policies implemtation would be 17 billion dollar in 2020 and as many as 22 billion dollar in 2030. However, cost savings from reductions of electricity and natural gas demand would be approximately three times grater than the investments (see Table 6.7 of Brown et al., (2010) for more details).

[21] The price effects induced by increased energy efficiency and demand reduction (so called Demand Reduction Induced Price Effects (DRIPE)) has recently received attention in the field of energy efficiency research. For more details, see Laitner (2009) and Laitner et al. (2010).

after taking into account the 0.8 million job losses in conventional fossil fuel sectors (Pollin et al., 2009). Another more recent study estimated that doubling U.S. energy productivity[22] by 2030 could create 1.3 million jobs, while increasing the GDP by 2 percent (Houser, 2013).

The number of jobs created per $1 million spending (named employment coefficient) can be a common indicator to compare across these studies. The Input-Output model provides the estimation of direct, indirect, and induced employment coefficients by industrial sector, which is calculated based on annual tracking of the national gross output of the transactions among diverse industries and government agencies (Miller & Blair, 2009). Table 3 shows employment coefficients by job sector that are used in three studies. As three studies analyzed different packages of clean energy investments, the categories of job sectors are different. In addition, each study calculated the employment coefficients by applying own designs of selective industries and weights under each job sector category. Therefore, the job coefficients and job estimates are not fully comparable across studies.

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[22] Energy productivity, measured in $output/unit energy, is the reciprocal of energy intensity.

Table 2.1 Employment Coefficients by Sector in Three Studies

Job Sector	Total Job Creation (Jobs/$2009 M)	Reference
Energy Efficiency		
Construction and installation from nine EE policies	16.94	Brown et al. (2010)
Construction and CHP installation	14.50	Baer, Brown, and Kim (2015)
Building retrofits	17.20	Pollin et al. (2009)
Mass transit/freight rail	22.97	Pollin et al. (2009)
Smart grid	12.88	Pollin et al. (2009)
Fossil Fuels		
Natural gas	8.68	Brown et al. (2010)
Natural gas	6.60	Baer, Brown, and Kim (2015)
Coal & petroleum	7.40	Baer, Brown, and Kim (2015)
Oil and natural gas	5.36	Pollin et al. (2009)
Coal	7.11	Pollin et al. (2009)
Utility		
Electricity	5.80	Brown et al. (2010)
Electricity	5.70	Baer, Brown, and Kim (2015)
Second-order	15.50	Baer, Brown, and Kim (2015)

Therefore, in terms of methodology, despite the strengths and applicability of I-O modeling, most studies have acknowledged the inherent limitations of the method. In fact, the results of job analysis should not be taken as firm predictions because they highly depend on static assumptions and selective parameters. Therefore, further sensitivity and uncertainty analyses are often performed to assess a variation of estimated value (Baer et al., 2015; Brown et al., 2014).

Behind the growth of the analytical approaches to the green economy, there are skeptical views of "green," because the mechanisms shaping labor market outcomes are more complex than suggested by the numeric evidence in the existing literature. Morriss et al. (2009) pointed out the mythologies of this rapidly growing literature. Even though government mandates, subsidies, and technological interventions can provide massive benefits, the green job literature is deeply defective by making dubious assumptions about economics, forecasting, and technology. They first pointed out that there is still no standard definition of green jobs. Therefore, green estimates might not necessarily be related to productive employment, as in producing goods and services. In terms of analysis methodology, the job estimates are not reliable, since the studies are built on faulty economic models based on dubious assumptions. Meanwhile, the direction of green job policies could go away, since government actions for promoting more jobs instead of more productivity may ultimately generate stagnation (Adler, 2000; Morriss et al., 2009). In addition, it is often argued that firms and people have the talent and skills to react efficiently to market demands, without government-led technological improvement (Morriss et al., 2009).

2.3 Innovation Diffusion Theory: A Conceptual Framework for Hypotheses Design

I assume that innovation diffusion theory can provide an explanatory framework to answer my research questions and assist in my associated hypotheses development. A wide range of studies on economic growth and development have attempted to define the patterns of innovation and diffusion and how they affect technological advance and economic development. The focus in my dissertation is on the mechanism of diffusion, particularly by the firms as adopters of new technologies based on their nature of self-transformation in competitive market as well as actors in regional economic development, and the role of policy environments in the process of diffusion that involves early adoptors and laggards with regards to clean energy and climate actions.

2.3.1 Fundamentals of Innovation Diffusion Theory

Innovation theory provides knowledge about the process of technological change in three stages: invention, innovation, and diffusion (Schumpeter, 1934). Invention describes the original development of novel process of production while innovation entails actual introduction of new products or knowledge and its tentative economic utilization. Diffusion describes its introduction by adoptors (or competitors, see discussions on evolutionary process in next section) and entails further innovation on the part of both producers and consumers. Schumpeter introduced the distinction of three stages and viewed innovation-originated market power as stronger than the power of the invisible hand and price competition to revive economic change.

After Schumpeter, while a variety of studies have attempted to define the nature of innovation and have developed multiple models to explain what drives diffusion, this research focuses on Rogers's (2003) definition of innovation, "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p.12), and diffusion, "the process in which an innovation is communicated through certain channels over time among the members of a social system" (p.5). Here, the four main elements that expedite diffusion are: (1) innovation (including entrepreneurship), (2) communication channels, (3) time, and (4) social learning systems. Therefore, he characterized diffusion as a kind of “social change” in which participants create and share knowledge in the structure and function of a social system. The diffusion can happen generally not only in spontaneous conditions (e.g., a political revolution, a natural event, or a government policy change), but also in planned spread of new ideas and technologies (Rogers, 2003). This research explores a stream of cultural economy theory in depth later to understand a nexus of innovation, social learning, intra- or inter-firms communication, regional cultural structure, and economic development.

Rogers (2003) notes that the term, *innovation*, can be used as a synonym of *technology* so that diffusion can be analyzed in a conceptual framework of *technological innovation diffusion*. *Technology* encompasses a mixture of hardware and software, which illustrates a combination between a tool and the way it is used. Thus, the innovation adoption process essentially includes “an information-seeking and information-processing activity in which an individual is motivated to reduce uncertainty about the advantages and disadvantages of the innovation” (Rogers, 2003. p. 14). He also identified a time-ordered sequence in five stages, explaining how firms would perform the decision process of innovation adoption (or rejection):

> *(1) Knowledge function*, in which the individual is exposed to the new knowledge of the innovation,
> *(2) Persuasion*, in which the individual shows an initial sense that is favorable or unfavorable about the innovation,
> *(3) Decision*, in which the individual engages in activities to adopt or reject the innovation,
> *(4) Implementation*, in which the individual applies an innovation by intention, and
> *(5) Confirmation*, in which the individual decides to reinforce the implementation or to reverse this decision.

At each stage, there is a selection process and feedback, but these do not automatically lead to the next stage. The selection process would be the decision between innovation adoption and rejection. In the process of innovation adoption, the diffusion goes along with innovators, early adopters, early majority, late majority, and laggards by the dimension of time. After all, the basic elements of innovation diffusion that Rogers established in 1962 have applied to further research on the innovation diffusion theory, the economics of innovation, and economic development.

Therefore, Rogers's framework of innovation diffusion can be widely used to explain the drivers and barriers of clean energy technology adoption (or rejection) by firms. This research uses his definition of innovation as well as the conceptual framework of the diffusion process. It will provide the rationales of the four categories of missing points in green job discussions that were depicted in Figure 1.1.

Meanwhile, innovation theorists have explained different attitudes of innovation adoption across regions and seek an explanatory variable from observations about the pattern of policy process with the concept of *policy entrepreneurship*. While the term, entrepreneurship, represents firms' innovative actions of clean technology adoption throughout this dissertation, the "policy entrepreneurship" describes the emergence of policy entrepreneurs who lead policy change (Mintrom & Norman, 2009). Following a stream of policy change theories, particulary policy incrementalism (Lindbloom, 1959), policy streams (Kingdon, 1995), and advocacy coalition (Sabatier & Weible, 2007), Mintrom and Norman (2009) suggest that four elements are central to policy entrepreneurship: displaying social acuity, defining problems, building teams, and leading by example. Policy entrepreneurs are able to discern windows of opportunities for policy action (Kingdon, 1995), and act rapidly along with their early creation of advocacy coalitions, their patient efforts to keep their personal and professional networks, and their recognition of the value of incremental gains from policy change (Mintrom, 1997; Mintrom & Norman, 2009). In terms of energy efficiency and renewable energy policies, environmental policy entrepreneurs who share beliefs of climate change and advocate necessary efforts for clean energy expansions and greenhouse gas reductions put the energy issues onto state legislative agendas. Their actions involve strong coalitions from the group of governors, industry, and interest groups. As Rabe (2008) argued, environmental policy entrepreneurs often emphasize the advantages of clean energy promotion for economic development, which could result from development of clean energy technologies.

As this research aims to address why clean energy policy impacts have revealed different attitudes in terms of clean energy profiles and employment consequences, This chapter explores literatures about a innovation adoption gap between energy management states and *laissez-faire* states. Thus, my research questions include **"How different is the intensity of clean energy policies adopted by regions (states)?" "Why?"** and **"How would differences in policy entrepreneurship cause different performances of clean energy (CHP and DG) generation and job market?"**

2.3.2 Innovation Adoption and Economic Development

Innovation adoption is a critical step of technological advancement. A wide range of scholars, in both economics and associated other disciplines, have been studying technological change as proceeding through an “evolutionary process” (Cohen et al., 1996; Dosi, Marsili, Orsenigo, & Salvatore, 1995; Dosi & Nelson, 2010; Freeman, 1994; Metcalfe, 1994; Mokyr, 1990, 2010; Nelson, 1993; Schumpeter, 1934; Stoneman, 1995). As mentioned above, Rogers (2003) and other scholars, such as Schumpeter (1934) and Stoneman (1995), also viewed innovation as technological change progress.

The base of this evolutionary approach can be first found from Adam Smith (1776)’s definition of modern capitalism that is driven by workers’s (Smith called “philosophers” or “men of speculation” (p.21)) productivity in the processes of trials and errors, gross mistakes, and unexpected successes (Smith, 1776). Many scholars (Atkinson, 1993; Boothroyd & Davis, 1993; Bradshaw & Blakely, 1999) have applied Smith’s concept to explain technological and industrial change by which firms persistently search for and adopt new skills of production and new technologies, as well as new economic behaviors, as means of surviving over their competitors.

Dosi and Nelson (2010) highlighted that technological advance is acquired through well-codified knowledge (technology as designed “recipes”), learning-by-doing experience (technology as “routines” or “make or do things”), and a set of incremental procedures for shaping artifacts in input-output relations, rather than through formal training. Using Schumpeter (1934)’s distintion between innovation, inventioin, and diffusion, Dosi and Nelson developed *Schumpeterian competition* where heterogeneous firms compete on their products and services and get selected, with some firms growing, some declilning, some disappearing (so called “creative destruction” by Schumpeter (1942)), and some always entering on the belief that they can be successful in the competition. Such processes of competition and selection are played by continuous firms’ efforts of learning by doing, imitation, innovation, and adaptation. In evolutionary perspective, the learning processes become a powerful driver of innovation diffusion, which ultimately lead to industrial structure change and economic development (Cohen & Levinthal, 1990; David, 2005; Dosi et al., 1995; Freeman, 1994; Metcalfe, 1994; Mokyr, 1990; Nelson, 1993). In particular, as Metcalfe et al. (2006) argued, the growth of employment is mutually linked to the growth of productivity and industrial output that are determined by multiple connections between investment, innovation, and structural transformation in the market process. In this context, this research developed hypotheses based on an assumption that job creation would have a close relationship with the regional tendency of innovation adoption. The existing literature rarely measures this relationship.

2.3.3 Innovation Diffusion and Regional Economic Development

A body of economic growth research has developed models and theoretical framework about drivers of innovation diffusioin, including industrial productivity growth, cooperative networks among firms, the role of university-industry interactions, and a variety of government programs and policies supporting technological advance, which would not have emerged without an innovation-driven evolutionary process. Here, a fundamental notion is that firms essentially seek economic profits. Stoneman (1995) argued that the sellers of new technology would make economic profits when innovations diffuse. The profits may lead to a reaction to do the next steps of invention and further innovation.

The reasons why companies prefer to co-locate with related industries reflect the drivers of innovation diffusion and Rogers's four elements of innovation diffusion. Firms co-locate to take advantage of agglomeration economies, such as sharing common infrastructure, local labor pools, incremental technologies, operation services, and transportation costs (Clark, Huang, & Walsh, 2010). This concept of "localization externalities" was theorized by Alfred Marshall (1890) on 19th-century industrial districts. By the early 1990s, a stream of regional economic development research has continued to explain the rise of aggolomeration economies, which has been developed to contemporary 'cluster' economy (Porter, 1994, 1998), and the growth of local institutional infrastructure of specialized services and networks. The neo-Marshallian research argued that the localization externalities allow small firms to enjoy the benefits of local 'industrial atmosphere' for knowledge accumulation and creation (Martin and Sunley, 2001; Marshall, 1890). By doing so, the "knowledge spillover" effects stimulate technological improvement and diffusion through the exchange of ideas and technologies among individual companies. These approximation economies would satisfy Rogers's conditions, shaping communication channels and the social learning system and fostering the rapid adoption of innovations over time.

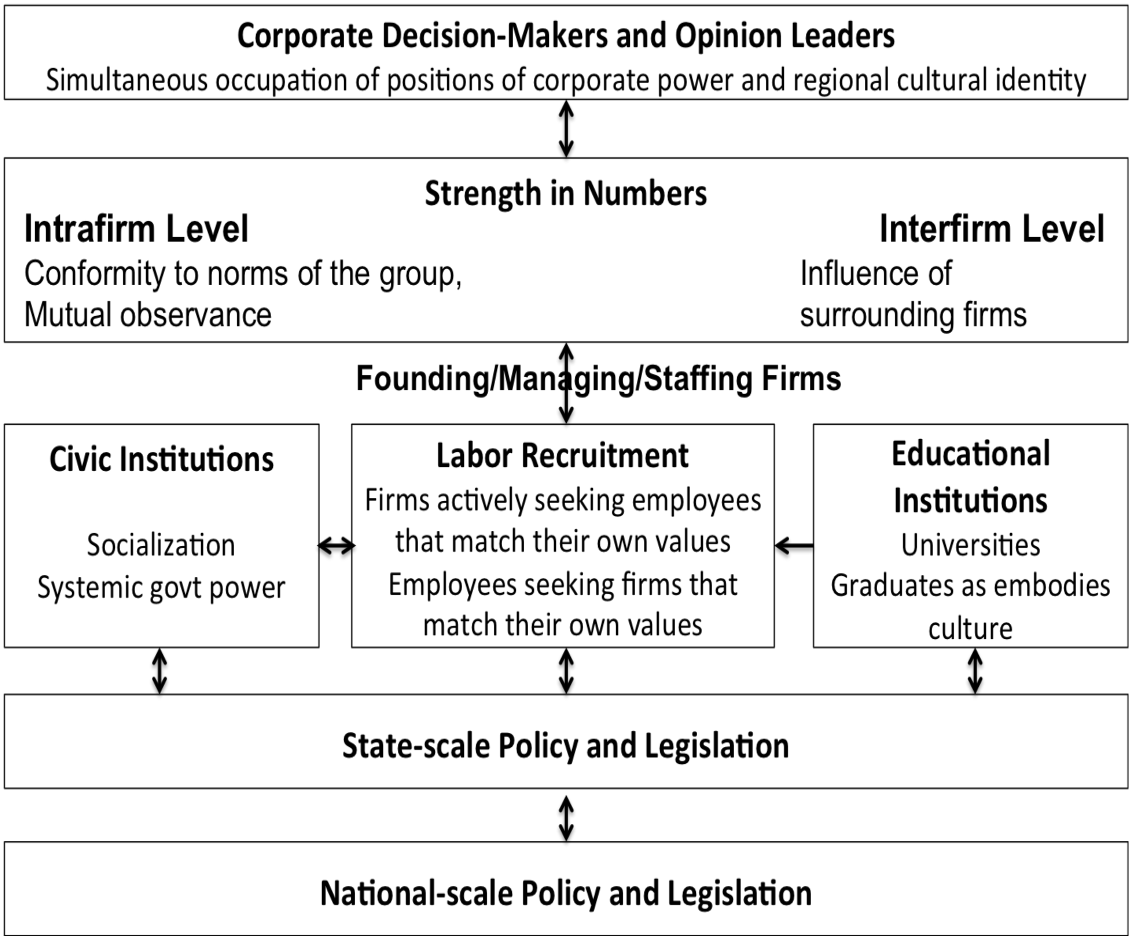
Since the early 1990s, a new research stream has focused on the emergence of regionally specific cultures in shaping local knowledge production, learning and innovation, knowledge exchange, and hence economic growth and development (Storper, 1995a; MacKinnon et al., 2002). Among them, Saxenian's comparative study between Silicon Valley and Boston's Route 128 (1994) provided empirical evidences of the competitive benefits of the cultural economy on innovation creation and adoption.

Saxenian argued that two regions successfully formed industrial agglomeration economy in the market of information technology and semiconductor industries, but faced differences in performance during 1980s' economic downturn. Silicon Valley rebounded and stabilized the leadership in the world market while Route 128 stumbled. She addressed that the Silicon Valley's success cannot be explained without a caution of socio-cultural structures and institutions of a local economy that promote learning, entrepreneurship, knowledge creation, and diffusion (Saxenian, 1994). She argued that the key reason was California's distinctive atmosphere among local industries. This is demonstrated by California's openness to risk-taking; respect for entrepreneurship; wide acceptance of failure as a learning process; rejection of traditional hierarchy systems; and ability to exchange knowledge through informal social networks, professional clubs, university-industry interconnections, and cross-firm labor mobility (Saxenian, 1994). This contrasts to Route 128's conservative business culture: social hierarchy ties, stability, risk-aversion, lower levels of cross-firm interactions, and regional learning.

Building on Saxenian's study of regional cultural economy, regional economists and other scholars have developed theoretical frameworks and empirical analyses to understand the role of regional socio-cultural systems on innovation and economic development. Among them, James (2005, 2007, 2011) developed causal mechanisms linking regional culture to economic growth. He argued that regional innovative culture is reinforced through a series of employment mechanisms, involving: (1) labor recruitment culture, in which firms seek employees that match their innovative culture, (2) educational mechanisms, in which universities and educational institutions teach and share values, norms, and beliefs that have been established along with the firms that subsequently employ their graduates; (3) socialization programs offered by civic institutions that provide a social glue and activities over members; and (4) local, state, and national legislations that strengthen the power of the employer as well as support the right of employee in the workplace (Figure 2.2).

Figure 2.2 The Mechanisms of Regional Cultural Economy and the Role of Employment

(Souce: James, 2007 p. 409)



The James's (2007) conceptual framework provides a rationale that explains how regional culture structures and policy environments promote innovation adoption, and hence activate employment market. James (2011) argued that the causal mechanism can be realized through “which the cultural influences on firms’ learning and innovation behaviors and overall performance are (re)produced on an everyday basis” (p.254). This notion emphasized the importance of routine practices and active intra- and interfirm communications for clean energy technology deployment or energy saving efforts by firms or by policy-makers. As Rogers (2003) proposed the important role of communication channel, time, and social learning systems on innovation diffusion, firms’ behaviors in regard to clean energy and climate mitigation could be increased when locally dominant socio-cultural norms, values, beliefs and conventions play a significant role in shaping routine cross-firm learning for the use of cleaner and more efficient energy technologies. The complex firms’ decision-makings of new technology adoption are not rigid or static, but change over time along with cross-firm interactions and related policy changes in innovative milieu. For example, once an entrepreneurial firm successfully installs CHP systems and operates with lower energy costs, other firms would be willing to imitate the innovator. It simultaneously reflects two theories of regional cultural economics and evolutionary economics, which support my hypotheses design to figure out a nexus of clean energy policy, technological adoption, employment, and regional economic development.

2.3.4 Clean Energy Policy and Innovation Diffusion

The innovation diffusion process can or should be stimulated by policy implementation, because it is difficult for firms or individuals to capture immediate utility from innovation adoption if left to the market alone. The base of the policy intervention on the potentially harmful consequences of economic activities on the environment involves a concept of “externality,” in which the firm does not have an economic incentive to minimize the external costs of pollution. Environmental and energy policies attempt to equalize this imbalance by raising the incentive for a firm to minimize the externalities. Policy tools are generally designed in one of two general ways—either by financially internalizing the environmental costs (regarding clean energy, financially subsidizing technology adoptions for increasing renewable energy and energy efficiency), or by imposing a limit on the level of environmental pollution (regarding clean energy, setting a goal on the level of renewable energy or setting a standard for the level of energy efficiency) (Popp, Newell, & Jaffe, 2010).

For example, in clean energy and climate actions, the diffusion of new energy technologies would be hampered by the nature of market failure that clean energy policy makers might be concerned (Grossman, 2009; Levine et al., 1994). Consumers do not necessarily care which sources of electricity generation that they use, but are very concerned about how much they will pay. A new energy technology could potentially be worth billions of dollars in the long term, but entrepreneurs must bear considerable development costs while their benefits are uncertain. The problem of uncertain or non-excludable benefits, but fully internalized development expenses, means that entrepreneurs will be reluctant to invest in innovative clean energy technologies, which will consequently be undersupplied if left to the market alone (Popp et al., 2010). Therefore, government intervention, such as the state goals for renewable energy generation or energy efficiency standards, could be good news for both clean energy technology manufacturers and consumers since it plays a significant role in guaranteeing the steady marketability after innovative technology adoption.

Asymmetry in states' renewable energy standards is another example of a renewable electricity market failure. If an RPS program is to be implemented across the nation, all state governments should find a way to connect a federal policy and existing local policies. However, the existing renewable energy policies in the U.S. vary by states. Some state governments have gradually engaged in adopting a statewide RPS or strengthening existing requirements, but other state governments seem to take *laissez-faire* actions. By 2017, only 29 states and the District of Colombia have RPS and seven states have goals to enact it. This might be a natural reaction, since there are no incentives for innovators to bear clean air costs because it is a public good. Even though RPS could provide a market-based solution to mitigate the inevitable gaps from trading renewable energy or energy efficiency credits among states and then competitive reactions in renewable energy adoption, these different state attitudes may lead to dissimilar performances in their innovative technology adoption and job creation.

Therefore, the inherent characteristics of clean energy market could be obstacles in creating energy-related job opportunities. In general, firms make decisions to maximize their market profits. Adopting technological change might be a challenge to their business strategies. Then, the firms' innovation decision, implementation, and confirmation will affect employment decisions, such as whether to hire or fire in a certain sector. Hence, an important link between the evolution of individual firms and aggregate market dynamics rests upon their changing shares of output and employment (Dosi and Nelson, 2010).

2.3.5 Diffusion of Clean Energy Policy

A great deal of literature has suggested how and why policy innovation diffuses across states. Under the traditional theory of policy diffusion, researchers have tested policy diffusion as a function of policy learning and intergovernmental competition, which is exhibited when states emulate successful policy implementations of earlier adopter states (Baybeck, Berry, & Siegel, 2011; Berry & Berry, 2007; Berry & Berry, 1990; Boehmke & Witmer, 2004; Matisoff & Edwards, 2014; Mintrom, 1997) or when states compete for economic development (Baybeck et al., 2011; Saikawa, 2013; Shipan & Volden, 2008). In the literature on policy innovation and diffusion, two major models have been employed to explain fundamental processes and determinants of policy diffusion—one is the internal determinants model and the other is the regional diffusion model. With recognition of a need of climate change mitigation and clean energy development, a growing number of literatures have applied these two models to examine the determinants of state clean energy policy adoption and diffusion.

First, the regional diffusion model examines state policy adoptions as emulation of earlier adoptions by other states. State policy makers are more likely to adopt a proposed policy when uncertainty can be reduced by referring to neighboring state experiments. Walker (1969) created a framework of the diffusion processes of policy innovation, which illustrates a new program diffusion initiated from political leaders' awareness of adoption of new programs in other states. In the framework, interstate communications are an important factor enabling policy diffusion. Using a factor analysis of the diffusion of 88 programs from the time period of 1870-1966, Walker (1969) concluded that the states can be grouped into five cohort regions. The states in each group are not neccessarily geographic neighbors, but share a specialized set of communication channels based upon similar political and economic culture.

Berry and Berry (2007) applied the regional diffusion model to explain the process of state government policy diffusion as an intergovernmental emulation process. State governments learn from one another, compete with each other, and possess a federal system, which means states have pressure to obey the rules that are accepted nationally. Berry and Berry (2007) argued that decisions of innovation adoption and rejection resulted from the hypothesis that states emulate each other. As shown in Figure 2.3, for example, the number of state adopters of a RPS program has increased over time to 2010.[23] In addition, states are influenced primarily by those states that are geographically proximate; for example, eight states grouped in the Southeast have not engaged in creating RPS programs (Figure 2.4). Berry and Berry (2007)'s application of innovation theory is consistent with Rogers (2003)'s typology of the innovation-decision process.

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[23] Some states have taken steps toward weakening or eliminating RPS laws. For example, on June 13th, 2014, Ohio Governor John Kasich signed into Senate Bill 310, which freezed the original RPS goal for two years so that extended the current goal (at least 12.5% of total energy from renewable sources by 2025) to 2027 (Mufson & Hamburger, 2014). The governor and other proponents of the freeze suggest to reevaluate the efficacy of RPS. They argue that requiring utilities to produce their electricity from renewables distorts the free market (Energy and Policy Institute, 2014). Since renewable sources such as wind and solar have become cheaper and accessible in recent years, they should compete against non-renewables on the free market. These current debates will be discussed while I analyze the intensity of clean energy policies in the Chater 6 of multi-case study.

Figure 2.3 Timeline and Location of RPS Adoption in 29 States and DC

(Created by author from the data source: DSIRE, 2018)

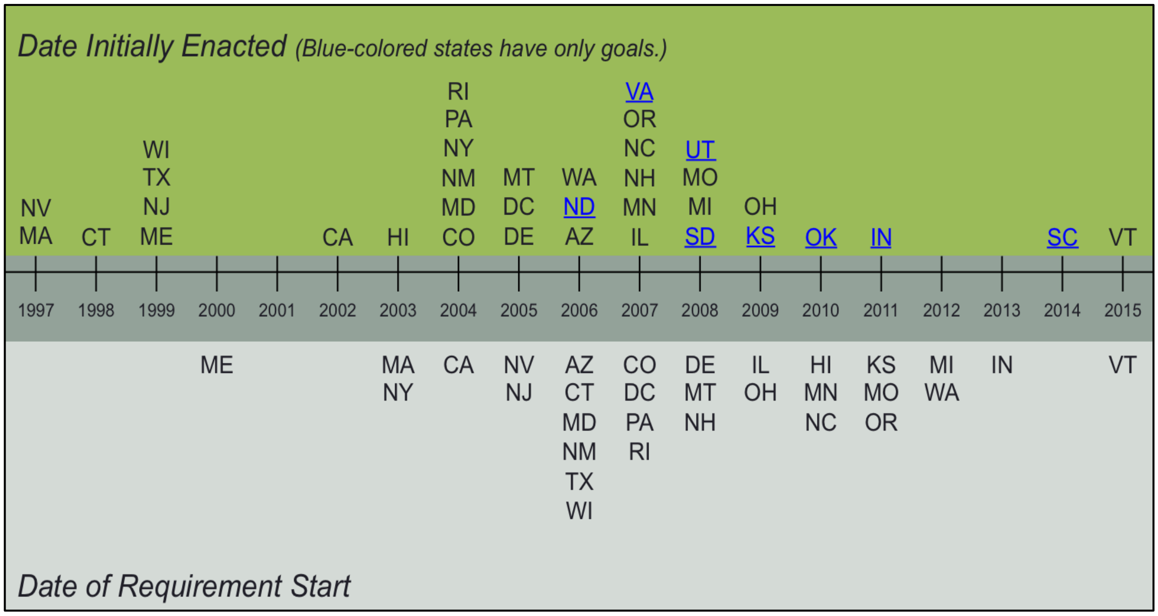
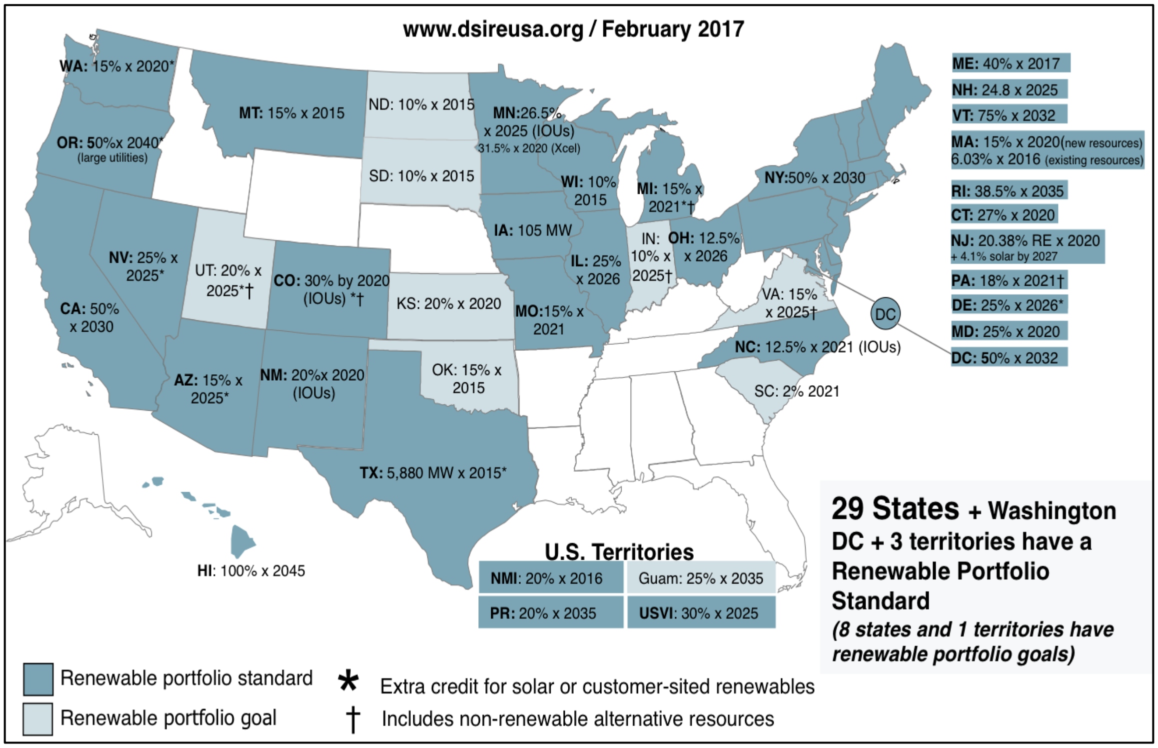


Figure 2.4 RPS Adoption in 29 States and DC

(Source: DSIRE, 2018)



Next, an internal determinants model allows an explanation of what makes states more likely to adopt policy innovations. As discussed above, although the federal government tries to require a certain level of renewable energy production and consumption, like the ARRA fundings and the proposed CPP rule implemented by the Obama administration, state governments can decide to adopt the alternative energy strategies or not, considering their own internal determinants. Matisoff and Edwards (2014) and many other researchers use the internal determinants model and provide sufficient evidences of what drives the adoption of renewable energy and energy efficiency policies.

Stream (1999) identified five main categories of internal determinants on state health-reform policy adoption: political context, fiscal health, problem severity/demand, and regulatory stringency. Matisoff and Edwards (2014) developed an empirical model by applying Stream's categories into the processes of clean energy policy diffusion across states. Using an event history analysis model, Matisoff and Edwards found statistically significant correlations between states internal determinants and the likelihood of policy adoption, such as;

- Political context: Liberal states are more willing to adopt innovative clean energy/climate change policies,
- Problem severity/demand: States with worse air quality get more pressure to adopt new policies,
- Fiscal health: States with higher tax revenue have higher capacity to implement new policies, and
- Regulatory environment: Higher citizen engagement can be a driver to improve policy adoption.

Among these internal determinants, Matisoff and Edwards (2014) demonstrated that political culture is the most consistent and predictive determinant on the adoption and diffusion of clean energy policies, while the impacts of other internal determinants vary for different types of clean energy policies. This finding supports that political culture is the most important determinant of policy diffusion in Walker (1969)'s five grouping of states. In the same context, Bauer and Steurer (2014) argued that an important factor of clean energy policy diffusion is due to intergovernmental competition based on policy learning from cohort states, defined by cultural, historical, and political similarities, rather than geographical. On the other hand, Matisoff and Edwards (2014) suggested evidences explaining some clean energy policies are not necessarily the outcome of intergovernmental competition. For instance, public benefit funds, personal tax credits, rebates, and energy efficiency mandates are unlikely to generate intergovernmental competition because these policies would promote environmental goals, but do not provide "a direct economic pay-off to states because they reduce spending and tax revenue (p.799)."

Some scholars argued that state policy innovation diffusion needs to take into account a unified theory of internal determinants and regional diffusion. For example, Berry and Jaccard (2001) argued that the use of the RPS program is spreading in the U.S. as well as European countries and Australia because "it maintains an incentive for renewable producers to reduce costs, links the regulated market outcome to an environmental target, and reduces government involvement (p.263)." The regional diffusion of certain clean-energy policies, therefore, may be due to a relationship between regional diffusion and intermal determinants.

Chapter 3 Research Questions, Hypotheses, and Methodology

3.1 Research Questions and Hypotheses

As noted, this research began from recognizing the lack of theoretical approaches and empirical analyses in current EBED strategies and raised two main questions: *How do clean energy policies affect clean energy deployment and job creation?* and *What would a technological shift to clean and efficient energy mean for regional competitiveness?*

There are three main areas of inquiry I will investigate: first, whether state clean energy policies (defined in Section 1.2) successfully influence DG technologies' adoption at the state level, by comparing the historic trends of energy generation diversification and industrial sector changes associated with CHP generation growth; second, how the elements of innovation diffusion (identified by Rogers) impact CHP technology adoption (in numbers of generation units) and energy production (in capacity); and third, how job creation is affected by CHP technology diffusion and the different levels of clean energy policy implementation in the U.S..

Through the identification of key research gaps between existing empirical analyses and theoretical approaches, I proposed my research sub-questions and hypotheses, as summarized in Table 3.1. The next section details the proposed method that will be used to test the hypotheses.

Table 3.1 Research Questions and Hypotheses

	Hypotheses	Justification
RQ1. How do state clean energy policies affect the expansion of technological innovation adoption by end-use consumers? 1-1. What are the drivers and barriers of innovative technology adoption?		
	H1: Industries are more likely to adopt innovative technologies where the state government provides a number of policy instruments defined by Goulder and Parry's policy framework as shown in Table 1.3.	The nature of market failure in clean energy adoption justifies the role of governmental intervention, such as state goals for renewable energy generation or energy efficiency standards, which could provide the steady marketability of innovative technologies for both clean energy technology manufacturers and consumers. Section 2.3.4 discusses the nature of market failure.
	H2. Industries are more likely to adopt innovative technologies when they can be convinced of economic profitability.	A concept of *Spark Spread* suggests that electricity and natural gas prices are critical on new CHP technology adoptions.
	H3: Industries are more likely to adopt innovative technologies when they are exposed to a communication channel	Rogers (2003) defined innovation diffusion as "the process in which an innovation is communicated through certain channels over

<table>
<tr><td></td><td>of information sharing provided by state governments.</td><td>time among the members of a social system (p.5).” For local energy-based economic development and energy resource diversification, the existence of a communication channel can be an important factor to promote innovative technology adoptions.</td></tr>
<tr><td colspan="3">RQ2. How do clean energy policies affect the development and diffusion of clean energy technologies?</td></tr>
<tr><td></td><td>H4: An existing industrial base, which are distributed differently state-by-state, would be a key determinant to clean energy technology development and job creation.</td><td>Rogers (2003) suggested that a social learning system promotes innovation diffusion, and other urban economists and geographers (e.g., Clark and Huang, 2010) addressed the importance of the clustering of innovative firms and the spillover effects from their agglomeration economies.</td></tr>
<tr><td colspan="3">RQ3. How do state clean energy policies influence job creation, in terms of the time spent on clean energy initiatives and the degree of energy efficiency and renewable energy standards?</td></tr>
<tr><td></td><td>H5: States that have legislated clean energy policies earlier than other states will have experienced a higher</td><td>Rogers (2003) addressed that innovation diffusion and employment impact evolve over time.</td></tr>
</table>

	job creation.	
	H6: States that have stronger standards of EE and RE energy generation will have experienced a higher job creation.	Policy interventions correct the market failure of the clean energy market. Section 2.3.4 discusses the nature of market failure.

3.2 Methodology

The hypotheses of RQs 1 - 3 can be investigated once the intensity of clean energy policies is estimated for all 50 states. The methodology of measuring the intensity of clean energy policy implementation will be an update and an expansion of the American Council for an Energy-Efficient Economy's (ACEEE) *State Energy Efficiency Scorecard* (Berg et al., 2017), which scores the progress of state CHP policies and programs.

First, the detailed characteristics of selective clean energy policies in Table 1.3 are listed by state. The characteristics include the first year the policy was enacted, applicable sectors, the number of regulation requirements (e.g., tax credits, financial incentives, or standards), the range of eligible CHP technologies, system size, and fuel. Based on the metrics of the policy characteristics, a credit of 1 point for each criterion is added to get a total score for each state. When creating the panel dataset, credits were given for a period of policy implementations from the first year of enactment by a legislative body and more thereafter if the policy implementation continues. For example, Iowa enacted RPS in 1983, but since the RPS mandate has now been surpassed, the law is no longer driving any development in the state after 2009. In this case, I do not give credit for the RPS after 2009. In terms of eligible technology options, for interconnection standards and net metering policies, the applicability of all forms of CHP, regardless of fuel type and size, is additionally scored with an extra point, this criterion being crucial to cover smaller DG systems.

Based on the scoring method, the total policy score in each state is assumed to represent the degree of state policy entrepreneurship that Mintrom (1997) and Rabe (2008) identified as an element of innovative technology diffusion. The state policy implementation data mainly relies on secondary sources, such as the Database of State Incentives for Renewables and Efficiency (DSIRE) and the EPA's CHP Policies and Incentives Database (called dCHPP, U.S. EPA, 2016), which are available online. State legislation documents are also used to confirm the details of regulation. The results of scoring can be found in Section 4.

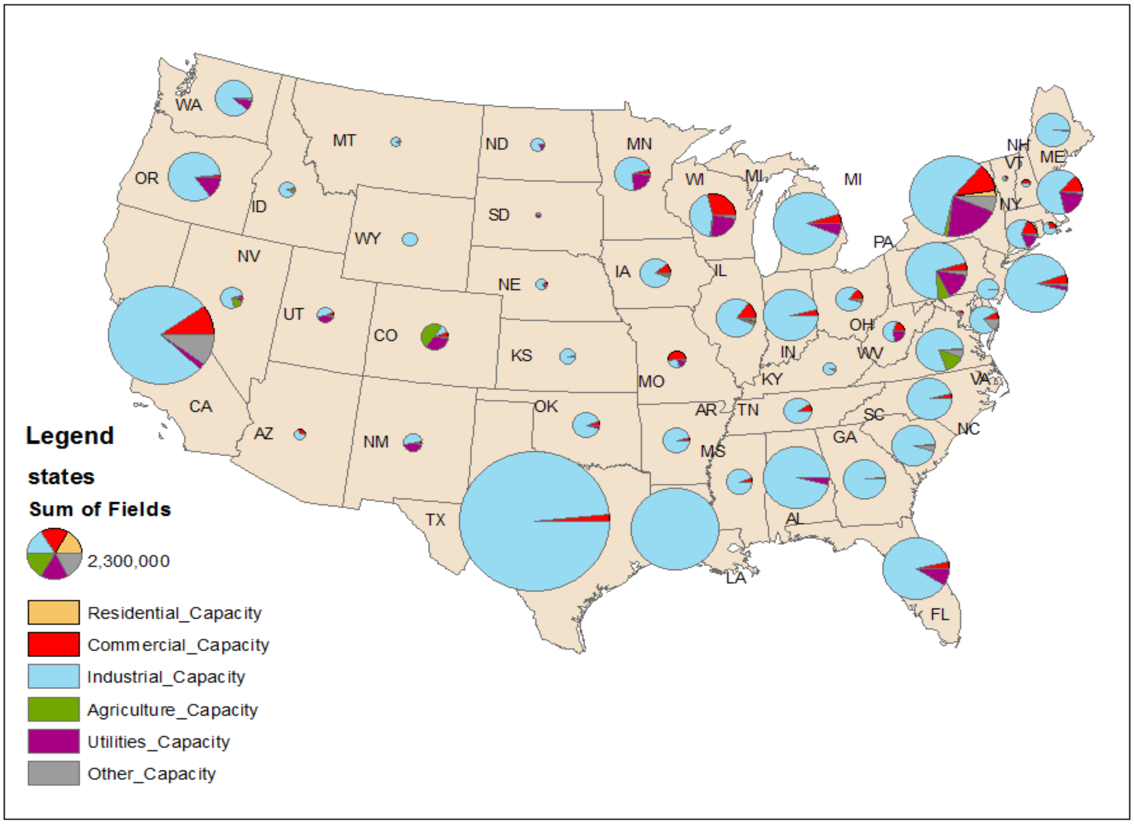
Next, the amount of each state's CHP technology capacity is measured, which is used in a panel data analysis. The data is available from DOE's CHP Installation Database (2016), which contains well-constructed data on plant-level CHP units. It is derived and annually updated by ICF International Inc. The plant-level CHP capacity is aggregated by state, year, and end-use sector. To count for small-sized CHP units, the number of CHP units are also counted by state, year, and end-use sector.

This regional diversity of CHP installations can be an important independent variable to explain the dynamics of job generation associated with DG expansion. To test the first hypothesis, I examine the relationship between the ranked score of clean energy policies and the regional distribution of CHP installations in 2016. The models are organized based on two categories—the size of new CHP capacity addition and the number of new CHP units installed in a given year. The characteristics of installed CHP technology, which include fuel sources, industrial sector (represented by North American Industry Classification System (NAICS) codes), and installation year, would also provide interesting evidence of regional differences in CHP technology adoption.

Using the Geographic Information System (GIS), Figure 3.1 illustrates the regional distribution of electricity capacity generated by a total of 4,305 CHP facilities in 2016. Some states—such as TX, CA, LA, and NY—have built a large amount of CHP capacity, but other states have not, as shown by the relative sizes of the pie charts. However, most states have installed CHP technology for industrial usage—represented by chemicals, pulp and paper products, and food processing industries.

To test the second and third hypotheses, I find a relationship between the ranked scores of clean energy policies and private-sector employment from 1990 to 2014.

Figure 3.1 Regional Distribution of CHP Capacity by Sectors, in 2016
(Data source: CHP Installation Database, accessed 10/2016, U.S. DOE)



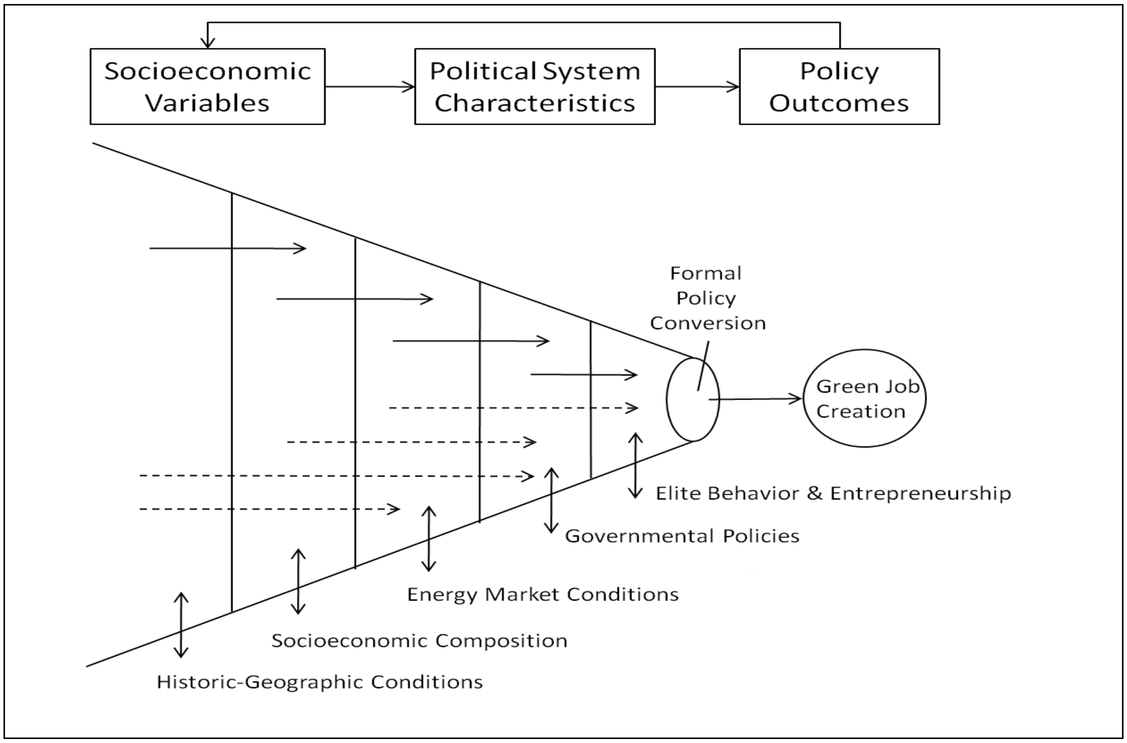
3.3 Empirical Research Model Design

I employ a comparative policy study model introduced by Blomquist (1999), which compares statewide clean energy policies and their outcomes between entrepreneurial states and *laissez-faire* states.

According to Dawson and Robinson (1963), the 50 states share common governmental structures and policy accountability, but differ in political direction, social and economic structure, and cultural composition. Therefore, a researcher can assume that the results of comparing certain variables by states will provide information on solely the policy contribution by holding the other conditions constant (Blomquist, 1999). Dye, Sharkansky, and Hofferbert (Dye, 1965; Hofferbert, 1974; Sharkansky, 1970) developed the policy process called the DSH model. The DSH model demonstrates through system theory that external and historical conditions have influenced a political system, which feeds back into the environment by means of policy outcomes (Blomquist 1999). My research framework fits well with this DSH model since the model can examine how internal and external determinants of innovation diffusion merge into policy outcomes (innovative technology adoption and employment) over time. To test my first, second, third, fifth and sixth hypotheses, I developed a quantitative analysis framework using the DSH model, as Figure 3.2 shows.

Figure 3.2 Research Design Framework for Comparative Policy Studies

(Source: Revised DSH model (Blomquist 1999; Hofferbert, 1974))



This comprehensive framework lays out a variety of independent variables affecting policy outputs (Models 1-4: CHP technology adoption). In addition to policy variables, exogenous variables such as historic-geographic circumstances and socioeconomic composition influence a policy system. Therefore, these exogenous variables are added to control for non-policy conditions. The generic form of the labor demand equation to be explored is:

$$L_{\text{group } i} = f\,(socioecon, geog, energy \;/\, policy) \qquad \text{(Eq.1)}$$

The details of each variable and data sources are explained in Section 5 and Table 5.1. These variables represent internal determinants of *socioecon*, *geog*, and *energy* as well as innovative diffusion factors of *policy*. In order to reflect time-invariant conditions such as historic-geographic circumstances, a random-effects (RE) regression model is employed to explain how clean energy policy entrepreneurship affects consumer-side CHP technology adoption within or between 51 states (the 50 states plus Washington, D.C) in a period of 1980 to 2014. The RE model can examine cross-sectional time-series data by including dummies of regions and years. Section 5 will explain the details of RE models and measurements.

Chapter 4 Evolution of State Clean Energy Policies

This chapter introduces state regulations, plans, and incentives that measure the scores of state clean energy entrepreneurship.

4.1 Energy and Climate Change Plan

State governments have established broad and long-term roadmaps to reduce GHG emissions and to have competitive energy economy. As of 2016, 33 states and Washington, D.C. published energy plans and/or climate change plans. These plans established goals of reducing GHG emissions, increasing DG/CHP/RE generations by assessing current and future energy supply and demand, examining existing energy policies, and identifying emerging energy/climate change challenges and opportunities (NASEO, 2017).

In the state energy and climate change plans, CHP is listed as an important emerging technology to reduce GHG emissions as well as to improve energy efficiency. In regards to energy reliability, CHP is listed as a technology that can provide relief to the natural gas industry, be used for back-up power, and reduce vulnerability for the industrial sector. Appendix II - Table 4.1 provides goals, key recommendations, and initiation years of state energy/climate change plans.

Hawaii was the first state to announce its state energy strategy in 2000, and could be the first state in the United States to meet 100 percent of its electricity demand with renewable resources, such as wind, solar, and geothermal. In 2015, a bill (HB 623) was proposed and passed renewable energy standards to set a goal of 30 percent of new electricity sales to be generated from renewable resources by 2020, 40 percent by 2030, 70 percent by 2040, and 100 percent by 2045. Since January 1, 2015, Section 269-92 of Hawaii Revised Statutes (HRS) requires renewable electrical energy sales to be counted towards the RPS.

4.2 Environmental and Energy Regulation

State environmental and energy regulations support CHP by outlining output-based regulations, special permitting procedures for CHP, regional initiatives, and other state laws and executive orders (Appendix II – Table 4.2).

Output-based emission regulations define emission limits based on the amount of emissions produced per unit of useful “output” (e.g. tons of CO_2 per megawatt-hour of electricity). This is in contrast with traditional input-based emissions regulations, which define limits on the amount of emissions produced per unit of fuel input (e.g. tons of CO_2 per million BTU of coal). Compared to conventional generation systems, efficient CHP systems can reduce fuel inputs and produce fewer emissions of all pollutants, not just those limited by regulations. The output-based emission standards thus can capture the efficiency benefits of CHP and other distributed generation systems, which is not recognized with input-based standards.

While increasing inclusion of output-based emissions standards helps states to encourage CHP, an important best practice is to use an "avoided emissions approach"

(Ragulatory Assistance Project, 2003). This approach allows a compliance credit against its actual emissions from thermal output displaced by a CHP system's more efficient process.

A number of state programs, such as in CA, CT, ME, MA, RI, TX, and WA, have adopted output-based emission regulations, emission standards for large and small generators, avoided emissions approach, cap and trade allowance allocation systems, and generation performance standards (Appendix II – Table 4.2). These states establish an output-based emission standard for NOx, PM, SO_2, CO_2, and/or Hg emissions from fossil fuel-fired plants.

4.3 Interconnection Standards and Net Metering

In 46 states and Washington, D.C., public utilities commissions have established interconnection standards and/or net metering rules to provide consistent standards. The standards explicitly set procedures and standards for connecting to the electric grid and enabling purchases of supplemental or backup power from the grid. Appendix II - Tables 4.4 and 4.5 identify eligible technologies, applicable sectors, and system capacity limits in each state. With the consistent interconnection standard, CHP and DG system developers can avoid complicated transaction processes and related costs.

The Interstate Renewable Energy Council (IREC) and ACEEE have evaluated the state interconnection standards and net metering rules, and presented elements of best practices (IREC, 2017; ACEEE, 2017). The ACEEE's interconnection best practices include:

- covering all distributed generation technologies (including all forms of CHP, regardless of fuel type);
- applying to a wide range of system sizes;
- offering transparent, uniform and accessible application information, forms, procedures, and including dispute resolution guidance;
- using current technical standards dealing with safety considerations and interconnection maintenance, such as IEEE 1547 and UL 1741; and
- prohibiting unnecessary external disconnect switches and requirements for additional insurance where the proposed system does not need it for safety reasons.

Net metering policies have facilitated on-site renewable generation. The net metering allows a customer-generator to receive a financial credit based on a kWh net excess generation by their onsite system, and to offset the customer's next electricity bill, usually at the same retail rate. For customers on a time-of-use rate, off-peak and on-peak kWh are tracked and credited accordingly. At the end of a customer’s 12-month billing period, any surplus NEG is reconciled through either a check or billing credit at the utility's avoided-cost rate in many states. However, the rate structure varies by state. For example, in California, the net surplus compensation rate is based on a 12-month rolling average of the market rate for energy (California Public Utilities Commision, 2018).

In addition to billing credits for NEG selling back to the grid, participating net metering customers are exempt from standby charges, departing load charges, and costs associated with interconnection application fees, studies, and distribution upgrades (e.g. Missouri).

Net metering policies can assist states in meeting their renewable energy portfolio standards because they allow customers to own renewable energy credits (RECs). For example, California, Colorado, and Florida net metering customers can receive RECs associated with excess generation and sell back to the utility. In California, this RECs payment is equal to the new surplus kWhs multiplied by the renewable attribute adder rate, which reflects an average premium utilities pay for renewable energy in order to comply with California's RPS (California Public Utilities Commission, 2018).

As of 2016, interconnection standards and net metering policies have been successfully implemented by California, Oregon, Ohio, Massachusetts, and Utah. This is consistent with IREC's scoring results (Interstate Renewable Energy Council, 2015).

4.4 Renewable and Energy Efficiency Portfolio Standard

The RPS sets a goal that utilities must increase the percentage of electricity generated by renewable energy. As shown in Appendix II - Table 4.5, utilities can meet savings requirements through a number of methods including demand side management incentives, peak demand reductions, building codes, CHP systems, self-direction, and old demand side management programs that achieved energy savings. For the CHP, both the electric and thermal outputs of renewable-fueled CHP systems are credited in many states. In general, the thermal output from CHP is credited at a conversion rate of 3,415 Btus = 1 Renewable Energy Certificate (REC), and the electricity output from CHP is credited at a conversion of 1 kWh = 1 REC (for example, Arizona).

4.5 Utility Rate Policies

The structure of utility rates and the price of fuel (mostly, natural gas) significantly impact how quickly CHP and other renewable DG customers will pay back their investments because most utilities' profitability is directly related to the amount of electricity sales and utility rates. However, deploying more DG and CHP technologies often conflicts with increased electricity generation and transmission from central utilities. Under this structure and the bold nature of utility monopoly power, a utility has essentially little to no incentive to generate their own energy on site. Therefore, smart policy options have been developed to provide win-win approaches for utilities and customers. These include decoupling, time-of-use rates, and demand charges.

The purpose of a decoupling mechanism is to remove a direct disincentive of utilities' revenue reduction from lowering retail sales by building more DG. Under decoupling, instead of linking utility revenues to the amount of electricity sales, profits are linked to the number of customers served. To be most effective in promoting energy efficiency and DG, decoupling is linked with specific targets and thus creates rewards for utilities that achieve environmental targets beyond their mandates.

Time-of-use rates aim to provide appropriate price signals to customers. As the demand for energy grows at certain peak times of the day, utilities can charge different rates for generating electricity at different times, and let customers choose to conserve energy or pay increased prices.

Utilities also offer discounts or exemptions of fees for customers with on-site power generation and/or CHP. These rates can be derived from state or federal policies, or they can come from individual utilities. Design criteria that account for CHP include a reduction or exemption from standby rates and/or exit fees, the application of daily or monthly as-used demand charges, the option to buy backup power at market prices, and guidelines for dispute resolution processes. For example, as shown in Appendix II – Table 4.6, gas companies in Arizon, California, Nevada, Connecticut, Hawaii, New Jersey, New York, and Pennsylvania offer discounted gas rates for CHP customers using natural gas for distributed power generation.

4.6 Financial Incentives

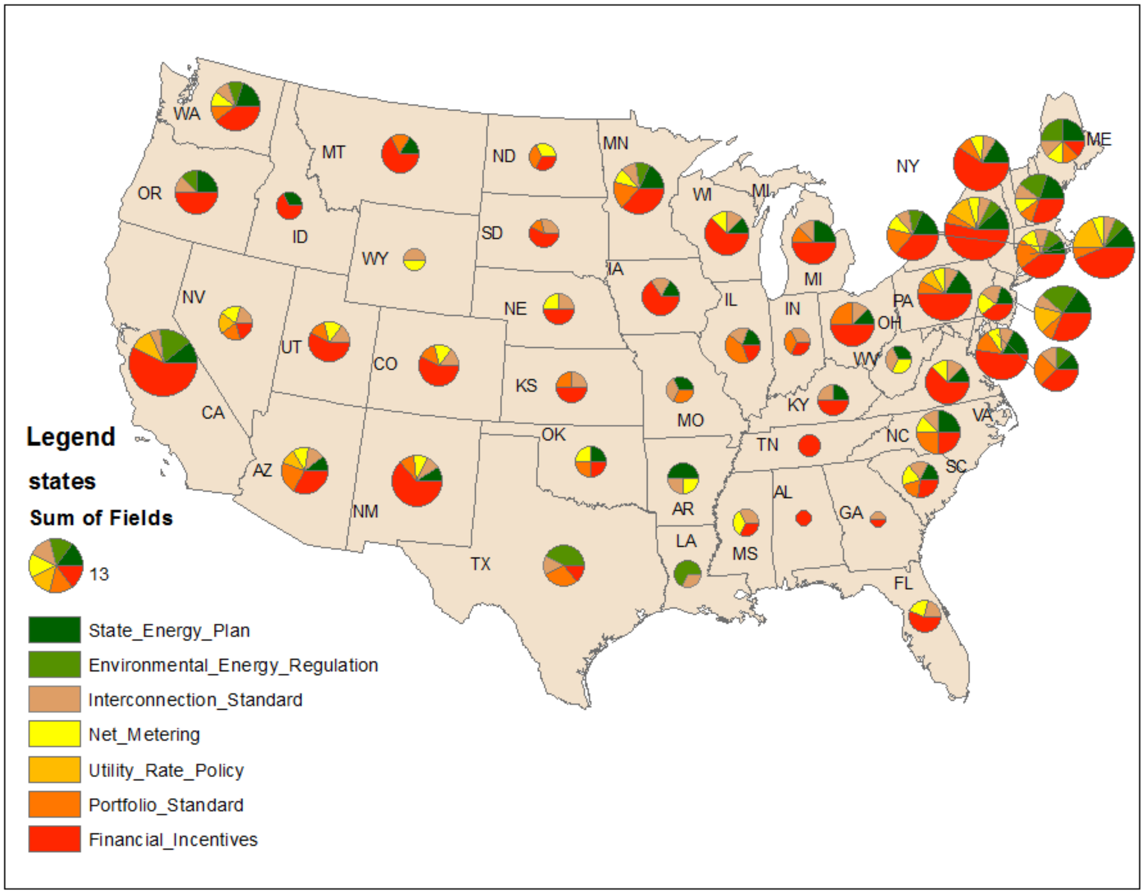
Most of states offer financial incentives in the form of rebates, tax credits, grants, bonds, and loans for developers and owners of new CHP projects, or retrofit existing systems with CHP. Appendix II – Table 4.7 provides state financial incentives for CHP projects. Public benefit funds (PBF) offer state-level incentives typically developed during electric utility restructuring by some states (e.g. Texas and Ohio) in the late 1990s to ensure continued support for renewable energy resources, energy efficiency and low-income energy programs. These funds are commonly supported through a very small surcharge on electricity consumption. PBFs commonly support rebate, loan programs, research and development, and energy education programs.

Among types of incentives, loans and loan guarantees are the most popular tool to help CHP projects move forward. The program usually prioritize low-interest and long-term payments to CHP projects. States favor loans because it requires lower burden to the government compared to tax incentives, and most of the CHP projects that apply for loans are reliable projects (Chittum and Kaufman, 2011). Investment tax credits and production tax credits are another common and helpful incentives for CHP developers and customers. Tax credits were noted to be very useful to investors in CHP systems because they can guarantee cost savings in advance of invetment. While investment tax credits help CHP developers reduce its upfront investment costs, production tax credits, such as New York's CHP Performance Program, were highly attracted by developers who have existing facilities (Chittum and Kaufman, 2011). The other type of a game changer was a feed-in-tariff (FIT). A FIT subsidizes a CHP system by a set amount per kWh generated. However, unlike a production tax credit, a FIT provides a fixed rate for years, giving a CHP consumers substantial assurance a certain premium for a certain period of years. California is the first state initiating a FIT that allows small generators (1.5 MW or less) to sell power to the utility at predefined terms and conditions.

4.7 Total Policy Score

The measurement of policy entrepreneurship is based on the summation of 0-1 scale scores of whether or not states have climate/environmental plans, environmental regulations, interconnection standards, net metering, renewable energy goals, energy efficiency requirements, and financial incentives. The score is credited after the first year of each policy's implementation unless the policy is discontinued. As mentioned in Section 3.2, an additional score is given based on whether interconnection standards and net metering allow all size and all fuel of CHP generation, which covers small-scale CHP generation. Details of state scores in 2017 are shown in Figure 4.1 and Table 4.1.

Figure 4.1 State Clean Energy Score in 2017*



* Note: Data Source: U.S. EPA dCHPP (CHP Policies and Incentives Database) & DSIRE.org (derived from 02/2016 ~ 10/2016)

Table 4.1 Total Scores of State Clean Energy Policies in 2017

State	**Score Total**	**Energy/Climate Change Plan**	**Environmental/Energy Regulation**	**Interconnection Standard**	**Net Metering**	**EE Portfolio Standard**	**Renewable Portfolio Standard**	**Utility Rate Policy**	**Financial Incentives**									
									Public Benefit Funds	Feed-in-Tariff	Commercial PACE	Production Incentive	Renewable Tax Credit	Grant	Rebate	Bond	Loan	Tax Exemption
AL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AK	4	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0
AZ	10	1	0	1	2	1	1	1	0	0	0	0	1	0	1	0	0	1
AR	5	2	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
CA	17	2	4	2	0	1	0	1	1	1	1	0	1	1	1	0	1	0
CO	6	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	1
CT	13	2	1	1	1	1	1	1	1	0	1	0	1	1	0	0	1	0
DE	7	1	1	1	0	1	1	0	1	0	0	0	0	0	0	0	1	0
DC	6	1	0	1	2	0	0	0	0	0	1	0	1	0	0	0	0	0
FL	5	0	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0	1
GA	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
HI	9	1	0	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0
ID	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
IL	5	1	0	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0
IN	4	0	0	2	0	0	1	0	0	0	0	1	0	0	0	0	0	0
IA	6	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	1	1

KS	4	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1
KY	4	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0
LA	3	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ME	10	1	2	2	2	1	1	0	1	0	0	0	0	0	0	0	0	0
MD	9	2	0	1	1	1	1	0	0	0	0	1	0	1	0	0	1	0
MA	11	1	1	2	2	1	1	0	1	0	0	1	0	0	1	0	0	0
MI	9	2	0	2	0	1	1	0	0	0	1	0	1	0	0	0	0	1
MN	10	1	1	1	1	1	1	0	1	0	0	1	0	1	0	0	1	0
MS	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
MO	3	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0
MT	4	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1
NE	3	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0
NV	6	0	0	1	2	1	0	1	0	0	0	0	0	0	1	0	0	0
NH	10	2	2	1	1	0	1	0	1	0	1	0	0	1	0	0	0	0
NJ	13	2	3	2	0	0	1	1	0	0	0	0	1	1	0	0	1	1
NM	10	1	0	1	1	1	1	0	0	0	0	1	1	0	1	1	0	1
NY	14	2	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	0
NC	9	2	0	2	1	1	1	0	0	0	0	0	1	0	0	0	1	0
ND	3	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0
OH	8	1	0	1	0	1	1	0	0	0	0	0	1	0	1	0	1	1
OK	4	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0
OR	8	2	1	1	0	0	0	0	1	0	0	0	1	1	0	0	1	0
PA	10	2	0	1	1	1	1	1	0	0	0	0	0	1	1	0	1	0
RI	10	1	1	2	1	1	1	0	1	0	0	1	0	0	0	0	1	0
SC	5	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0
SD	4	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1

TN	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TX	7	0	3	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0
UT	6	0	0	1	1	0	1	0	0	0	0	0	1	0	0	1	0	1
VT	9	2	0	1	1	1	0	0	1	0	0	1	0	0	0	0	1	1
VA	5	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0
WA	9	2	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0
WV	3	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
WI	10	1	0	1	1	1	1	0	1	0	1	0	0	0	1	0	1	1
WY	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Chapter 5 Assessment of Impacts of State Clean Energy Entrepreneurship on CHP Technology Adoption and Employment

Using a research design framework created based on the DSH model, random-effects (RE) regression analysis is employed to explain how clean energy policy entrepreneurship affects consumer-side CHP technology adoption and job creation within or between 51 states (50 states plus Washington, D.C) over time.

5.1 Methodology: Random-Effects Regression Model

A RE model is basically designed to study the causes of changes within and between entities—U.S. states in this study—while allowing analysis of cross-sectional time-series data (also known as panel data). A fixed effects (FE) model is usually contrasted with the RE model. While a FE model treats unobserved differences between entities as a set of fixed variables, a RE model treats unobserved differences as random variables with a specified probability distribution (Allison, 2009). Since each state has its own time-invariant characteristics that may or may not influence the observed changes (CHP technology adoption in this study), certain things need to be controlled. These include culture, political system, geographic location, environmental conditions, and so on of each of the 51 states. These time-invariant characteristics are assumed to be unique to the state. This means that each state's error term and constant should not be correlated with others' error terms and constants because the model captures individual unique characteristics (Torres-Reyna, 2007). In other words, a FE model removes the effects of these time-invariant characteristics so that we can examine the net effect of the changes (Kohler & Kreuter, 2012).

By contrast, a RE model assumed the variation across entities to be random and uncorrelated with the predictor or observed variables included in the model. If the variation across individuals was random or uncorrelated with the independent variables (so, the each states' error terms were correlated with independent variables), a RE model would be more suitable. When comparing across 51 states, a certain outcome would be unlikely to happen independently. For example, decision-making about CHP technology adoption in a state might be affected by policies or market conditions outside of the state. The subjects or interventions in 51 states would have differed in ways that would have impacted the technology adoption, and therefore we should not assume a common fixed effect. In this case the RE model is more easily justified than the FE model. A Hausman Test helps analysts decide between fixed or random effects under this rationale.

The FE and RE regression models can be formulated as:

$$Y_{r,t} = \alpha_r + \beta X_{r,t} + \gamma_r + \delta_t + u_r + \mathcal{E}_{r,t} \qquad \text{(Eq.2)}$$

where $Y_{r,t}$ is dependent variable (Models 1 & 3 = a number of new CHP units, Models 2 & 4 = total new CHP capacity per state GDP in kW/million dollars) in state *r* and year *t*, $X_{r,t}$ is a vector of measured explanatory variables including policy scores; fuel-mix variables for coal, natural gas, nuclear, and renewables; energy prices variables for coal, natural gas, and end-use electricity; personal income per capita, and CO_2 emission per capita in state r and year t. The term α_r ($r = 1 \dots\dots.51$) is an intercept that may be different for the 51 states, and β is a vector of coefficients. The term γ_r is for region dummies that control for state fixed effects. The term δ_t denotes a vector of time dummies that control for time fixed effects. The two error terms, u_r and $\mathcal{E}_{r,t}$ varies independently across states and time. There is a different $\mathcal{E}_{r,t}$ for each state at each point in time, but u_r only varies across states, not over time. A crucial difference between FE and RE models are, instead of treating u_r as a set of fixed numbers, a RE model assumes that u_r is a set of random variables with a specified probability distribution. A RE model assumes that the state's error term is not correlated with the independent variables, which allows for time-invariant variables to be included as explanatory variables.

Another way to see the FE and RE model is by using binary variables. The equation for the FE model becomes;

$$Y_{r,t} = \beta_0 + \beta_1 X_{1,rt} + \cdots + \beta_k X_{k,rt} + \gamma_2 E_2 + \cdots + \gamma_n E_n + \delta_2 T_2 + \cdots + \delta_t T_t + u_r + \mathcal{E}_{r,t} \qquad \text{(Eq.3)}$$

where $Y_{r,t}$ is the dependent variable in state r and year t, $X_{k,rt}$ is the independent variable, and $\beta_k$is the coefficient for the independent variable. E_n represents the dummy variables for 51 states with state *n* (*n*=51 in this paper), where we have n-1 (=50) entities included in the model for the 50 states. γ_n is the coefficient for the regional dummies. T_t is the year t (t=35 for the period from 1980 to 2014). The model includes n-1 (=34) year dummies. δ_t is the coefficient for the time dummies.

Both Eq. 2 and Eq. 3 are equivalent. The coefficient β_k on $X_{k,rt}$ is the same from one state to the next 50 states. The state-specific intercepts in Eq. 1 and the dummy variables in Eq. 2 have the same source that varies across states but not over time (Allison, 2009).

After RE regression models are conducted, a lagged-effects model is employed to test policy impacts at a later point in time. A lagged dependent variable in time series models is often used as a means of capturing dynamic effects in political processes (Keele & Kelly, 2006). This happens when an attitude, policy, or condition at time *t* is a function of that same condition at *t-1* as modified by new information, rather than viewing a condition at time *t* as a linear function of independent variables. These models are useful because they offer the possibility of enhancing our ability to determine the direction of causality among variables that are associated with one another (Allison, 2009). In sum, innovative technology adoption or employment may be affected by a certain type of policy at an earlier or later time point.

A panel data set for the 50 states and Washington, D.C. with a time period from 1980 to 2014 is collected for the RE regression analysis. The year of 1980 is used as the base year for three reasons. First, according to Figure 1.2, new CHP technologies have been installed in increasing numbers since 1980. Second, most existing clean energy policies were enacted after 1980. Only two states, North Carolina and Ohio, offered renewable energy tax credits before 1980. Last, the EIA database of state CO_2 emissions is available only from 1980 onwards.

5.2 Data and Measurements

Following the theoretical framework explained by Eq. 1-3, two groups of RE models are designed to address the influence of state clean energy policy tools. The first group of models aims to examine the policy impact on CHP technology adoption (Hypothesis #1). Two dependent variables are measured: the total new CHP capacity per GDP in kilowatts per million dollars of GDP (*TotalCHPCapperGDP*) and the number of new CHP units installed each year (*TotalCHPCount*). States with larger scale of economy would require greater demand of CHP capacity. Thus, the dependent variable of capacity models was divided by state GDP to capture the size effects of the installed capacity. The data on CHP capacity and units were collected from DOE's CHP Installation Database and state GDP was collected from Bureau of Economic Analysis.

Four Models were developed. In Models 1 and 3, the dependent variable is the total number of new CHP units installed (*TotalCHPCount*). In Models 2 and 4, the dependent variable is total new CHP capacity per GDP (*TotalCHPCapperGDP*). The independent variable is presented as total policy score to test its impacts on CHP installations in Models 1 and 2, as well as nine individual policy scores to test separated impacts on CHP installations in Models 3 and 4. This comes from the result of a multicollinearity test, which was tested by calculating "variance inflation factors (vif)" for the independent variables. It suggested that the *PolicyScore* variable, which is the aggregated scores of nine individual policy scores from each year, would have collinearity when applied with nine individual policy variables in the same model. Thus, two types of RE models were designed; one with independent variables including only the *PolicyScore* and another including nine individual policy scores without the *PolicyScore*.

The energy market conditions are represented by the variables of fuel-mix generation and fuel prices. The share of each fuel generation variables are separated by type for coal, natural gas, nuclear, and renewables generation in percentage. The fuel price variables are also separated by type for prices of coal, natural gas, and electricity (averaged price for all residential, commercial, industrial, and transportation sectors) in dollars per million BTU. These data are collected from EIA's State Energy Data System (SEDS). CHP systems, especially small ones, are often fueled by natural gas to produce electricity and heat, although there have been instances of systems run on a variety of fuels, both fossil- and renewable-based. Therefore, natural gas generation might be positively correlated with new CHP deployment while natural gas prices might be negatively correlated with new CHP deployment.

The socio-economic characteristics by state are represented by the personal income per capita, salary employment, and CO_2 emission per capita. Electricity demand is closely tied to state economies. Therefore, control variables of economic activity are needed to account for these effects in a model. Personal income and salary-paid employment are added to explain the increased effects that larger economies have on electricity consumption and generation. In addition, CO_2 emission per capita is included because state legislation efforts for clean energy are likely to grow in states with higher carbon emissions. Yi (2015) examined the impacts of state clean energy policies on CO_2 emissions and addressed that improving carbon intensity and energy efficiency would be key to reducing CO_2 emissions when the state economy is growing.

Data on personal income in thousands of dollars and salary employment is collected from the Bureau of Economic Analysis (BEA).[24] The state-level income data consists of the incomes that persons residing in each state receive in return for their provision of labor, land, and capital used in current production, as well as other incomes. The wage and salary employment data measures the average annual number of full-time and part-time jobs in each state. The CO_2 emission data, measured in million metric tons of CO_2, is collected from EIA's State Carbon Dioxide Emission Database.[25]

Table 5.1 summarizes the selective variables in the FE model and descriptive statistics. The correlations among the dependent and independent variables can be found in Appendix III.

Hausman tests were conducted to test the specification of fixed-effects versus random-effects. Based on the tests, the null hypothesis, being that the difference of the coefficients estimated by the two specifications of each pair of fixed and random models is not systematic, cannot be rejected. Thus, a RE model is chosen for Models 1 to 4 (Chi^2 = 1.18 and *p* value = 0.278 for Model 1; Chi^2 = 0.32 and *p* value = 0.569 for Model 2; Chi^2 = 1.43 and *p* value = 0.231 for Model 3; Chi^2 = 0.22 and *p* value = 0.636 for Model 4).

A Breusch Pagan test is also conducted to examine whether the RE model's error term might be heteroskedastic. Examination of a pooled OLS regression with Breusch Pagan showed heteroskedasticity in the dataset. Thus, the RE models were run with robust standard errors to control for heteroskedasticity.

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[24] https://www.bea.gov/regional/downloadzip.cfm, assessed on October 2016.

[25] https://www.eia.gov/environment/emissions/state/. assessed on October 2016.

Table 5.1 Summary of Variables

Variables		Measures	Observations	Mean	Standard Deviation	Min	Max
Dependent Variable: CHP Technology Adoption	TotalCHPCount	Number of CHP units	1,785	2.1429	6.8778	0	102
	TotalCHPCap per GDP	kW per million dollars	1,785	0.2228	0.8157	0	12.91
Independent Variable: Policy Activities	PolicyScore	-	1,785	1.7927	2.7422	0	17
	EnergyClimateChangePlan	0 - no plan; Add 1 credit per a plan from initial year and thereafter	1,785	0.1485	0.4233	0	2
	Environmental Regulation	0 - no plan; Add 1 credit per a plan from initial year and thereafter	1,785	0.0992	0.4388	0	4
	Interconnection Standard	0 - no plan; 1 - from initial year and thereafter; extra 1 credit for no size limits	1,785	0.2683	0.5254	0	2
	NetMetering	0 - no plan; 1 - from initial year and thereafter; extra 1 credit for no size limits	1,785	0.2924	0.5669	0	2
	EEPortfolioStandard (EERE)	0 - no plan; 1 - from initial year and thereafter	1,785	0.1160	0.3203	0	1

	REPortfolioStandard (RPS)	0 - no plan; 1 - from initial year and thereafter	1,785	0.1608	0.3674	0	1
	UtilityRatePolicy	0 - no plan; 1 - from initial year and thereafter	1,785	0.0314	0.1744	0	1
	RETaxCredit	0 - no plan; 1 - from initial year and thereafter	1,785	0.1401	0.3471	0	1
	TaxExemption	0 - no plan; 1 - from initial year and thereafter	1,785	0.0812	0.2733	0	1
Independent Variables: **Electricity Generation by Fuel Type**	CoalShare	Percent	1,785	0.1962	0.2969	0	0.9642
	NGShare	Percent	1,785	0.1233	0.2094	0	0.8155
	NucShare	Percent	1,785	0.2341	0.2704	-0.0265	0.9435
	REShare	Percent	1,785	0.3274	0. 3417	0.0013	1.0265
Independent Variables: **Energy Prices by Fuel Type**	Coal Price	$ / Million Btu	1,785	1.7681	0.72	0	4.90
	Average Electricity Price	$ / Million Btu	1,785	22.0948	8.71	4.16	99.96
	NGPrice	$ / Million Btu	1,785	6.8049	3.73	0.68	44.19
Control Variables: Socio-	Personal Income perCapita	Thousands of dollars / Person	1,785	26.5149	11.90	7.13	70.47

economic Characteristics	Wage and Salary Employment	Persons	1,785	2,442,432	2,644,568	200,930	16,700,000
	CO_2 Emission per Capita	Million Metric Tons of CO_2 / Person	1,785	2.41 e-05	1.84 e-05	4.25e-06	13.06 e-05

5.3 Results of Consumer-Side Innovative Performance Models

Table 5.2 illustrates how the number of new CHP units (*TotalCHPCount*) or new CHP capacity per GDP (*TotalCHPCapperGDP*) is affected by states' clean energy policy efforts, which are represented by policy scores. According to R-squares, Models 1 and 3 with *TotalCHPCount* explain by 14-19% within a state and 74-81% between states, while Models 2 and 4 with *TotalCHPCapperGPD* explain only by 5% within a state and 22-23% between states. This implies that counting the number of new CHP units accounts for increases of small-sized CHP installations in response to state efforts for clean energy expansion. The upper chart in Figure 5.1 shows states where the increases of the number of small-sized CHP units coincide with the increases of policy score. The chart of *TotalCHPCount* over *PolicyScore* (above) presents the growth of small-sized CHP units in California, New York, and Connecticut by adding a policy score. In the chart between *TotalCHPCap* and *PolicyScore* (middle in Figure 5.1), however, the impact is hardly seen by highlighting new deployments of large-sized CHP mostly in Texas. Therefore, the model of *TotalCHPCount* has a higher R-square than the model of *TotalCHPCapperGDP* (Table 5.2).

Table 5.2 Random-Effects Models for Total Number of CHP Deployments or Total CHP Capacity

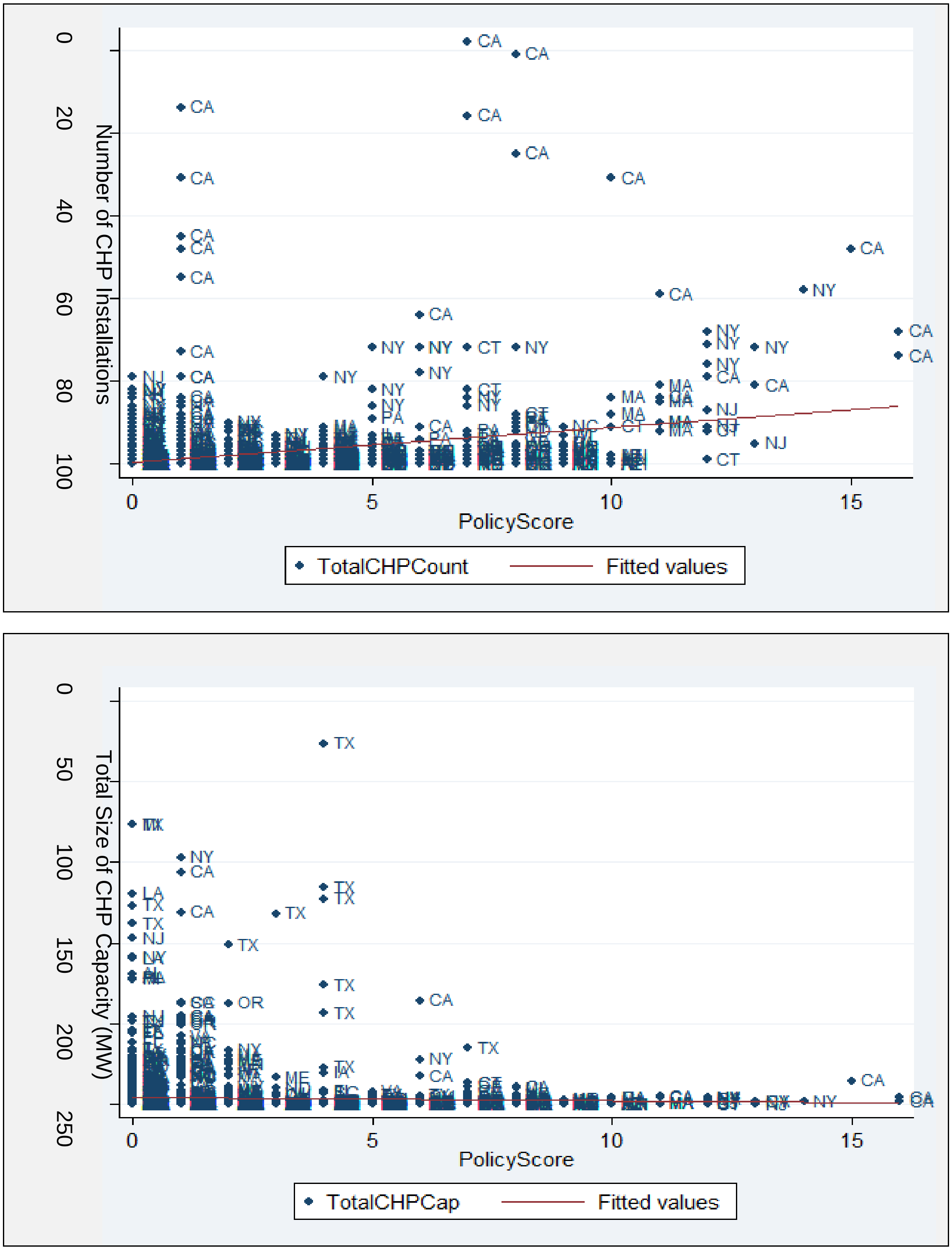
Variables	**Model 1 DV:** TotalCHPCount	**Model 2 DV:** TotalCHPCapperGDP	**Model 3 DV** TotalCHPCount	**Model 4 DV:** TotalCHPperGDP
PolicyScore	0.620** (2.94)	-0.00861 (-0.95)		
EnergyClimatePlan			0.495 (0.59)	-0.00705 (-0.17)

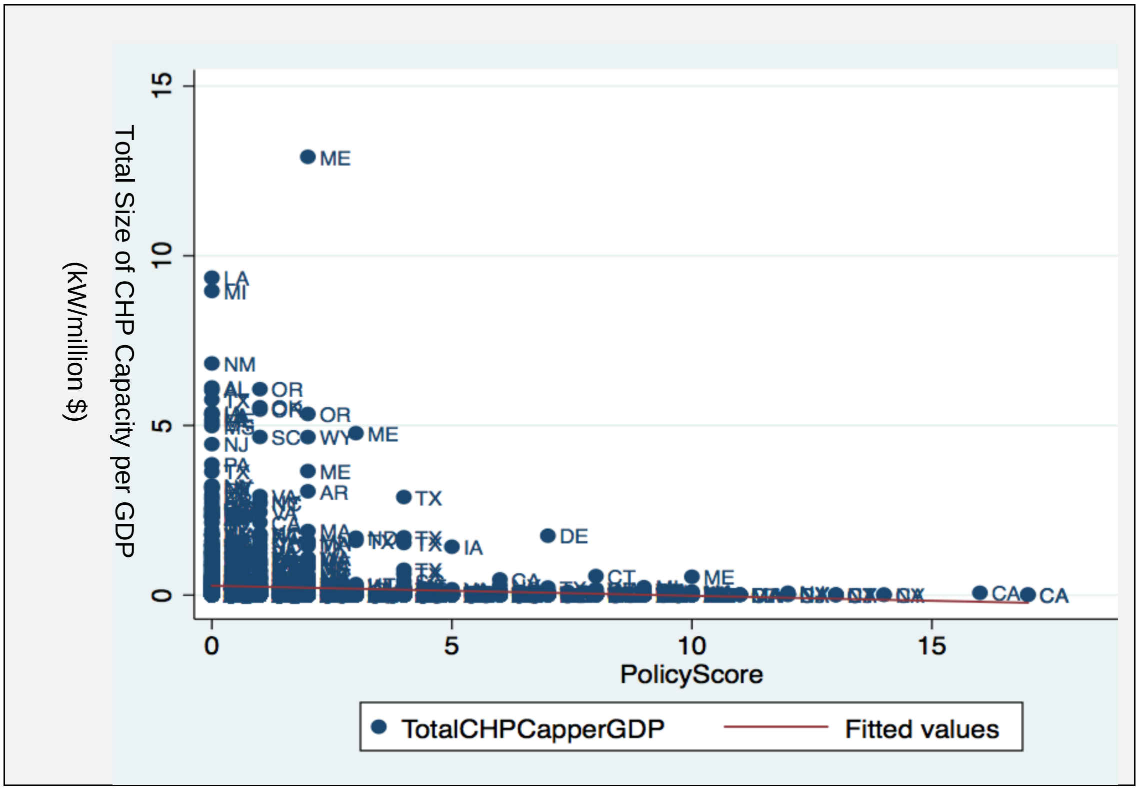
Environmental			0.229	-0.0741
Regulations			(0.51)	(-1.82)
Interconnection			0.880	-0.0485
Standard			(1.49)	(-1.13)
NetMetering			-0.367	0.0438
			(-1.28)	(0.69)
EERE			1.010	0.0333
			(1.11)	(0.60)
RRS			-0.466	0.0210
			(-0.85)	(0.43)
UtilityRatePolicy			9.698**	-0.00572
			(2.90)	(-0.07)
RETaxCredit			-0.942	-0.0235
			(-0.88)	(-0.51)
TaxExemption			-0.720	-0.0377
			(-0.89)	(-0.71)
CoalShare	-2.219	-0.305**	-3.805*	-0.332**
	(-1.66)	(-2.93)	(-2.07)	(-3.02)
NGShare	-1.935	0.255	-4.397	0.202
	(-0.85)	(1.33)	(-1.71)	(0.97)
NucShare	-1.752	-0.0725	-3.595	-0.108
	(-1.18)	(-0.64)	(-1.79)	(-0.91)
REShare	-1.431	-0.0402	-2.253	-0.0817
	(-1.19)	(-0.35)	(-1.48)	(-0.66)
CoalPrice	0.0517	0.0144	-0.0104	0.0136
	(0.20)	(0.41)	(-0.05)	(0.40)
AverageElectricity	0.176**	-0.00343	0.110**	-0.00342
	(2.69)	(-0.77)	(3.18)	(-0.68)
NGPrice	-0.382*	0.00722	-0.421***	0.00480
	(-2.50)	(0.66)	(-4.09)	(0.39)
PersonalIncome	0.110*	0.00128	0.103*	0.000776
perCapita	(2.32)	(0.31)	(2.09)	(0.17)
Wageandsalary	0.00000146*	2.10e-08*	0.00000124**	2.60e-08**
Employment	(2.31)	(2.56)	(3.19)	(3.20)
CO2percapita	31172.2*	2610.1	13245.6	2540.0
	(1.97)	(1.65)	(1.32)	(1.56)
Constant	-3.935	0.102	-0.575	0.142
	(-1.88)	(0.89)	(-0.37)	(1.26)
Observations	1785	1785	1785	1785
R^2_within	0.135	0.0457	0.189	0.0486
R^2_between	0.738	0.2340	0.809	0.2200
R^2_overall	0.461	0.0593	0.524	0.0609

Year Fixed Effect	Yes	Yes	Yes	Yes
State Fixed Effect	Yes	Yes	Yes	Yes

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Figure 5.1 Scatter Plot Charts of Policy Score vs. Total Number of New CHP Units (Top), Total Size of New CHP Capacity (Middle), and Total New CHP Capaciy per GDP (Bottom)





In Model 1, *PolicyScore* has significantly positive impacts on the number of new CHP deployments at the 0.01 level of significance. Thus, we can agree with hypothesis #1, "Firms are more likely to adopt innovative technologies where the state government provides a number of policy instruments." In addition, from non-significant coefficient of *PolicyScore* in Model 2 of CHP capacity per GDP, we can infer that customers of small-sized CHP systems are likely to adopt a new system when there is a policy support.

Model 1 also suggests that averaged electricity price, natural gas price, personal income per capita, wage and salary employment, and CO_2 emissions per capita significantly affect the number of new CHP deployments. The averaged electricity price (which is the average of electricity prices for residential, commercial, industrial, and transportation sectors), personal income per capita, wage and salary employment, and CO_2 emissions per capita are positively correlated with new CHP deployments. Thus, it appears that the higher the electricity prices within a state, the more CHP systems are deployed. In addition, states with higher levels of income, employment, and CO_2 emissions also tend to have more CHP deployments. On the other hand, natural gas prices, and are negatively correlated with new CHP deployments, as anticipated.

Only wage and salary employment is positively and significantly correlated with new CHP deployment in all four models. It is not surprising that states with high levels of employment lead to higher numbers of new CHP deployments as well as greater CHP capacity.

In terms of natural gas prices, Models 1 and 3 reveal interesting effects regarding firms' economic profitability. The coefficient for natural gas price is negative and significant in both Models 1 and 3. It appears that, on average, the total number of new CHP installations in a given state decreases by 0.382 in Model 1 and by 0.421 in Model 3 with each 1 dollar per million BTU increase in natural gas price over time. On the other hand, as noted above, the coefficient for averaged electricity prices of all sectors is positive and statistically significant in both Models 1 and 3. The magnitude of the coefficient in Model 1 suggests that the total number of new CHP installations in a given state increases by 0.176 on average with each 1 dollar per million BTU increase of average electricity price over time. These two price coefficients confirm that firms' decision-makings for energy technology adoption to produce electricity basically rely on their economic profitability.

A common metric for estimating the profitability of natural gas-fired electric generators refers to *spark spread*, which is “the difference between the price received by a generator for electricity produced and the cost of the natural gas needed to produce the electricity” (U.S. EIA, 2013). According to the equation for spark spread as provided below, higher power price and lower natural gas price will increase the spark spread if the heat rate of a generating unit remains the same. The effect of electricity and natural gas prices on new CHP adoption are thus confirmed.

> *Spark spread ($/MWh) = power price ($/MWh) – [natural gas price ($/mmBtu) * heat rate (mmBtu/MWh)]*

A previous study by Chittum and Kaufman (2011) addressed unfavorable spark spread as one of the critical barriers to CHP deployment, as a result of interviews with CHP project developers and supporters. The study argued that states in which spark spread was unfavorable to CHP development have notably low electricity prices. If states have low electricity rates, the cost of fuel alone could be enough to make the CHP project uneconomic to build and operate. This is confirmed by the positive and statistically significant coefficient of average electricity price in Model 1 and 3.

The significant effects of electricity price might be consistent with the effect of utility rate policies on CHP adoption, as shown by Model 3. Among selective clean energy policies, utility rate policies are positively and significantly correlated with firms’ decisions of new CHP installations at the 0.01 level. This indicates that firms are willing to invest in a cogeneration system when they can be convinced long-term payback will result from utility price stability. Moreover, the magnitude of utility rate policy coefficient becomes higher by lagging 1 and 2 years at the 0.01 level. As a result, we can agree with hypothesis #2: “Industries are more likely to adopt innovative technologies when they can be convinced of economic profitability.” On top of that, the results determine that the role of utility rate policies is critical for CHP technology adoption not only in a shor term, but also the effects would stay for several more years.

The other policies have no significant relationship with new CHP adoption in Table 5.2. Therefore, it can be concluded that firms’ responses regarding new power technology adoption could be diverse in various conditions other than policy support. However, when we apply lagged-effects of each policy, as shown in Table 5.3, energy and climate change plans appear significantly positive impacts on the number of CHP adoptions after lagging 3 years (Model 4-4 in Table 5.3). Therefore, with regards to hypothesis #3, we agree that information sharing provided by state governments’ climate change and clean energy plans would be insignificant in a short term right after its enactment, but would work in awakening firms when time passes.

Table 5.3 Lagged-Effects Models for Total Number of CHP Deployments

Variables	**Model 1-1** **No Lag:** TotalCHPCount	**Model 1-2** **1 Year Lag:** TotalCHPCount	**Model 1-3** **2 Year Lag:** TotalCHPCount	**Model 1-4** **3 Year Lag:** TotalCHPCount	**Model 4-1** **No Lag:** TotalCHPCount	**Model 4-2** **1 Year Lag:** TotalCHPCount	**Model 4-3** **2 Year Lag:** TotalCHPCount	**Model 4-4** **3 Year Lag:** TotalCHPCount
PolicyScore	0.620** (2.94)							
L.PolicyScore		0.616** (2.99)						
L2.PolicyScore			0.638** (2.84)					
L3.PolicyScore				0.609** (3.01)				
EnergyClimatePlan					0.495 (0.59)			
L.EnergyClimatePlan						0.386 (0.43)		
L2.EnergyClimatePlan							0.859 (1.20)	
L3.EnergyClimatePlan								1.453** (2.68)
Environmental Regulations					0.229 (0.51)			
L.Environmental Regulations						-0.180 (-0.26)		
L2.Environmental Regulations							-0.139 (-0.16)	
L3.Environmental Regulations								-0.304 (-0.35)

Interconnection Standard	0.880			
	(1.49)			
L.Interconnection Standard		1.467		
		(1.50)		
L2.Interconnection Standard			1.753	
			(1.25)	
L3.Interconnection Standard				2.261
				(1.26)
NetMetering	-0.367			
	(-1.28)			
L.NetMetering		-0.325		
		(-1.07)		
L2.NetMeteing			0.00681	
			(0.02)	
L3.NetMeteing				0.0198
				(0.06)
EERE	1.010			
	(1.11)			
L.EERE		0.287		
		(0.36)		
L2.EERE			-1.244	
			(-0.74)	
L3.EERE				-2.229
				(-1.06)
RRS	-0.466			
	(-0.85)			
L.RPS		-0.332		
		(-0.54)		
L2.RPS			0.0125	
			(0.02)	
L3.RPS				0.102
				(0.13)

UtilityRatePolicy					9.698**			
					(2.90)			
L.UtilityRatePolicy						11.98**		
						(2.70)		
L2.UtilityRatePolicy							13.04**	
							(2.70)	
L3.UtilityRatePolicy								10.41**
								(3.08)
RETaxCredit					-0.942			
					(-0.88)			
L.RETaxCredit						-1.241		
						(-1.09)		
L2.RETaxCredit							-1.290	
							(-1.14)	
L3.RETaxCredit								-0.939
								(-0.87)
TaxExemption					-0.720			
					(-0.89)			
L.TaxExemption						-0.540		
						(-0.63)		
L2.TaxExemtion							-0.216	
							(-0.23)	
L3.TaxExemtion								-0.232
								(-0.24)
CoalShare	-2.219	-2.407	-2.690	-2.798	-3.805*	-4.175	-4.448	-4.334
	(-1.66)	(-1.57)	(-1.49)	(-1.46)	(-2.07)	(-1.95)	(-1.86)	(-1.79)
NGShare	-1.935	-2.028	-2.290	-2.403	-4.397	-4.249	-4.702	-4.811
	(-0.85)	(-0.87)	(-0.94)	(-0.98)	(-1.71)	(-1.60)	(-1.70)	(-1.69)
NucShare	-1.752	-1.871	-2.046	-2.133	-3.595	-3.875	-4.129	-4.110
	(-1.18)	(-1.14)	(-1.11)	(-1.11)	(-1.79)	(-1.65)	(-1.57)	(-1.50)
REShare	-1.431	-1.693	-1.992	-2.022	-2.253	-2.394	-2.570	-2.371
	(-1.19)	(-1.33)	(-1.41)	(-1.40)	(-1.48)	(-1.39)	(-1.37)	(-1.29)
CoalPrice	0.0517	0.105	0.156	0.200	-0.0104	-0.0271	-0.134	-0.210
	(0.20)	(0.43)	(0.65)	(0.83)	(-0.05)	(-0.12)	(-0.41)	(-0.54)

AvrElecPrice	0.176**	0.175**	0.174**	0.183**	0.110**	0.0945*	0.0958*	0.129**
	(2.69)	(2.75)	(2.78)	(2.73)	(3.18)	(2.30)	(2.17)	(2.60)
NGPrice	-0.382*	-0.374*	-0.377**	-0.395*	-0.421***	-0.394**	-0.409***	-0.420***
	(-2.50)	(-2.56)	(-2.59)	(-2.57)	(-4.09)	(-3.24)	(-3.39)	(-3.64)
PersonalIncome perCapita	0.110*	0.113*	0.111*	0.110*	0.103*	0.0964	0.0812	0.0907
	(2.32)	(2.30)	(2.25)	(2.18)	(2.09)	(1.83)	(1.55)	(1.76)
Wageandsalary Employment	0.00000146*	0.00000144*	0.00000142*	0.00000142*	0.00000124**	0.00000124**	0.00000126**	0.00000133**
	(2.31)	(2.30)	(2.32)	(2.30)	(3.19)	(3.15)	(3.21)	(3.08)
CO2percapita	31172.2*	30626.6	30069.6	30559.5*	13245.6	10396.7	6811.5	9141.1
	(1.97)	(1.90)	(1.89)	(2.02)	(1.32)	(1.00)	(0.61)	(0.82)
Constant	-3.935	-4.107*	-3.612	-3.640	-0.575	-0.140	0.926	0.183
	(-1.88)	(-2.02)	(-1.90)	(-1.84)	(-0.37)	(-0.07)	(0.37)	(0.08)
Observations	1785	1734	1683	1632	1785	1734	1683	1632
R^2 _within	0.135	0.122	0.111	0.0972	0.189	0.202	0.195	0.151
R^2 _between	0.738	0.734	0.733	0.732	0.809	0.813	0.821	0.807
R^2 _overall	0.461	0.463	0.466	0.467	0.524	0.541	0.551	0.531
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

Chapter 6 Multiple-Case Study: Comparing Footprints of Four States—California, Ohio, Texas, and Wyoming

The quantitative analysis is hindered by limitations on the availability of outcome and policy variables. This aspect of the quantitative analysis might bring up some questions of generalization validity. While this research takes sufficient samples from all the states and time-series outcome data from 1980 to 2014, there will still be limitations on the explanatory power due to variation in regional characteristics. Usage of case studies help address these limitations by examining descriptive questions (*what* happened?) and explanatory questions (*how* or *why* did something happen?) (Yin, 2014). Using multiple-case studies, I will illuminate particular situations by contextualizing the empirical data analysis results with a first-hand in-depth understanding of selective states.

6.1 Methodology of Case Study

While a well-designed experiment or archival analysis is necessary to explain causal relationships, the case study method is pertinent when researchers try to illustrate a process or a set of policy implementation processes over a period of time: why processes occurred, how they were implemented, and what results would be anticipated (Schramm, 1971; Yin 2014). In particular, this method is well suited for deliberate elicitation of contextual conditions. I employ the case study method to verify the empirical data analysis results, in particular, the empirical results under hypothesis #1, 3, 4 and 6, which follow the method described earlier in Section 5. Therefore, direct observations are made in natural settings, as opposed to relying on ‘derived’ data (Bromley, 1986, p.23; Yin, 2014).

A single-case study can be applied to see a critical, unique, or even a revelatory case of a state leading to implementation of a certain policy. A multiple-case study, however, would help strengthen (or weaken) the findings from comparisons or hypothesized variations (Yin, 2014). Therefore, a multiple-case study with developed processes of sample states selection will be used to analyze diverse clean energy policy implementations in states and associated social/economic reactions. To build the logical approaches of the multiple-case study, each case must be carefully selected so that it predicts contrasting results but for predictable reasons to verify a theoretical replication (Yin, 2014).

According to Yin (2014), there are six common sources of evidence in doing case studies—documents (e.g. media articles and reports), archival records, interviews, direct observations, participant-observation, and physical artifacts. Since the unit of my case study is state governments’ decisions regarding clean energy policy implementation and firms’ decisions regarding CHP technology adoption, I mainly collect evidence using legislative documents, and archival records. Documents will provide time-sequential evidence of the processes of state policy legislation. Archival records will provide state-specific details of firm-level reactions to CHP technology adoption under state clean energy policies in selective states. Moreover, a wide range of statistical data will be used to analyze state-level distinct bases of economic, demographic, and environmental assets.

Table 6.1 Sources of Case Study Evidence: Strengths and Weakness
(Revised from Yin, 2014)

	Strengths	Weaknesses
Documentation	• Stable—can be reviewed repeatedly • Unobtrusive—not created as a result of the case study • Exact—can contain exact names, references, and details of an event • Broad—can cover a long span of time, many events, and many settings	• Retrievability—can be low • Biased selectivity, if collection is incomplete • Reporting bias—reflects (unknown) bias of any given document's author • Access—may be deliberately withheld
Archival Records	• [Same as Documentation] • Precise and usually quantitative	• [Same as Documentation] • Accessibility due to privacy reasons

First, documentary information would be an essential source to answer the case study topic. In particular, exploring documentary resources will target states in groups A and C in Table 6.2, in order to answer how actively state governments against climate change have engaged in developing their clean energy policies and viewed their economic pathways. Resources include media announcements of state governments' policy legislation, administrative documents (e.g. proposals and progress reports), formal policy reports, and newspaper and website articles created by interest groups and associated stakeholders. Content analysis of the states' clean energy policy legislation documents and associated media searches would play a key role in corroborating and augmenting evidence from other sources. In addition to legislation documents, I searched through newspaper articles to understand state governments' clean energy activities, associated legislation processes, and general energy market reactions in a certain state. To avoid a risk of biased selectivity or reporting bias (Table 6.1), I built up a time sequence for the processes of policy legislations and amendments and develop a comparative structure of media dialogues between advocates and opponents.

Second, archival records will be used. Many energy-related organizations provide state-level data of energy production and consumption. In particular, the CHP installation database was used again to specify the characteristics of companies that employ CHP technologies under clean energy policies in a selective state. I also applied a variety of open sources of archival and statistical data to provide precise and quantitative evidence of state-specific energy market conditions, and economic base analyses. These archival data were collected from a variety of resources, including BLS's location quotient index, BEA's employment, unemployment, and GDP data, Census Bureau's population survey, and EIA's state energy data system.

6.2 Selection of Four Sample States

The multi-case study was begun by selecting four sample states. By using a scoring of the state clean energy policy entrepreneurship (Chapter 4) and examining the current CHP installations by state (Chapter 5), I created a quadrant table that categorizes 51 states into four different groups (Table 6.2). The 51 states were first separated into two categories—higher or lower in clean energy policy scores in comparison to the U.S. average, as seen in the horizontal axis in Table 6.2. Then, those two categories were each characterized into two groups that reflected a higher or lower number of new CHP units in comparison to the U.S. average, as seen in the vertical axis in Table 6.2. One sample state was selected from each of the four resulting groups: California for group A (High-High), Texas for group B (Low-High), Ohio for group C (High-Low), and Wyoming for group D (Low-Low).

A multi-case study of the states in groups A and D would turn out as predicted. A closer understanding of those states would have provided compelling support for my initial set of assumptions from theoretical reviews of innovation diffusion and the role of state policy entrepreneurship. If the case studies are of groups B and C, the initial assumptions must be revised and retested with another set of hypothesis tests or theoretical reviews. Otherwise, in-depth understanding of those states could provide another explanation outside of my focus of drivers or barriers on clean energy technology diffusions and job creation.

Table 6.2 Proposed conditions in a relationship between state clean energy policy entrepreneurship and CHP technology adoption

		The Intensity Of State Clean Energy Policy Entrepreneurship	
		Low	High
A Number of New CHP Projects	High	**(Group B)** AK, **TX**	**(Group A)** **CA**, CT, MA, NC, NJ, NY, PA, WI
	Low	**(Group D)** AL, AR, CO, DC, FL, GA, IA, ID, IL, IN, KS, KY, LA, MD, MS, MT, ND, NE, NV, OR, SC, SD, TN, UT, WV, **WY**	**(Group C)** AZ, DE, HI, MD, ME, MI, NM, **OH**, OR, RI, VA, VT, WA

6.3 Economic Base Study

The economic sector in which a CHP system is being considered impacts how economically attractive it appears. Depending on which area of the country the CHP project is to be located, economic drivers and barriers are formed in different degrees.

The four selected states are different in terms of real gross domestic product (real GDP).[26] In 2017, as shown in Table 6.3, California is the top-grossing state with 14.3% of the United States' GDP, while Wyoming shares only 0.2%. Texas has the second-highest real GDP with 9.1%, and Ohio is the seventh largest with 3.3%. California and Texas have shown steady growth rates since 2000. Ohio experienced economic decline by 4% from 2005 to 2010 in the period of U.S. economic stagnation, and Wyoming shows recent stagnation starting from 2010. However, when regarding Wyoming's small size of population, its real GDP per capita is relatively high as $61,091, compared to the average of U.S. GDP per capita. California and Texas also generate higher levels of GDP per capita while Ohio stays lower than the U.S. average.

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[26] According to the Bureau of Economic Analysis, Real GDP is defined as an inflation-adjusted measure that reflects the value of all goods and services produced by an economy in a given year.

Table 6.3 Real GDP and GDP per Capita of Four States and the U.S.*

	Real GDP Billions of chained 2009 dollars (Growth %)					**Per Capita Real GDP** Chained 2009 dollars (Growth %)				
	2000	2005	2010	2015	2017	2000	2005	2010	2015	2017
United States	12,617	14,203 (13%)	14,628 (3%)	16,148 (10%)	16,721 (4%)	44,714	48,062 (7%)	47,289 (-2%)	50,301 (6%)	51,337 (2%)
California	1,639	1,910 (17%)	1,936 (1%)	2,250 (16%)	2,386 (6%)	48,223	53,320 (11%)	51,878 (-3%)	57,637 (11%)	60,359 (5%)
Ohio	485	512 (6%)	492 (-4%)	547 (11%)	562 (3%)	42,678	44,684 (5%)	42,673 (-5%)	47,098 (10%)	48,188 (2%)
Texas	931	1,047 (13%)	1,197 (14%)	1,488 (24%)	1,521 (2%)	44,432	45,966 (3%)	47,422 (3%)	54,200 (14%)	53,737 (-1%)
Wyoming	25	30 (18%)	36 (23%)	36 (-1%)	35 (-2%)	50,814	57,642 (13%)	64,618 (12%)	61,304 (-5%)	61,091 (0%)

* Data Source: U.S. Department of Commerce, Bureau of Economic Analysis (BEA), updated in 05/2018

6.3.1 Demographics

The U.S. Census Bureau estimated that the total U.S. population was 326 million in 2017 (American Community Survey, 2017). California is the most populous state at 12.1% (40 million) of the U.S. population. Texas is the second largest state with 8.7% (28 million). Ohio has 3.6% (12 million), and Wyoming has only 0.2% (0.6 million). In terms of growth rate, Texas shows the fastest growth with a 13% increase from 2010 to 2017 while Ohio is the slowest with only an 1% increase in the same time period (Table 6.4).

Table 6.4 State Population in 2010 and 2017

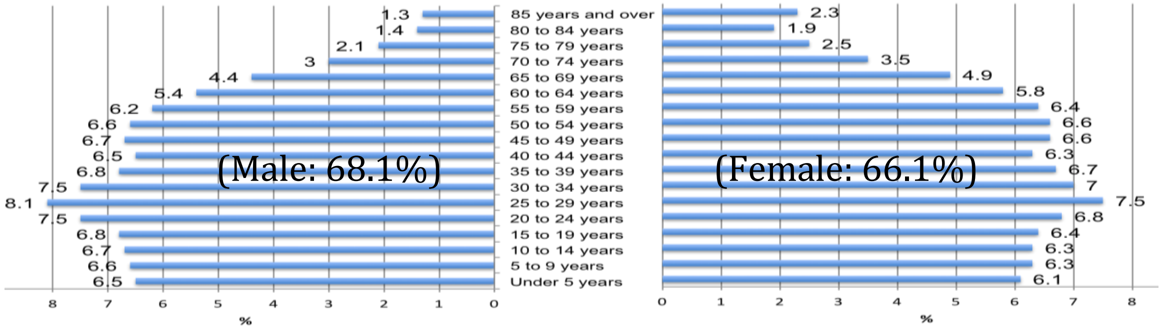
(Source: U.S. Census Bureau, ACS 2017)

Rank	State	2010 Census	2017 Estimate	Change
-	U.S. 50 States + DC	308,745,538	325,719,178	5.50%
1	Texas	25,145,561	28,304,596	12.56%
17	California	37,253,956	39,536,653	6.13%
31	Wyoming	563,626	579,315	2.78%
41	Ohio	11,536,504	11,658,609	1.06%

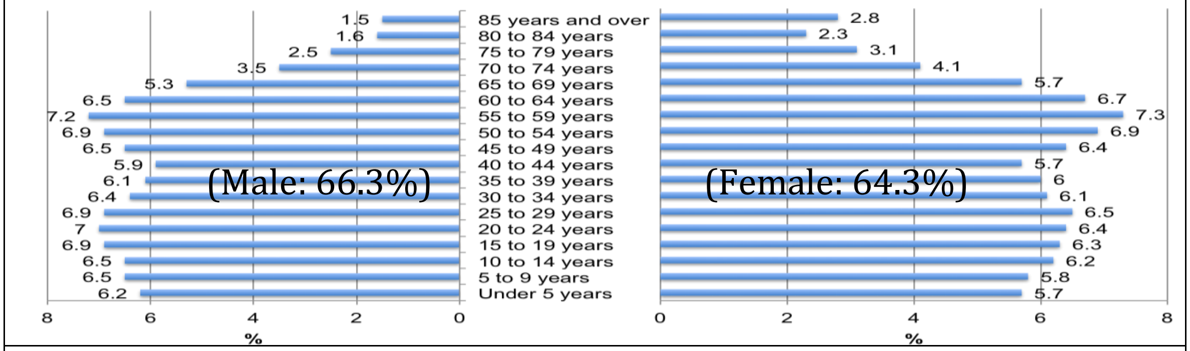
The labor force, which is the number of people officially employed or unemployed, is a key source of economic development in a certain region. Figure 6.1 shows the population portion in each age range for the four states. In 2016, on average at the national level, 66.4% of the total U.S. male population and 64.9% of the total U.S. female population make up the working age population (aged 15 to 64). In Figure 6.1, compared to this U.S. average, a larger ratio of the populations of California and Texas are working age, while Ohio and Wyoming have lower ratios. In addition, by looking at the shape of Figure 6.1, we can see higher ratios of aging population in Ohio and Wyoming. In contrast, Texas shows a larger layer of young population aged under 15 year. According to the ACS 2016 estimates, the median ages of each state are 36.4 for California, 39.3 for Ohio, 34.5 for Texas, and 37.2 for Wyoming when the U.S. median age is 38.2 year. Again, the state labor force is older in Ohio than the U.S.'s average of 38.2 years.

Figure 6.1 Population Distribution by Age and Sex in 2016

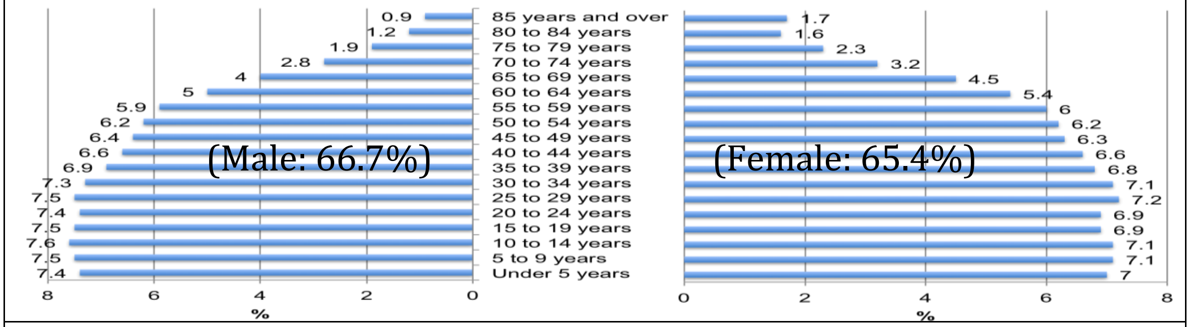
California total: 39.3 million - Male : 19.5 million, Female: 19.8 million



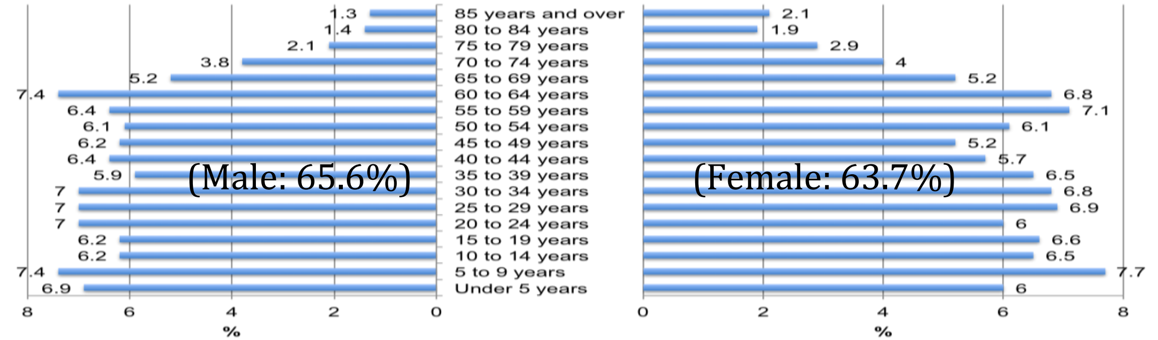
Ohio total: 11.6 million - Male: 5.7 million, Female: 5.9 million



Texas total: 27.9 million, Male: 13.8 million, Female: 14.0 million



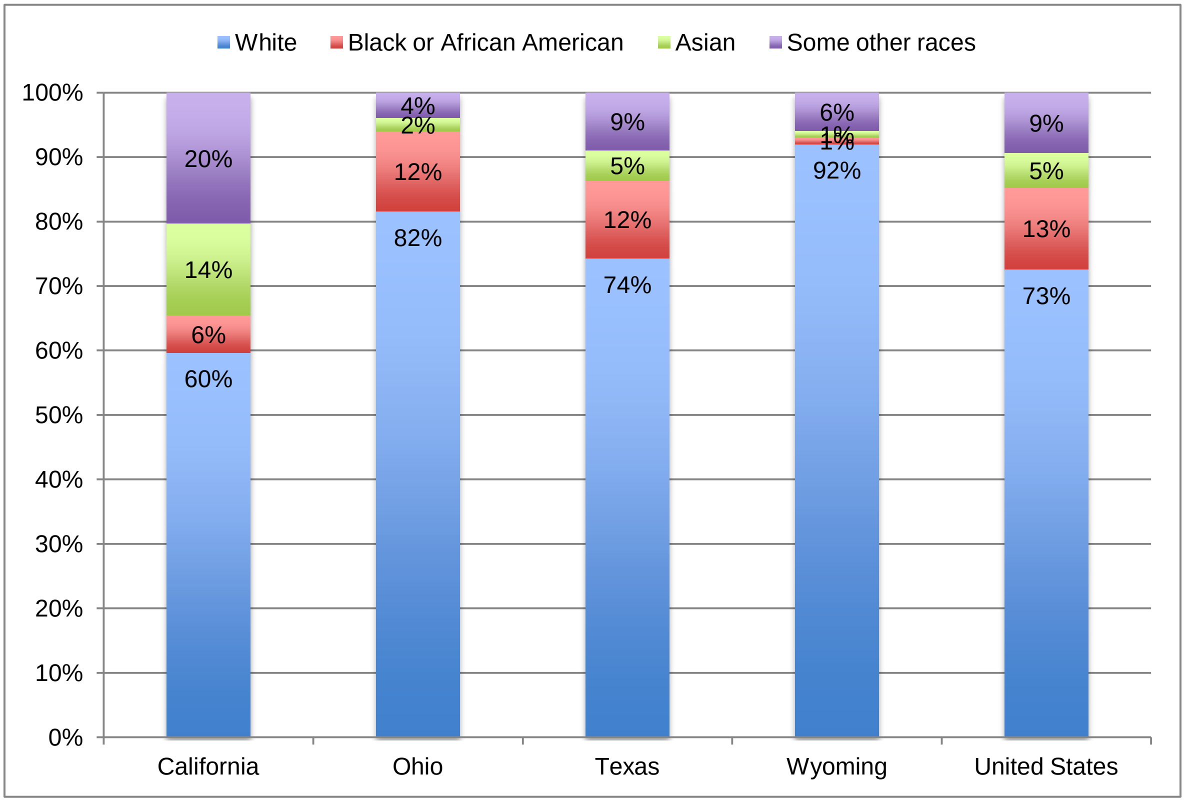
Wyoming total: 0.59 million, Male: 0.30 million, Female: 0.29 million



Note) The portion of working age population (15-64) shows in parenthesis.

Figure 6.2 shows that California has the most diverse community, in terms of race. While 73% of the total population is white in the U.S., California's population consists of 60% white people, 6% African-American, 14% Asian, and 20% other races. With a diverse ethnicity, the region's global orientation inspires its multi-cultural character and climate for continued innovation, and thus, power of labor force.

Figure 6.2 Population Composition by Race in 2016

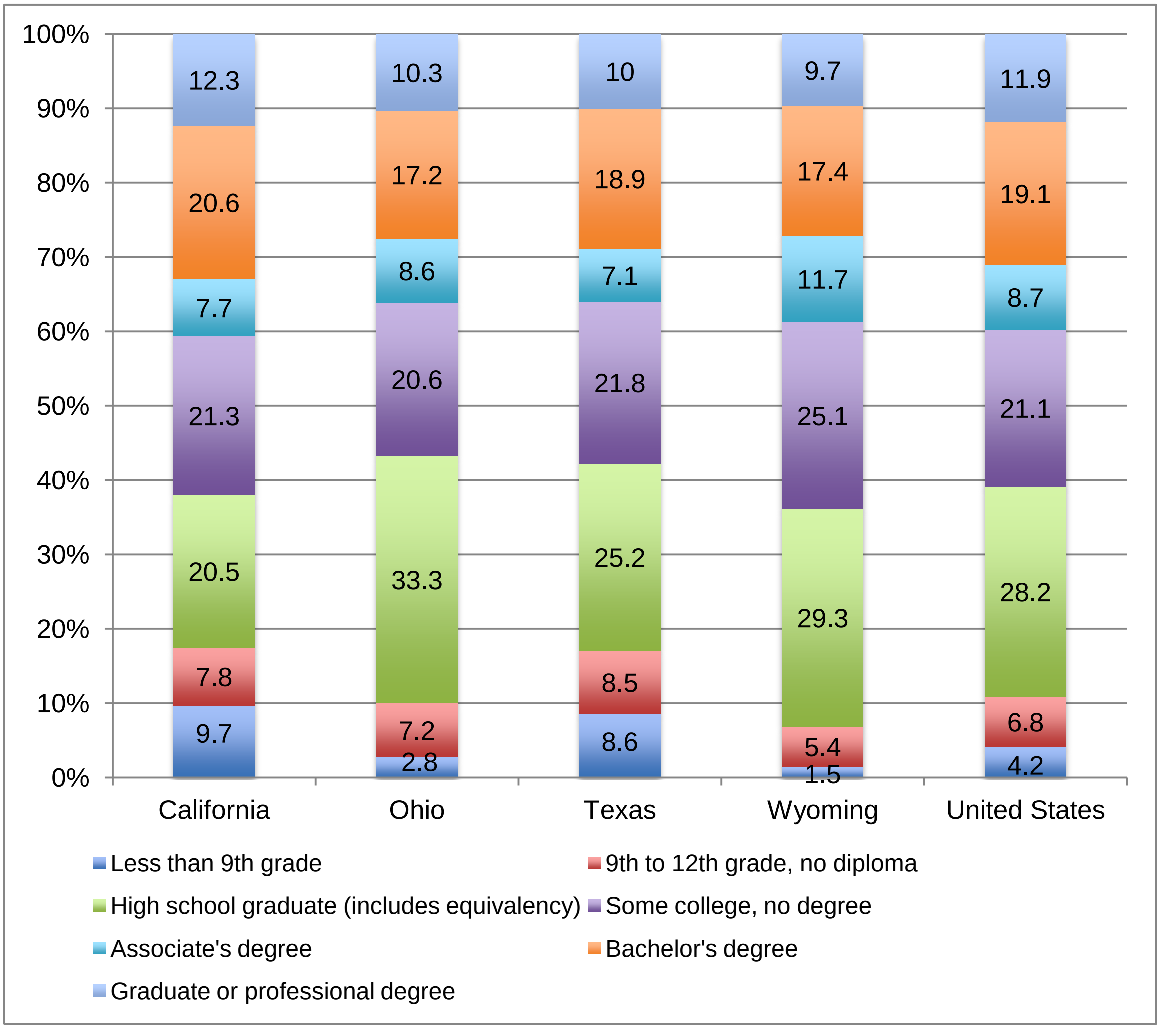


The level of education attainment seems to be a significant factor in consumption of states' human resources. Figure 6.3 demonstrates that California has a higher level of education attainment than the U.S. average. In particular, the number of attained bachelor's, graduate, and professional degrees are relatively high in California. In comparison, Ohio and Wyoming have an education attainment based more on high school graduates.

California has many universities, colleges, and seminaries. In this region, internationally

renowned universities and research facilities play a leading role in interacting with knowledge-based industries, such as information technology, computer science, and bioscience. Moreover, the strong foundation of education can promote innovation and creation, which in turn can cause a demand for a qualified labor force.

Figure 6.3 Population by Education Attainment

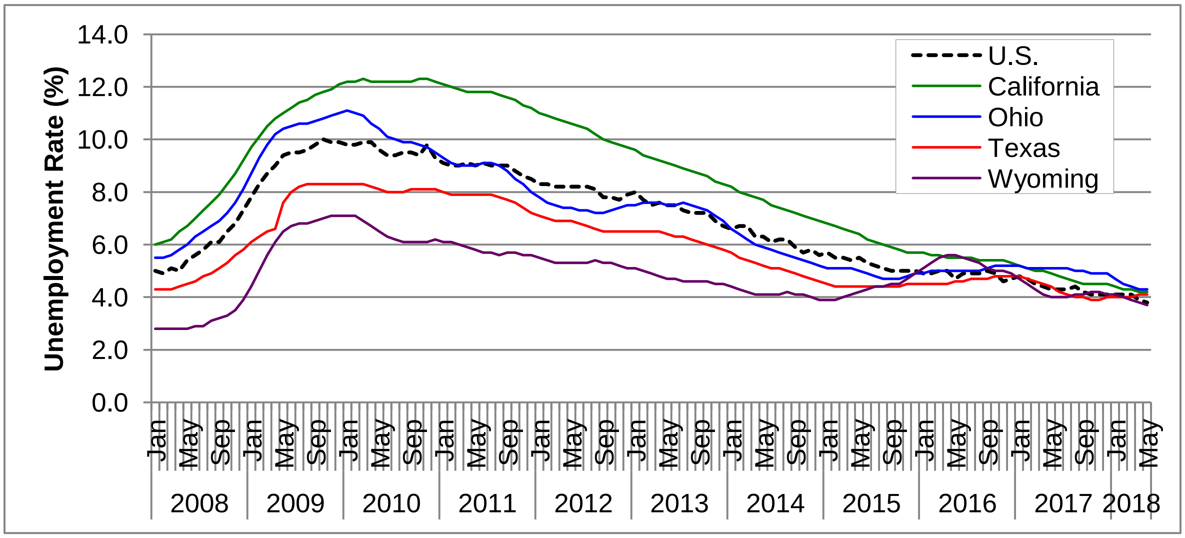


6.3.2 Economic Challenges - Unemployment

Even though states have richness of resources and human power, continuous unemployment rates and energy vulnerability are challenges in their economies. Figure 6.4 illustrates that the U.S. and the selected states have experienced decreases in unemployment rate after the Great Recession of 2007-2008. As of 2018, the unemployment rate is 3.8% across the nation on average. Among the four states, California and Ohio have had relatively higher unemployment rates than the national average, although the rates have overall steadily decreased since 2010. In Texas and Wyoming, the unemployment rates have oscillated in different time periods. Texas' unemployment rates were generally lower than the national average before 2017, but have recently increased to above the national average in 2018. Wyoming seems to have suffered a growth in unemployment rate in 2015 and 2016, but has now reduced its rate to below the national average after 2016.

Figure 6.4 Unemployment Rate Changes from 2008 to 2018

(Source: BLS, Local Area Unemployment Statistics, accessed on June 2018)



6.3.3 Economic Productivity – GDP and Jobs

Each state has economically grown based on different sets of industrial sectors. Understanding their economic base industries is crucial to determine drivers of innovation diffusion and policy entrepreneurship (Clark, Huang, & Walsh, 2010; Mintrom & Norman, 2009; Rogers, 2003; Porter, 1998; Schumpeter, 1934, See Chapter 2 for more theoritical reviews). Figures 6.5 and 6.6 show the industrial composition of GDP and employment by state in 2016. The U.S. GDP has grown based on three major sectors—(1) real estate, rental, and leasing, (2) government, and (3) manufacturing. In California, these three sectors are fairly dominant, and, in particular, the real estatate, rental, and leasing industries have played a significant role in the growth of GDP. Not surprisingly, California has been famous for high living costs resulting from actively rising housing prices. In addition, professional, scientific, and technical services and information industries have been critical for California's increasing GDP, as Silicon Valley has established international fame for information technology advances. Due to the large-scale economies in Silicon Valley, California has become one of the wealthiest regions in the U.S. However, extremely expensive costs of living offset the increased income.[27]

In Ohio, not only do the major three sectors share a large portion of GDP, but also health care, finance and insurance are growing sectors of economic output. The Columbus Region, consisting of 11 counties surrounding Columbus, made a "Columbus

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[27] Association of Bay Area Governments (http://www.abag.ca.gov) raised an issue of low housing affordability in its region. 53 percent of Bay Area's households and 51 percent of San Jose MSA's households had a burden of monthly housing costs by over 30 percent of their income. The local governments of the Bay Area addressed more than 215,000 additional housing units would have been needed with the population and job growth.

2020" plan to generate an economic development strategy and to organize partnerships with state and local partners. In the Columbus Region, financial and insurance companies—such as Huntington National Bank, JPMorgan Chase, and Nationwide Insurance—have headquartered in Ohio, and actively widen their market share across the nation.

In Texas, in addition to the major three sectors, the mining industry has been a dominant sector. On the other hand, in Wyoming, the mining industry accounts for more than 30% of GDP, based on their natural resources. As a result, the manufacturing sector has a relatively low share of the state's total GDP at only 4.9%.

In terms of employment in private sectors, four industrial sectors—health care and social assistance, retail trade, manufacturing, and accommodation and food services—account for 50% of total employment in the U.S. (Figure 6.5). In the four selected states, these four sectors play a significant role in generating jobs, in addition to professional, scientific, and technical services and administrative and waste management services. On the other hand, while real estate, rental and leasing industries generate a large portion of the GDP in all four states and the nation, it provides a relatively low number of job opportunities. As mentioned above, Wyoming is heavily dependent on the mining industry for job creation.

Figure 6.5 Composition of GDP by State in 2016 (Inflation-adjusted chained 2009 dollars)

(Source: Bureau of Economic Analysis, regional economic accounts, accessed on July 2018)

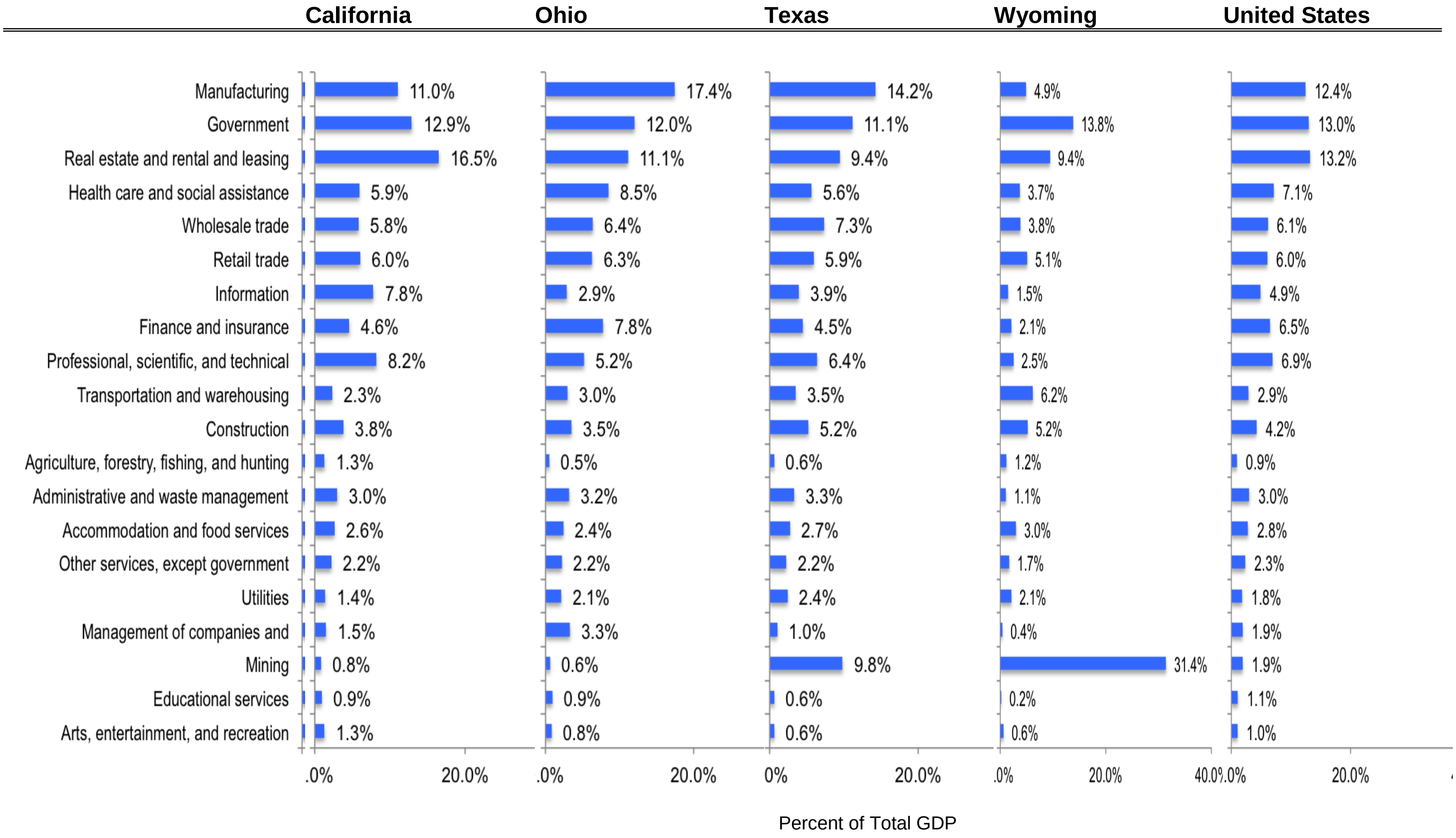
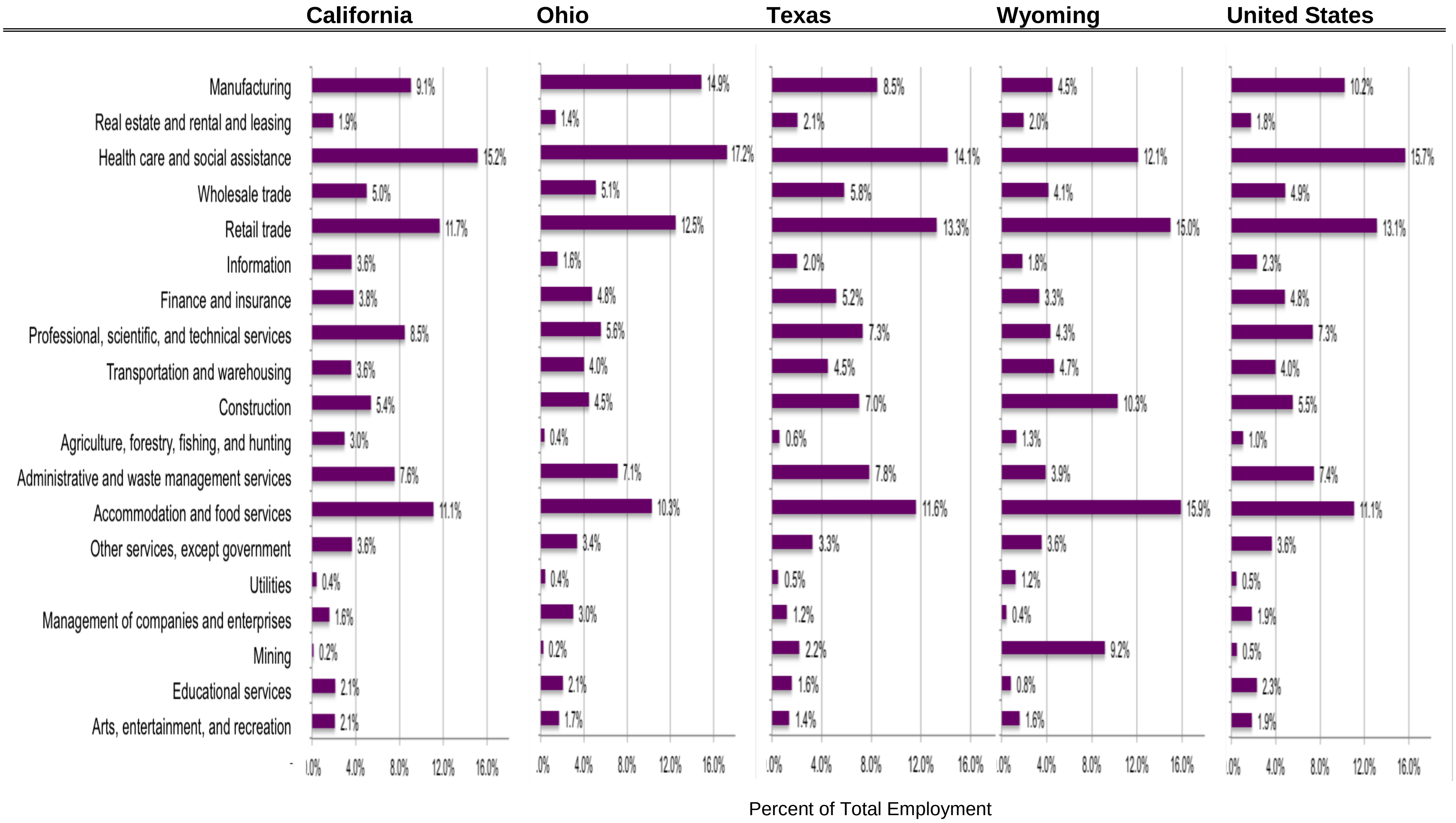


Figure 6.6 Composition of Private-sector Employment by State in 2016

(Data source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages, accessed on January 2018)



6.4 Industry Cluster Analysis – Location Quotient (LQ)

While theorists have addressed the importance of clustering of innovative industries and the spillover effects from their agglomeration economies on local economic development, as I reviewed in Section 2.3, existing studies of EBED have rarely examined the impact of existing industrial clusters in a certain region. This dissertation assumed that states with industrial clustering bases would be more attractive to clean energy technology development and job creation (Hypothesis #4 in Table 3.1). To test the fourth hypothesis, a LQ analysis is used to identify the existing industrial bases by state. A LQ analysis has been used in economic base analysis. Developed by Robert Murray Haig in 1928, LQ analysis provides ratios that allow an area's distribution of employment by industry to be compared to the U.S. national distribution. The formula for computing location quotients can be written as:

$$LQ = \frac{e_i/e}{E_i/E}$$

where:

$e_i =$ Local employment in industry *i*

$e =$ Total local employment

$E_i =$ Reference area (United States) employment in industry *i*

$E =$ Total reference area employment

If the calculation results in a ratio of "1," the industry share of local employment is equal to the industry share of national employment. An LQ greater than "1" means the supply of goods or services is greater than the local demand.

A LQ analysis helps to understand the "basic" industries in each state, which are those that export from the region and bring wealth in from the outside, while the non-basic industries support the basic industries. The LQ calculator is provided by the BLS website, which creates tables of private sector employment data by industry. The industries are defined under the NAICS industrial categories.

From BLS's QCEW dataset, the LQ data is gathered by state from the time period of 1990 to 2015. BLS provides the LQ by 10 major industrial categories, and NAICS 2-6 digits.

Figures 6.7 – 6.10 illustrate the industry clusters in the four sample states. Tables 6.5 – 6.12 provide the matching data of employment, LQs, and LQ changes over time. In Figures 6.7 – 6.10, the vertical axis is the LQ measurement in 2015, while the horizontal axis shows the percent change in LQ between 2010 and 2015. Industries based on the NAICS 2-digit code are plotted as bubbles with the circle size corresponding to their relative number of jobs. The graph's four quadrants can categorize various types of industry clusters.

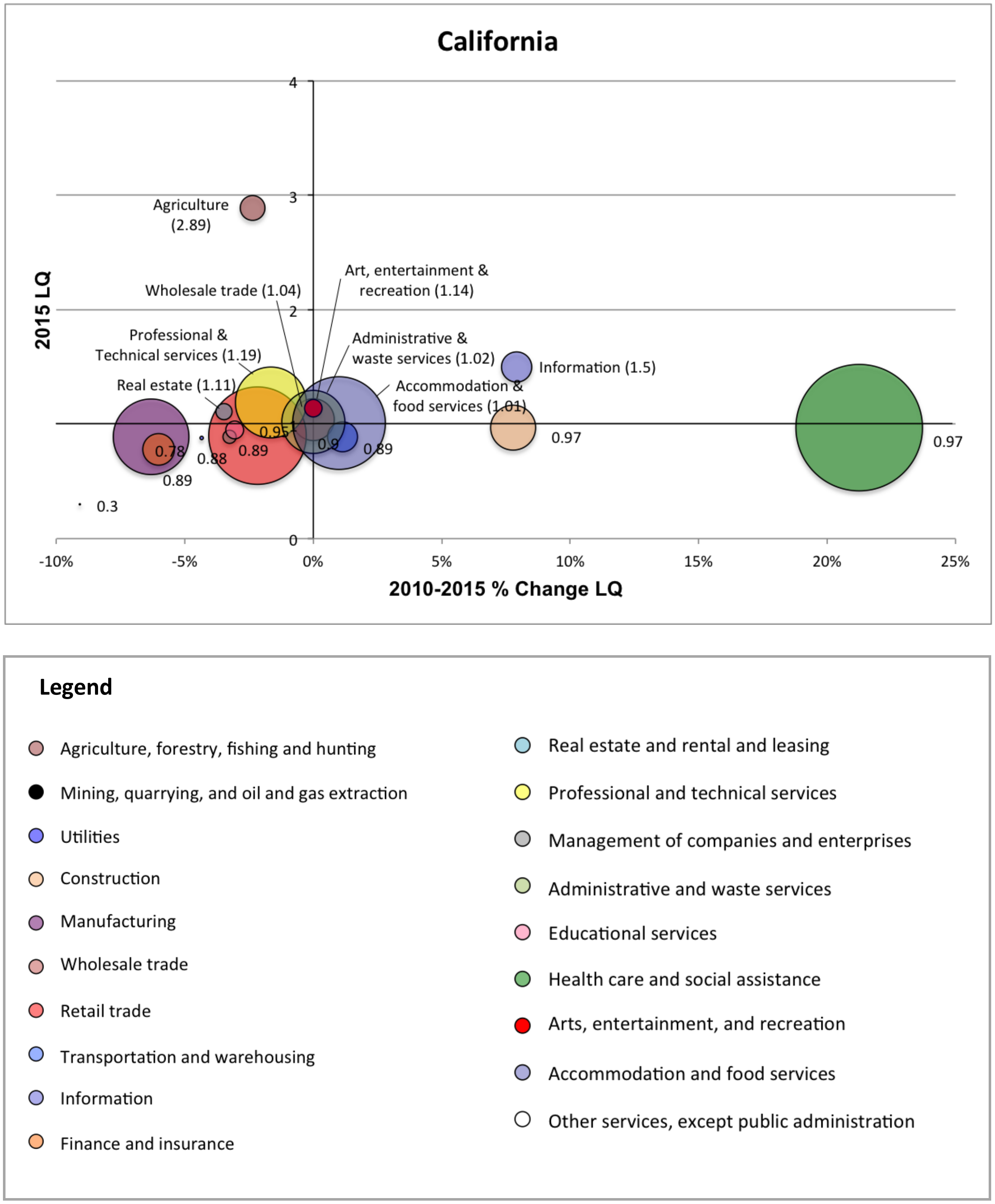
In California, industries in the upper right quadrant are information and accommodation and food services (Figure 6.7 and Table 6.5). The sectors of art, entertainment, and recreation, wholesale trade, and administrative and waste services are in the upper middle with 0% growth between 2010 and 2015. These industries are more concentrated in California in comparison to the national average, and the information sector and the accommodation and food service sector are becoming even more concentrated over time. These "standout" industries are both critical and high-performing, which means they will have increasing workforce demand and bring wealth in from other states. In particular, the information sector is rapidly emerging and includes high-potential regional export industries that should be developed further for the growth of California's economy. In Table 6.6, the information sector includes publishing, motion picture and sound recording, and broadcasting sectors, all of which are more clustered in comparison to the national average.

The lower right quadrant contains the industries of health care and social assistance, construction, and transportation and warehousing. These industries are not yet as concentrated in California as they are at the national level, but are becoming more clustered over time. In particular, the health care and social assistance sector increased significantly by 21% between 2010 and 2015, and by 17% between 1990 and 2015. Moreover, the health care sector has already generated the largest share of employment. The construction sector recently grew after the Great Recession. If these "pre-emergent" sectors continue to grow, they will eventually move into the upper right quadrant, and have the potential to become "standout" industries that contribute more to California's economic base.

The upper left quadrant contains industries— agriculture, forestry, fishing, and hunting, professional and technical services, and real estate, rental and leasing—that are more clustered in California than the national average, but their concentration is declining. When looking at percent changes between 1990 and 2015 in Table 6.5, the sectors of real estate, rental, and leasing, and professional and technical services are steadily declining. This shows that California is losing a major part of its export base in these sectors, even though the industry clusters are still a strong engine for California's economy.

Finally, the lower left quadrant includes sectors of mining, utilities, manufacturing, retail trade, finance and insurance, management of companies and enterprises, and educational services, which are less important regionally in comparison to the national average, and are also declining in employment.

Figure 6.7 Bubble Graph of Location Quotient and Employment in California



Note) Only industrial sectors that have LQ greater than 1 are labeled by the sector name in graph.

Table 6.5 California Location Quotients calculated by NAICS 2-digit

(Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages, accessed on September 2017)

State	Sectors	Employment 2016	LQ 1990	LQ 2000	LQ 2010	LQ 2015	LQ Changes 1990-2015	LQ Changes 2010-2015
California	NAICS 11 Agriculture, forestry, fishing and hunting	423,516	2.84	2.96	2.96	2.89	2%	-2%
	NAICS 21 Mining, quarrying, and oil and gas extraction	21,959	0.47	0.39	0.33	0.3	-36%	-9%
	NAICS 22 Utilities	58,273	0.74	0.81	0.92	0.88	19%	-4%
	NAICS 23 Construction	769,580	1.09	0.96	0.9	0.97	-11%	8%
	NAICS 31-33 Manufacturing	1,294,360	0.95	0.94	0.95	0.89	-6%	-6%
	NAICS 42 Wholesale trade	715,989	0.99	0.98	1.04	1.04	5%	0%
	NAICS 44-45 Retail trade	1,668,452	0.93	0.89	0.92	0.9	-3%	-2%
	NAICS 48-49 Transportation and warehousing	512,104	0.89	0.93	0.88	0.89	0%	1%
	NAICS 51 Information	517,390	1.23	1.31	1.39	1.5	22%	8%
	NAICS 52 Finance and insurance	540,807	1	0.84	0.83	0.78	-22%	-6%
	NAICS 53 Real estate and rental and leasing	275,950	1.25	1.13	1.15	1.11	-11%	-3%
	NAICS 54 Professional and technical services	1,212,898	1.25	1.22	1.21	1.19	-5%	-2%
	NAICS 55 Management of companies and enterprises	225,770	0.38	1.62	0.92	0.89	134%	-3%
	NAICS 56 Administrative and waste services	1,078,883	1.18	1.08	1.02	1.02	-14%	0%
	NAICS 61 Educational services	304,876	1.02	0.97	0.98	0.95	-7%	-3%
	NAICS 62 Health care and social assistance	2,165,926	0.83	0.8	0.8	0.97	17%	21%
	NAICS 71 Arts, entertainment, and recreation	298,889	1.16	1.09	1.14	1.14	-2%	0%
	NAICS 72 Accommodation and food services	1,586,193	1	0.97	1	1.01	1%	1%
	NAICS 81 Other services, except public administration	519,955	1.09	1.19	1.46	1.02	-6%	-30%

Table 6.6 California Location Quotients greater than 1 calculated by NAICS 2 & 3-digit, 2015

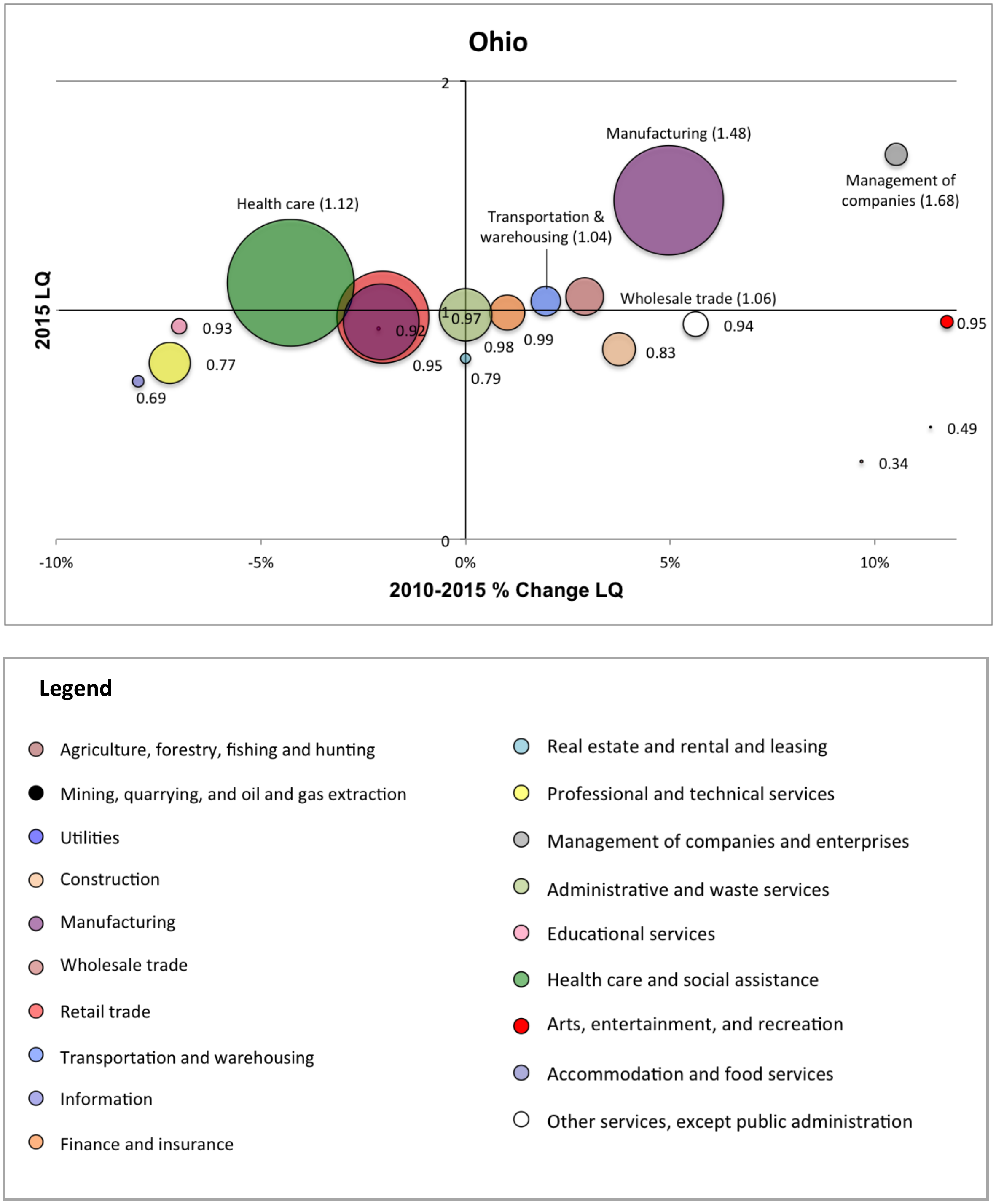
industry_code	Employment2015	LQ2015
NAICS 11 Agriculture, forestry, fishing and hunting	**421,288**	**2.89**
NAICS 111 Crop production	176,537	2.69
NAICS 115 Agriculture and forestry support activities	213,178	4.96
NAICS 42 Wholesale trade	**714,816**	**1.04**
NAICS 424 Merchant wholesalers, nondurable goods	273,836	1.15
NAICS 51 Information	**482,179**	**1.5**
NAICS 511 Publishing industries, except Internet	92,902	1.1
NAICS 512 Motion picture and sound recording industries	151,467	3.2
NAICS 515 Broadcasting, except Internet	41,654	1.27
NAICS 519 Other information services	80,937	2.85
NAICS 53 Real estate and rental and leasing	**270,251**	**1.11**
NAICS 531 Real estate	206,009	1.15
NAICS 54 Professional and technical services	**1,199,974**	**1.19**
NAICS 541 Professional and technical services	1,199,974	1.19
NAICS 56 Administrative and waste services	**1,052,274**	**1.02**
NAICS 561 Administrative and support services	1,005,506	1.03
NAICS 562 Waste management and remediation services	46,768	1.02

Figure 6.8 and Tables 6.7 & 6.8 illustrate the industry clusters in Ohio. The upper right quadrant contains manufacturing, management of companies and enterprises, wholesale trade, transportation and warehousing, and finance and insurance. In particular, the sector of management of companies and enterprises has shown the most growth in addition to becoming more concentrated over time. Manufacturing is the most important sector in Ohio's regional economy because it provides the second largest share of employment along with continuous growth over time. The LQ of the manufacturing sector grew by 5% between 2010 and 2015, and 7% between 1990 and 2015 (Table 6.7). When looking at the LQ by industry based on NAICS 3-digits (Table 6.8), the manufacturing sector includes a diverse range of subsectors, from food to furniture manufacturings. Primarily, metal manufacturing is the most concentrated manufacturing subsector with a LQ of 2.62 in 2015.

The lower right quadrant contains arts, entertainment, and recreation, finance and insurance, other services, construction, mining, quarrying, and oil and gas extraction, and agriculture, forestry, fishing and hunting sectors. As mentioned above, finance and insurance, which has a LQ of 0.99 in 2015, has a large potential to become a rising industry cluster in the Columbus Region.

In the upper left quadrant, the health care and social assistance sector shows the largest share of employment. Even though the LQ changes have fluctuated between 1990 and 2015 (Table 6.7), this sector seems to remain a major part of Ohio's economic base.

Figure 6.8 Bubble Graph of Location Quotient and Employment in Ohio



Note) Only industrial sectors that have LQ greater than 1 are labeled by the sector name in graph.

Table 6.7 Ohio Location Quotients calculated by NAICS 2-digit

(Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages, accessed on September 2017)

State	Sectors	Employment 2016	LQ 1990	LQ 2000	LQ 2010	LQ 2015	LQ Changes 1990-2015	LQ Changes 2010-2015
Ohio	NAICS 11 Agriculture, forestry, fishing and hunting	16,373	0.28	0.3	0.31	0.34	21%	10%
	NAICS 21 Mining, quarrying, and oil and gas extraction	11,066	0.6	0.57	0.44	0.49	-18%	11%
	NAICS 22 Utilities	19,275	1.12	0.95	0.94	0.92	-18%	-2%
	NAICS 23 Construction	205,826	0.86	0.87	0.8	0.83	-3%	4%
	NAICS 31-33 Manufacturing	685,058	1.38	1.39	1.41	1.48	7%	5%
	NAICS 42 Wholesale trade	235,251	0.98	1.02	1.03	1.06	8%	3%
	NAICS 44-45 Retail trade	575,498	1.05	1.04	0.99	0.97	-8%	-2%
	NAICS 48-49 Transportation and warehousing	184,311	0.75	0.91	1.02	1.04	39%	2%
	NAICS 51 Information	71,789	0.86	0.7	0.75	0.69	-20%	-8%
	NAICS 52 Finance and insurance	219,259	0.89	0.95	0.98	0.99	11%	1%
	NAICS 53 Real estate and rental and leasing	63,136	0.81	0.85	0.79	0.79	-2%	0%
	NAICS 54 Professional and technical services	257,074	0.77	0.82	0.83	0.77	0%	-7%
	NAICS 55 Management of companies and enterprises	138,334	0.25	1.09	1.52	1.68	572%	11%
	NAICS 56 Administrative and waste services	328,237	0.99	0.96	0.98	0.98	-1%	0%
	NAICS 61 Educational services	95,230	0.96	0.92	1	0.93	-3%	-7%
	NAICS 62 Health care and social assistance	793,637	1.13	1.1	1.17	1.12	-1%	-4%
	NAICS 71 Arts, entertainment, and recreation	78,088	2.45	0.9	0.85	0.95	-61%	12%
	NAICS 72 Accommodation and food services	473,177	0.71	0.97	0.97	0.95	34%	-2%
	NAICS 81 Other services, except public administration	155,636	0.96	1	0.89	0.94	-2%	6%

Table 6.8 Ohio Location Quotient greater than 1 calculated by NAICS 2 & 3-digit, 2015

industry_code	Employment2015	LQ2015
NAICS 31-33 Manufacturing	**685975**	**1.48**
NAICS 311 Food manufacturing	58326	1.03
NAICS 322 Paper manufacturing	19805	1.42
NAICS 323 Printing and related support activities	21500	1.27
NAICS 324 Petroleum and coal products manufacturing	4785	1.16
NAICS 325 Chemical manufacturing	43667	1.44
NAICS 326 Plastics and rubber products manufacturing	55955	2.16
NAICS 327 Nonmetallic mineral product manufacturing	25358	1.7
NAICS 331 Primary metal manufacturing	38685	2.62
NAICS 332 Fabricated metal product manufacturing	103205	1.89
NAICS 333 Machinery manufacturing	78853	1.88
NAICS 335 Electrical equipment and appliance mfg.	28164	1.96
NAICS 336 Transportation equipment manufacturing	123121	2.03
NAICS 337 Furniture and related product manufacturing	14894	1.04
NAICS 42 Wholesale trade	**235680**	**1.06**
NAICS 423 Merchant wholesalers, durable goods	129459	1.17
NAICS 425 Electronic markets and agents and brokers	38666	1.13
NAICS 48-49 Transportation and warehousing	**179903**	**1.04**
NAICS 484 Truck transportation	70772	1.3
NAICS 493 Warehousing and storage	44210	1.42
NAICS 55 Management of companies and enterprises	**139262**	**1.68**
NAICS 551 Management of companies and enterprises	139262	1.68
NAICS 62 Health care and social assistance	**778907**	**1.12**
NAICS 621 Ambulatory health care services	261574	1.01

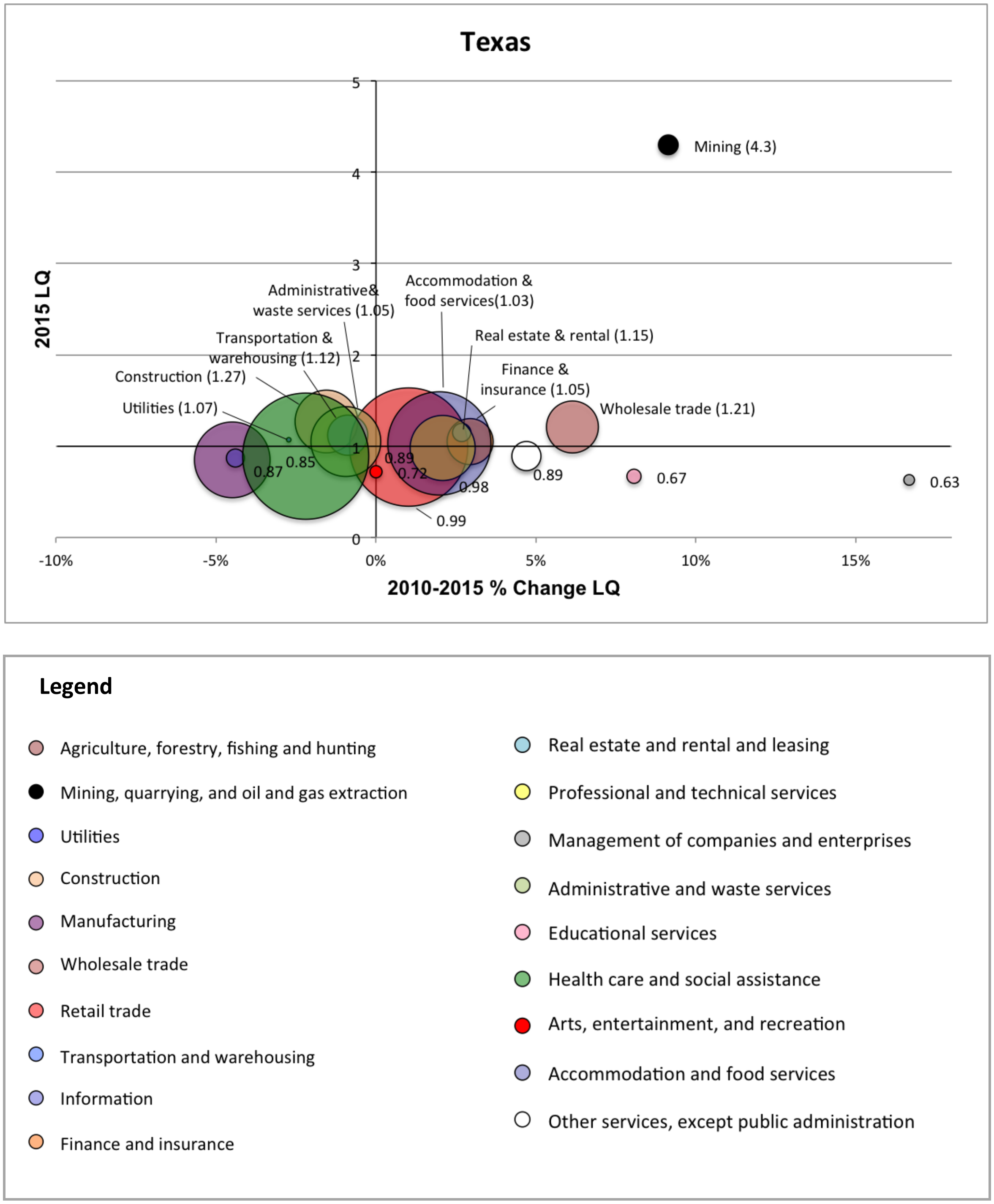
NAICS 622 Hospitals	246855	1.36
NAICS 623 Nursing and residential care facilities	168519	1.36

In Texas, Figure 6.9 shows an outlier in the upper right quadrant, mining, quarrying, and oil and gas extraction industries, which are constantly concentrated and growing over time as an export base. Based on NAICS 3-digits, Table 6.10 shows that mining sectors, oil and gas extraction sector has a LQ of 6.18, and support activities for mining sector has a LQ of 5.27, which means these sectors are highly clustered in Texas in comparison to the national average. The upper right quadrant also shows that wholesale trade, real estate, rental, and leasing, finance and insurance, accommodation and food services are important economic bases more concentrated in Texas than the national average.

The lower right quadrant indicates that retail trade, professional and technical services, management of companies and enterprises, and educational services are increasing, but are not yet above the national average. Professional and technical services, in particular, have great potential to become concentrated in the near future as its LQ is 0.98 and is growing constantly (Table 6.9).

The upper left quadrant contains construction, transportation and warehousing, utilities, and administrative and waste service sectors that are more clustered in Texas than the average, but are declining over time. However, some subsectors seem to be consistently dominant. For example, in Table 6.10, the pipeline transportation sector has a LQ of 4.35, which indicates a relatively strong cluster in the region. The concentration may be associated with the growing cluster of oil and gas extraction industries. The lower left quadrant includes agriculture, health care, information, manufacturing, and art, entertainment, and recreation sectors. The health care industry still generates the largest number of employments in 2015, but has been declining in LQ from 0.93 in 2000 to 0.89 in 2015 (Table 6.9).

Figure 6.9 Bubble Graph of Location Quotient and Employment in Texas



Note) Only industrial sectors that have LQ greater than 1 are labeled by the sector name in graph.

Table 6.9 Texas Location Quotients calculated by NAICS 2-digit

(Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages, accessed on September 2017)

State	Sectors	Employment 2016	LQ 1990	LQ 2000	LQ 2010	LQ 2015	LQ Changes 1990-2015	LQ Changes 2010-2015
Texas	NAICS 11 Agriculture, forestry, fishing and hunting	59,938	0.89	0.8	0.64	0.57	-36%	-11%
	NAICS 21 Mining, quarrying, and oil and gas extraction	219,987	3.78	3.85	3.94	4.3	14%	9%
	NAICS 22 Utilities	49,755	1.16	1.12	1.1	1.07	-8%	-3%
	NAICS 23 Construction	700,297	1.06	1.2	1.29	1.27	20%	-2%
	NAICS 31-33 Manufacturing	845,339	0.84	0.86	0.89	0.85	1%	-4%
	NAICS 42 Wholesale trade	580,547	1.12	1.14	1.14	1.21	8%	6%
	NAICS 44-45 Retail trade	1,321,673	1.05	1.02	0.98	0.99	-6%	1%
	NAICS 48-49 Transportation and warehousing	448,572	1.11	1.13	1.13	1.12	1%	-1%
	NAICS 51 Information	201,807	0.99	1.05	0.91	0.87	-12%	-4%
	NAICS 52 Finance and insurance	514,081	0.96	0.96	1.02	1.05	9%	3%
	NAICS 53 Real estate and rental and leasing	204,270	1.18	1.17	1.12	1.15	-3%	3%
	NAICS 54 Professional and technical services	726,921	0.91	0.95	0.96	0.98	8%	2%
	NAICS 55 Management of companies and enterprises	119,039	0.34	0.24	0.54	0.63	85%	17%
	NAICS 56 Administrative and waste services	779,706	1.06	1.04	1.06	1.05	-1%	-1%
	NAICS 61 Educational services	158,516	0.61	0.6	0.62	0.67	10%	8%
	NAICS 62 Health care and social assistance	1,409,399	0.92	0.93	0.91	0.89	-3%	-2%
	NAICS 71 Arts, entertainment, and recreation	136,101	1.01	0.7	0.72	0.72	-29%	0%
	NAICS 72 Accommodation and food services	1,153,361	0.97	1.01	1.01	1.03	6%	2%
	NAICS 81 Other services, except public administration	324,829	0.95	0.93	0.85	0.89	-6%	5%

Table 6.10 Texas Location Quotient greater than 1 calculated by NAICS 2 & 3-digit, 2015

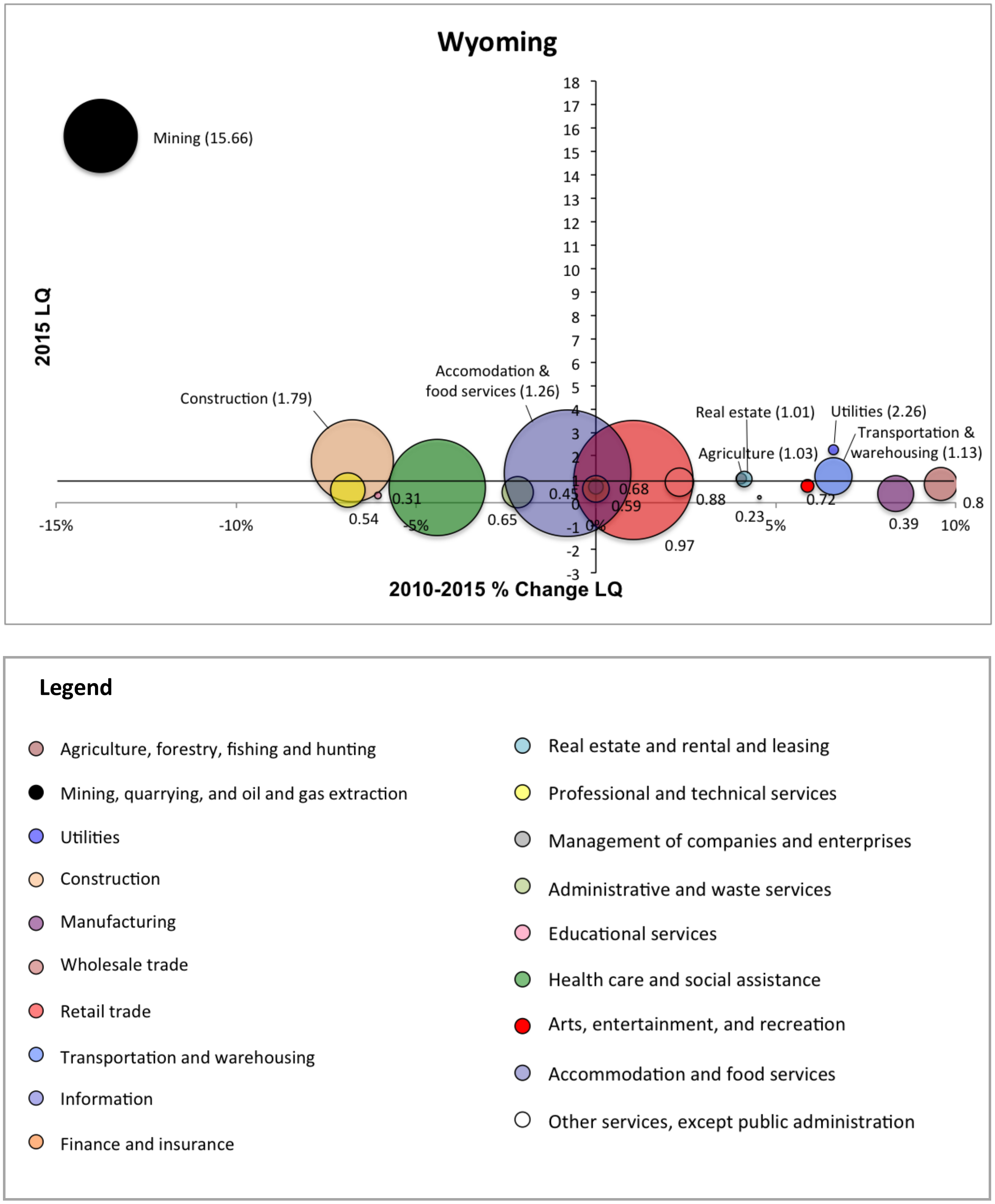
Industry Code	Employment2015	LQ2015
NAICS 21 Mining, quarrying, and oil and gas extraction	**269,965**	**4.3**
NAICS 211 Oil and gas extraction	99,353	6.18
NAICS 213 Support activities for mining	159,283	5.27
NAICS 22 Utilities	**49,434**	**1.07**
NAICS 221 Utilities	49,434	1.07
NAICS 23 Construction	**683,641**	**1.27**
NAICS 236 Construction of buildings	157,038	1.32
NAICS 237 Heavy and civil engineering construction	139,741	1.8
NAICS 238 Specialty trade contractors	386,862	1.14
NAICS 42 Wholesale trade	**594,734**	**1.21**
NAICS 423 Merchant wholesalers, durable goods	332,548	1.36
NAICS 424 Merchant wholesalers, nondurable goods	181,034	1.07
NAICS 425 Electronic markets and agents and brokers	81,151	1.07
NAICS 48-49 Transportation and warehousing	**429,623**	**1.12**
NAICS 481 Air transportation	58,352	1.53
NAICS 484 Truck transportation	143,519	1.19
NAICS 486 Pipeline transportation	17,671	4.35
NAICS 488 Support activities for transportation	81,963	1.51
NAICS 491 Postal service	869	1.66
NAICS 52 Finance and insurance	**504,365**	**1.05**
NAICS 522 Credit intermediation and related activities	255,468	1.19
NAICS 53 Real estate and rental and leasing	**201,247**	**1.15**
NAICS 531 Real estate	136,487	1.07
NAICS 532 Rental and leasing services	62,634	1.38

NAICS 533 Lessors of nonfinancial intangible assets	2,126	1.08
NAICS 56 Administrative and waste services	**770,339**	**1.05**
NAICS 561 Administrative and support services	738,422	1.05
NAICS 72 Accommodation and food services	**1,111,471**	**1.03**
NAICS 722 Food services and drinking places	993,295	1.08

As discussed above along with state GDP and employment by industry (Figure 6.5 and 6.6), Wyoming has been reliant on its mining industry for a long time. Figure 6.10 shows that the mining industry is highly clustered in Wyoming, but has declined since 2010 by 14% (Table 6.11). According to Table 6.12, the mining industry excluding oil and gas extraction is greatly concentrated in Wyoming (LQ = 23.62 in 2015), unlike Texas. The oil and gas extraction industry is also more greatly concentrated than in Texas. In the upper left quadrant, similar to the mining sector, the construction and accommodation and food service industries are highly clustered, but are declining over time.

The growing industrial bases in Wyoming are the utilities, transportation and warehousing, agriculture, and real estate, rental, and leasing sectors. However, the aggregated number of jobs from these industries are equivalent to the jobs only from mining sector, in 2016 (Table 6.11 and 6.12). The lower right quadrant includes retail trade, wholesale trade, manufacturing, management of companies, and arts, entertainment, and recreation. Only the retail trade sector has generated a 16% increase in employment rates, while other sectors generate a smaller share of jobs.

Figure 6.10 Bubble Graph of Location Quotient and Employment in Wyoming



Note) Only industrial sectors that have LQ greater than 1 are labeled by the sector name in graph.

Table 6.11 Wyoming Location Quotients calculated by NAICS 2-digit

(Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages, accessed on September 2017)

State	Sectors	Employment 2016	LQ 1990	LQ 2000	LQ 2010	LQ 2015	LQ Changes 1990-2015	LQ Changes 2010-2015
Wyoming	NAICS 11 Agriculture, forestry, fishing and hunting	2,667	0.96	1.08	0.99	1.03	7%	4%
	NAICS 21 Mining, quarrying, and oil and gas extraction	18,776	13.66	17.75	18.16	15.66	15%	-14%
	NAICS 22 Utilities	2,542	2.02	1.98	2.12	2.26	12%	7%
	NAICS 23 Construction	21,105	1.38	1.57	1.92	1.79	30%	-7%
	NAICS 31-33 Manufacturing	9,230	0.29	0.34	0.36	0.39	34%	8%
	NAICS 42 Wholesale trade	8,496	0.58	0.62	0.73	0.8	38%	10%
	NAICS 44-45 Retail trade	30,664	1.07	1.11	0.96	0.97	-9%	1%
	NAICS 48-49 Transportation and warehousing	9,554	1.12	0.85	1.06	1.13	1%	7%
	NAICS 51 Information	3,741	0.76	0.62	0.68	0.68	-11%	0%
	NAICS 52 Finance and insurance	6,825	0.63	0.62	0.59	0.59	-6%	0%
	NAICS 53 Real estate and rental and leasing	4,005	0.76	0.85	0.97	1.01	33%	4%
	NAICS 54 Professional and technical services	8,855	0.51	0.59	0.58	0.54	6%	-7%
	NAICS 55 Management of companies and enterprises	900	0.33	0.24	0.22	0.23	-30%	5%
	NAICS 56 Administrative and waste services	8,021	0.49	0.48	0.46	0.45	-8%	-2%
	NAICS 61 Educational services	1,700	0.25	0.33	0.33	0.31	24%	-6%
	NAICS 62 Health care and social assistance	24,771	0.66	0.74	0.68	0.65	-2%	-4%
	NAICS 71 Arts, entertainment, and recreation	3,287	1	0.99	0.68	0.72	-28%	6%
	NAICS 72 Accommodation and food services	32,563	1.52	1.5	1.27	1.26	-17%	-1%
	NAICS 81 Other services, except public administration	7,288	0.88	1.03	0.86	0.88	0%	2%

Table 6.12 Wyoming Location Quotient greater than 1 calculated by NAICS 2 & 3-digit, 2015

industry_code	Employment2015	LQ2015
NAICS 11 Agriculture, forestry, fishing and hunting	**2,599**	**1.03**
NAICS 112 Animal production and aquaculture	1,781	3.46
NAICS 21 Mining, quarrying, and oil and gas extraction	**23,860**	**15.66**
NAICS 211 Oil and gas extraction	4,253	10.9
NAICS 212 Mining, except oil and gas	9,458	23.62
NAICS 213 Support activities for mining	10,149	13.84
NAICS 22 Utilities	**2,535**	**2.26**
NAICS 221 Utilities	2,535	2.26
NAICS 23 Construction	**23,256**	**1.79**
NAICS 236 Construction of buildings	4,178	1.45
NAICS 237 Heavy and civil engineering construction	6,243	3.31
NAICS 238 Specialty trade contractors	12,835	1.56
NAICS 48-49 Transportation and warehousing	**10,510**	**1.13**
NAICS 484 Truck transportation	4,629	1.58
NAICS 486 Pipeline transportation	814	8.26
NAICS 491 Postal service	25	1.97
NAICS 53 Real estate and rental and leasing	**4,302**	**1.01**
NAICS 532 Rental and leasing services	2,044	1.86

As a result of LQ analysis, Table 6.13 shows industrial clusters for each state. In each cell of the table, the industrial sectors are ordered by LQ index.

Table 6.13 Summary of LQ Analysis Results

		California	Ohio	Texas	Wyoming
LQ >= 1	Standout & growing cluster	- Information, - Accommodation and food services, - Wholesale trade	- Management of companies and enterprises, - Manufacturing - Wholesale trade, Transportation and warehousing	- Mining, quarrying, and oil and gas extraction, - Wholesale trade, - Real estate, rental, and leasing, - Finance and insurance, - Accommodation and food services	- Utilities, - Transportation and warehousing, - Agriculture, forestry, fishing, and hunting, - Real estate, rental, and leasing
	Standout & Declining cluster	- Agriculture, forestry, fishing, and hunting, - Professional and technical services, - Real estate, rental, and leasing, - Administrative and waste services, - Other services except public administration	- Health care and social assistance	- Construction, - Transportation and warehousing, - Administrative and waste services, - Utilities	- Mining, quarrying, and oil and gas extraction, - Construction, - Accommodation and food services
LQ< 1	Pre-emergent cluster	- Health care and social assistance, - Construction, - Transportation and warehousing	- Finance and insurance, - Arts, entertainment, and recreation, - Other services except public administration, - Construction, - Mining,	- Retail trade, - Professional and technical services, - Other services except public administration, - Management of companies and enterprises,	- Retail trade, - Other services except public administration, - Wholesale trade, - Arts, entertainment, and recreation, - Manufacturing,

			quarrying, and oil and gas extraction, - Agriculture, forestry, fishing, and hunting	- Educational services	- Management of companies and enterprises
	Non-cluster	- Educational services - Manufacturing, - Management of companies and enterprises, - Utilities, - Finance and insurance, - Mining, quarrying, and oil and gas extraction	- Administrative and waste services, - Retail trade, - Accommodation and food services, - Educational services, - Utilities, - Real estate, rental and leasing, - Professional and technical services, - Information	- Health care and social assistance - Information, - Manufacturing, - Arts, entertainment, and recreation, - Agriculture, forestry, fishing, and hunting	- Information, - Health care and social assistance, - Finance and insurance - Professional and technical services - Administrative and waste services, - Educational services

6.5 Energy Market Analysis

States grow based on the diverse industrial bases, as well as a different composition of energy sources. Texas is one of the most energy-intensive states in the United States. Figures 6.11 and 6.13 show that Texas generated more than twice as much electricity as California, and consumed almost twice as much energy as California. However, Texas generated a lower real GDP by 64% in total, and by 89% in per capita base, as compared to California (Table 6.3). Coal is a dominant energy source in Ohio and Wyoming, with more than half of total electricity generation powered by coal. In Wyoming's unique mining-oriented economy, 84% of their electricity generation is coal-powered (Figure 6.12), and even more coal is used as an export (Figure 6.14). Meanwhile, in California, coal usage has almost entirely ceased, but natural gas consumption has risen. In 2018, natural gas made up 45% of electricity generation and 31% of energy consumption. Natural gas usage also grows in Ohio and Texas where manufacturing industries are concentrated. Renewable energy has grown into another replacement for coal, accounting for 34% of electricity generation in California. Figures 6.15 and 6.16 show that renewable energy consists of a diverse set of resources, such as solar (25%), wood and waste (17%), fuel ethanol (15%), hydro-electric power (15%), geothermal (13%), and wind (13%). Unlike California, wind is a single major renewable source in Texas and Wyoming.

Figure 6.11 Net Electricity Generation by Fuel for Four States, 2018

(Data Source: EIA. Electric Power Monthly with Data for March 2018, Retrieved from https://www.eia.gov/electricity/monthly/archive/may2018.pdf)

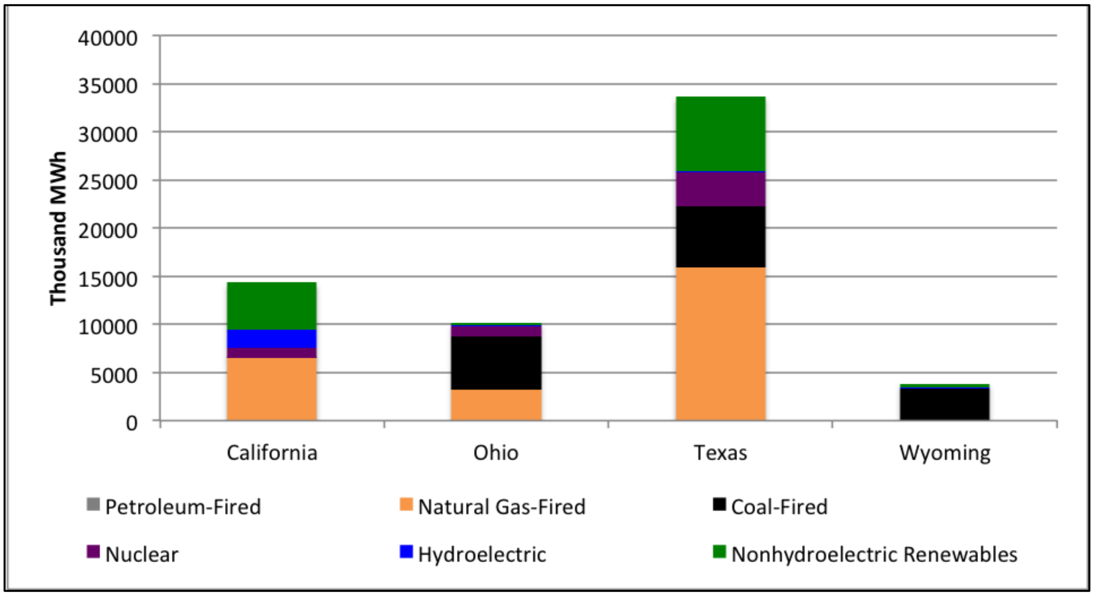


Figure 6.12 Energy Composition of Net Electricity Generation for Four States, 2018

(Data Source: EIA. Electric Power Monthly with Data for March 2018, Retrieved from https://www.eia.gov/electricity/monthly/archive/may2018.pdf)

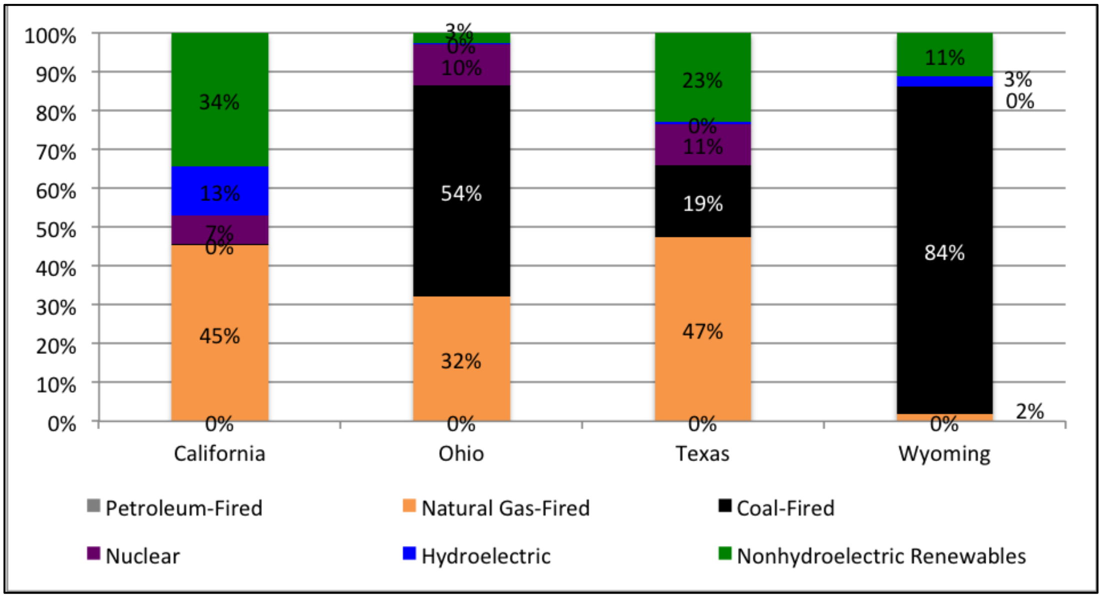


Figure 6.13 Energy Consumption by Energy Source for Four States, 2015

(Data Source: EIA, State Energy Consumption Estimates 1960 through 2016, June 2018)
https://www.eia.gov/state/seds/sep_use/notes/use_print.pdf)

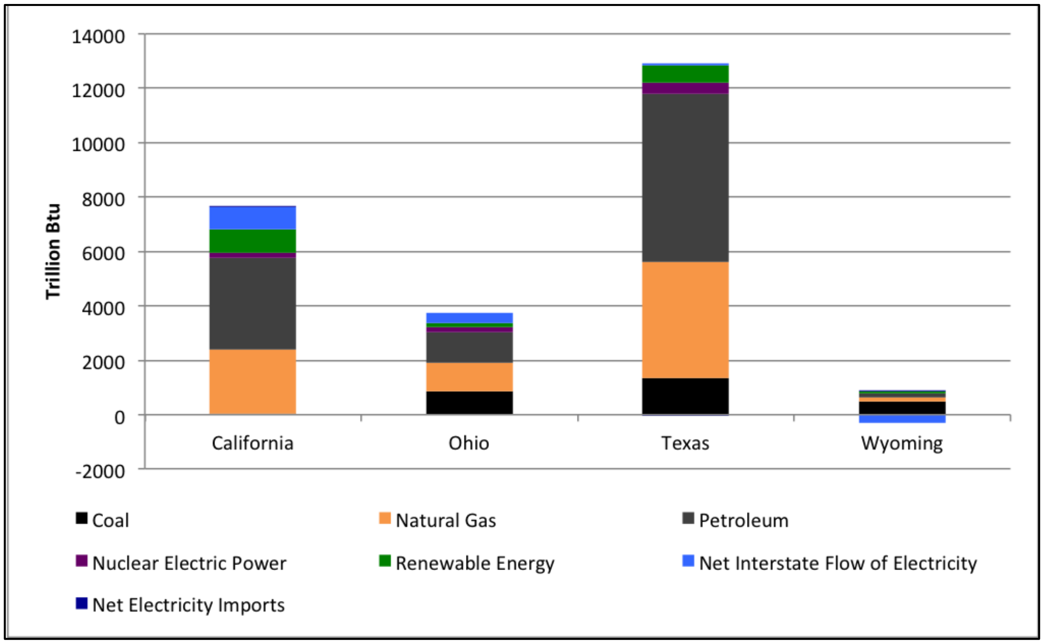


Figure 6.14 Fuel Composition (%) of Energy Consumption for Four States, 2015

(Data Source: EIA, State Energy Consumption Estimates 1960 through 2016, June 2018)
https://www.eia.gov/state/seds/sep_use/notes/use_print.pdf)

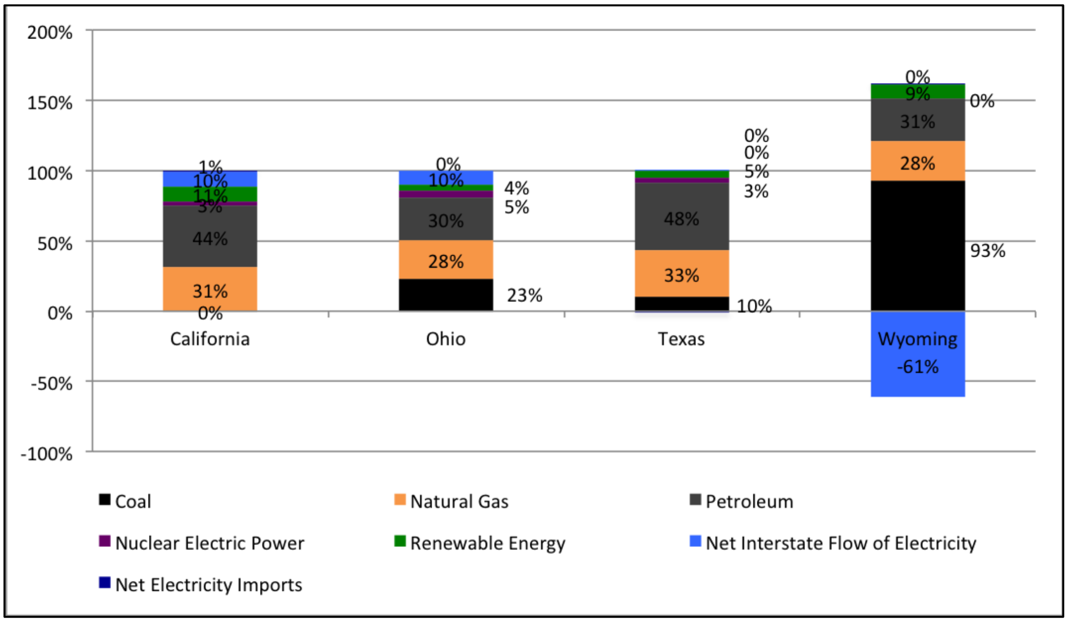


Figure 6.15 Renewable Energy Sources in Trilion Btu for Four States, 2015

(Data Source: EIA, SEDS, Table C3. Primary Energy Consumption Estimates 2015, https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_btu_totcb.html&sid=US)

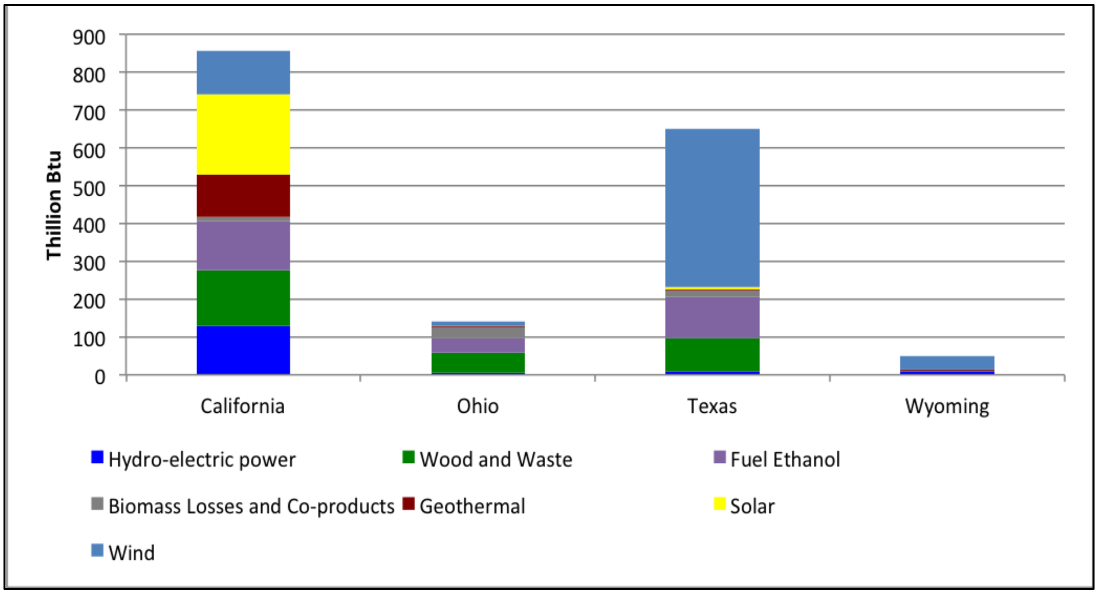
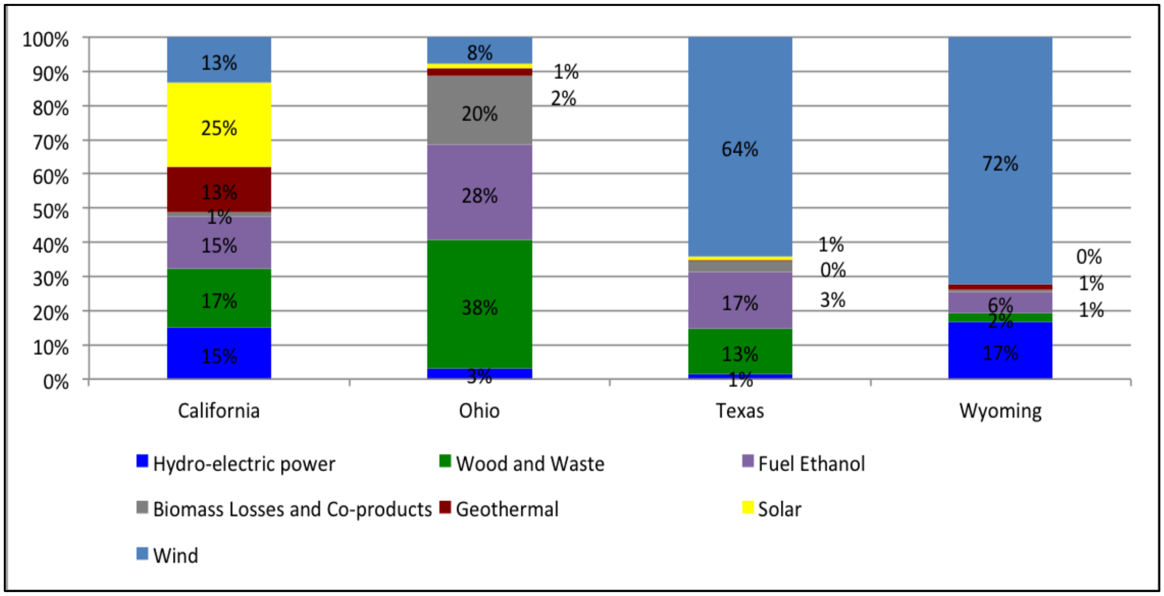


Figure 6.16 Renewable Energy Composition (%) for Four States, 2015

(Data Source: EIA, SEDS, Table C3. Primary Energy Consumption Estimates 2015, https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_btu_totcb.html&sid=US)



The most important indicators for CHP economics are electricity and gas prices. The energy price determines the long-term economics of CHP projects. California is well-known with the relatively expensive electricity prices in the nation. While the national average price for electricity is 12.99 cents/kWh, California charges 19.17 cents/kWh (Table 6.14) for residents. For industrial consumers, Californian companies have to pay almost double the national industrial average. The natural gas price in California is also higher than the national average. With such high energy prices, CHP and some other distributed generation would be more economically attractive than in other states.

Table 6.14 Electricity and Natural Gas Prices for Four States and the United States in March 2018

(Data source: U.S. EIA State Profiles and Energy Estimates, Retrived from https://www.eia.gov/state/ on July 2018)

		California	Ohio	Texas	Wyoming	United States
Electricity Prices	Residential	19.17 cents/kWh	12.55 cents/kWh	11.58 cents/kWh	11.05 cents/kWh	12.99 cents/kWh
	Commercial	14.83 cents/kWh	9.99 cents/kWh	8.32 cents/kWh	9.59 cents/kWh	10.47 cents/kWh
	Industrial	11.78 cents/kWh	6.56 cents/kWh	5.29 cents/kWh	6.94 cents/kWh	6.64 cents/kWh
Natural Gas Prices	City Gate	$2.76/thousand cu ft	$ 3.56 /thousand cu ft	$ 5.29 /thousand cu ft	$ 3.84 /thousand cu ft	$ 3.71 /thousand cu ft
	Residential	$12.27/thousand cu ft	$ 7.31 /thousand cu ft	$ 11.27 /thousand cu ft	$ 7.87 /thousand cu ft	$ 9.79 /thousand cu ft

Note: Prices are in nominal dollars.

6.6 CHP Supportive Policies and Legislation

Due to the lack of a coordinated CHP policy at the federal level, state-level activities are essential in creating a market environment that is favorable to CHP. Chapter 5 introduced empirical evidence explaining that states with proactive clean energy policies are likely to adopt more CHP technologies than states with fewer such policies. Among nine different types of clean energy policies, utility rate policies show positive and statistically significant correlationships with CHP deployment, and energy and climate change plans show positive and significant impacts after lagging 3 years.

The purpose of this section is to provide a closer look that explains distinctions between states that have worked to develop CHP-friendly policies and states that have done little to nothing for CHP-friendly policies. From the overview in Chapter 4, it was determined that active states are likely to work more towards initiating legislations and amendments, and, in the process, engage a greater number of stakeholders. Thus, the distictions between active and laggard states will be discussed in terms of three viewpoints—key policy contents, amendment history, and stakeholders.

6.6.1 California : High Policy Entrepreneurship / High CHP Adoption

States with active movements to develop CHP-friendly policies often establish a broad map, setting ambitious goals to develop CHP and DG resources. California is an outstanding state in creating and utilizing a clean energy roadmap. In recognition of the need for reduction of GHG emissions, their first plan was formed by passing the California Global Warming Solutions Act of 2006 (Assembly Bill 32, AB 32). The legislation originated from Governor Schwarzenegger's well-known Executive Order S-3-05, which set a long-term emission reduction goal by requiring an 80% reduction below 1990 levels by 2050. AB 32 let the California Air Resources Board (ARB) develop a *Climate Change Scoping Plan* that contained strategies for meeting those long-term goals by 2020. It set a target of 4,000 megawatts of additional CHP capacity by 2020 and 6.7 million metric tons of carbon dioxide reductions from CHP resources by 2020. The Scoping Plan was first approved by ARB in 2008 and updated in 2014. In 2016, Senate Bill 32 (SB 32) was passed, extending the statewide GHG emission reduction goals to 2030. SB 32 is based on Governor Edmund G. Brown Jr.'s Executive Order B-30-15 establishing a mid-term reduction goal of 40% below 1990 levels by 2030. Governor Brown also issued the *Clean Energy Jobs Plan* in 2010, which set a goal for 6,500 megawatts of additional CHP capacity by 2030. These goals aligned with President Obama's 2012 Executive Order calling for a national goal of 40 GW of new industrial CHP by 2020 (California Energy Commission, 2017).

Table 6.15 Summary of California's Clean Energy Goals

Goals	Source
- Reduce GHG emissions 40 % below 1990 levels by 2030 - Add 4,000 megawatts of additional CHP capacity by 2020, - Reduce 6.7 million metric tons of carbon dioxide from CHP resources, by 2020	Climate Change Scoping Plan (2008), Assembly Bill 32 (2006), Senate Bill 32 (2016)
- Add 20,000 MW of renewable energy capacity by 2020	Governor's Clean Energy jobs Plan (2010)

- Add 8,000 MW of large-scale renewables - Add 12,000 MW of distributed generation (localized and <20MW), including 6,500 MW of additional CHP capacity	

Other efforts for reducing GHG emissions, as well as conserving benefits of CHP, were established by 18 month-long negotiations between investor-owned utilities (IOUs), CHP trade representatives, and ratepayer advocacy groups. The California Public Utilities Comissioin (CPUC) filed the *Qualifying Facilities and Combined Heat and Power Program Settlement Agreement* in 2010. It replaced the federal PURPA program for qualifying facilities with the California's state CHP program.[28] The new program by the settlement mandates two goals: (1) IOUs will add a minimum of 3,000 megawatts (MW) of CHP over the program period, and (2) the IOUs will reduce 4.8 million metric tons of carbon dioxide, as recommended in the Scoping Plan. The website of CPUC[29] has uploaded and updated tracking reports of the additional CHP capacity and GHG reductions. IOUs submit performance reports to the CPUC on April and October of each year.

California has one of the most ambitious renewable energy portfolio standards of the nation. The RPS requires both IOUs and publicly-owned electric utilities (POUs) , as well as all other electricity retailers to increase their electricity generation of eligible renewable energy resources to 33% of retail sales by 2020, and 50% by 2030. The original RPS goal established in 2002 required 20% of electricity retail sales to be

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[28] See Section 1.1 to understand the roles of the PURPA for qualifying facilities

[29] http://www.cpuc.ca.gov/General.aspx?id=5168

generated by eligible renewable energy resources by 2010. The RPS was expanded and accelerated by subsequent legislations in 2006, 2008, and 2015. Most recently, in 2015, Governor Edmund G. Brown Jr. signed legislation that calls for 50% of California's electricity to come from renewable energy sources by 2030 (Senate Bill 350, 2015). In California, the Energy Commission and the CPUC work collaboratively to implement the RPS by certifying and verifying CHP facilities as eligible for the RPS.[30] The California Energy Commission estimated that about 30% of 2017 retail electricity sales were served by eligible renewable energy facilities, 36% of which was solar, 31% wind, 17% geothermal, 9% biomass, and 7% small hydroelectric (California Energy Commission, 2017). The amount of CHP capacity and waste heat is eligible to count towards the required percentage of RPS. The inclusion of CHP in RPS or EERS, therefore, plays an important role in strengthening the CHP market (Chittum & Kaufman, 2011). In this dissertation, Chapter 5 provided an empirical evidence supporting the significant role of RPS and EERS in promoting the capacity of CHP generation (Table 5.2, Model 3).

As of 2018, California installed 1,220 CHP systems with a combined capacity of 8,590 MW. Between 2010 and 2016, 201 new CHP units were installed with a capacity size of 518 MW.

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[30] Publicly-owned utilities are not regulated by the CPUC, but are affected by the law.

Figure 6.17 Number of CHP Installations by Application Sectors in California, 1980-2016

(Data Source: DOE's CHP Installation Database, accessed on July 2018)

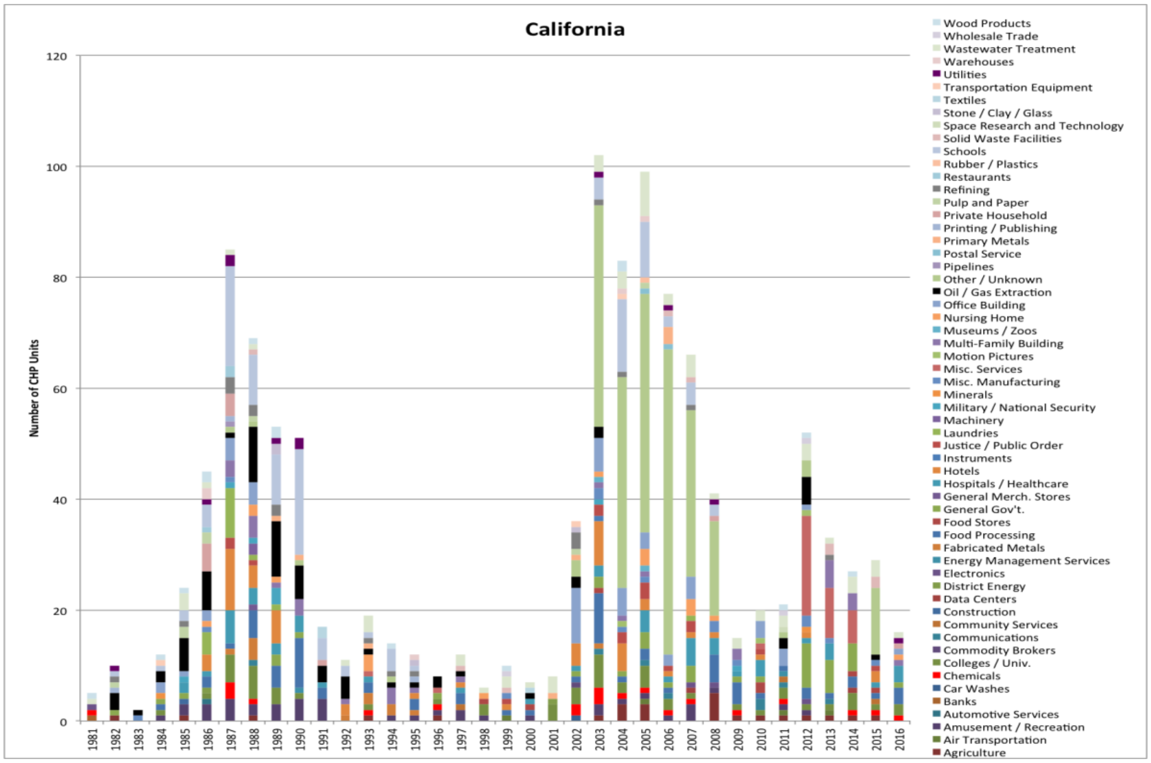
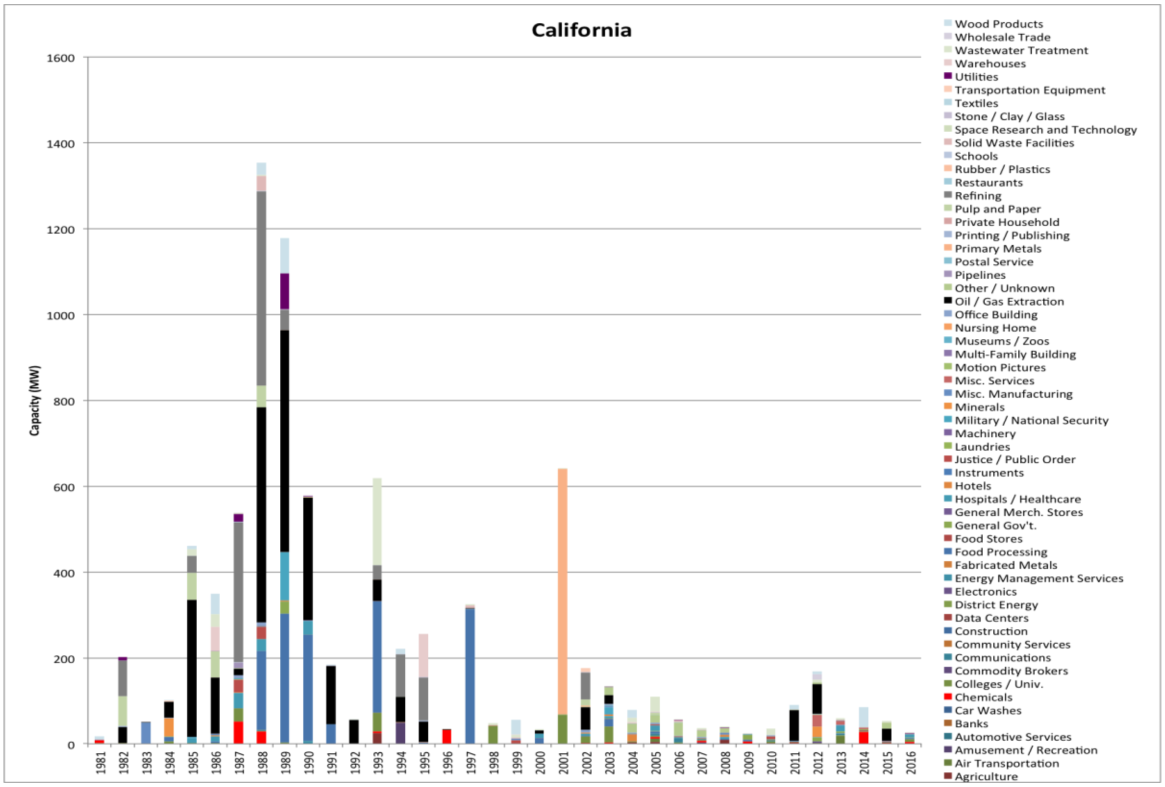


Figure 6.18 CHP Installations Capacity (megawatts) by Application Sectors in California, 1980-2016

(Data Source: DOE’s CHP Installation Database, accessed on July 2018)



6.6.2 Ohio : High Policy Entrepreneurship / Low CHP Adoption

While California’s transformation in the energy market came from efforts of GHG emission reductions, Ohio’s transformation was motivated by deregulation of their electricity market. The deregulation allowed consumers to choose a competitive supplier to buy energy, instead of automatically receiving it from the public utility. In 1999, the Ohio Electric Restructuring Act (Senate Bill 3) enabled restructuring of the energy market and raised the issue of electricity price increases. The Public Utilities Commission of Ohio (PUCO) and electric utilities developed *Rate Stabilization Plans* (RSPs) that regulated electricity prices. This approach significantly slowed competitive market development after electric market deregulation (Public Sector Consultants, 2016). In 2007, Governor Ted Strickland proposed the *Energy, Jobs and Progress Plan*, which advanced four major goals: (1) keep electricity rates stable and predictable; (2) support development of advanced and renewable energy technologies, (3) increase energy efficiency, and (4) modernize electric infrastructure. The plan did not include a specific target or goal related to clean energy. In 2008, Ohio enacted a broad electric restructuring legislation, Senate Bill 221 (SB 221), which established an *Alternative Energy Portfolio Standard*, mandating a 12.5% of renewable energy generation by 2025, and an *Energy Efficiency Resource Standard*, requiring a cumulative 22% reduction in electricity use by 2025. CHP and waste energy recovery systems were added later in 2012 as a qualifying renewable energy technology for either RPS or EERS. Qualifying CHP projects have to meet minimum performance metrics, such as achieving 60% of overall thermal-efficiency and at least 20% of useful thermal energy. Under RPS and EERS, utilities are required to file their energy efficiency program plans for a three year period and to submit annual status reports with evaluation, measurement, and verification to demonstrate their compliance with the annual targets.

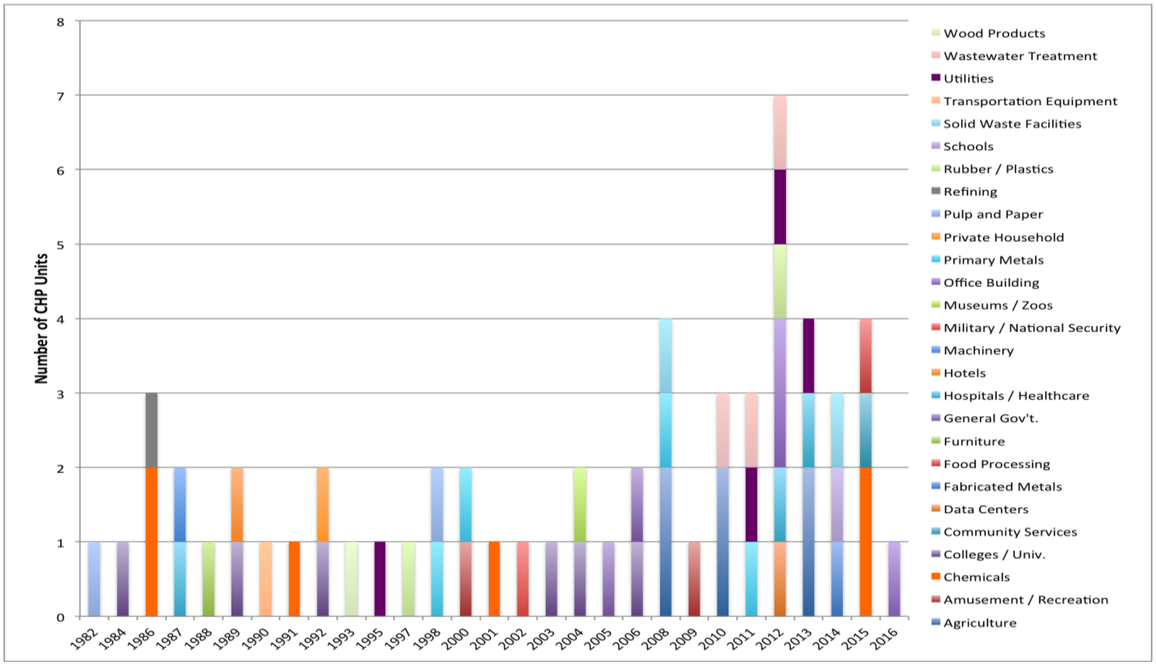
In 2014, however, Senate Bill 310 (SB 310) froze the RPS and EERS requirements for 2 years, postponing the final target deadline from 2024 to 2026. House Bill 554 of 2016 would have extended the freeze for an additional 2 years, but was vetoed by Governor John Kasich, effectively reinstating the RPS and EERS in 2017.

Governor Kasich proposed Ohio's *21st Century Energy Policy* in 2014 after discussing comprehensive energy policies for Ohio in a *21st Century Energy and Economic Development Summit* on September 2011. The participants were energy executives, environmental groups, business executives, cabinet directors, and the governor's office staff. The summit discussions translated into legislation of Senate Bill 315 (SB 315), which proposed ten pillars[31] to encourage a diverse mix of reliable and low-cost energy sources. The legislation also allowed waste energy recovery projects to qualify as a renewable energy source, as well as electricity utilities to use CHP to meet EERS.

As of 2018, Ohio installed 65 CHP systems with a combined capacity of 532 MW. Between 2010 and 2016, 25 new CHP units were installed with a capacity size of 76 MW.

Figure 6.19 Number of CHP Installations by Application Sectors in Ohio, 1980-2016

(Data Source: DOE's CHP Installation Database, accessed on July 2018)



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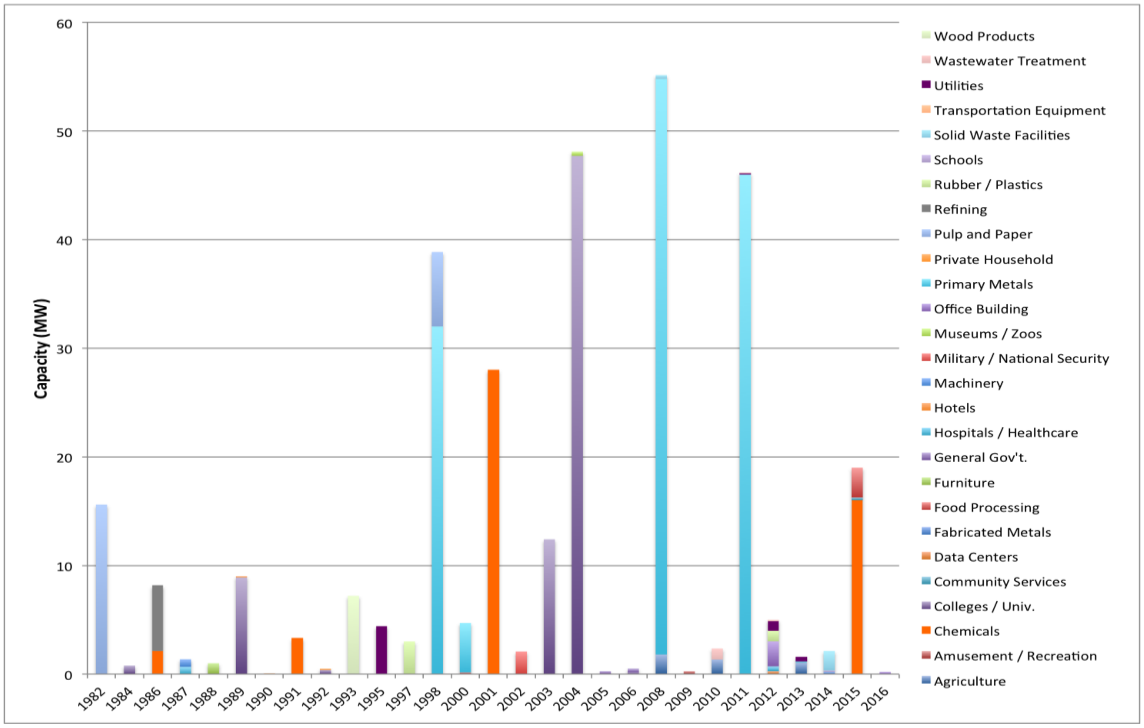
[31] The pillars include shale gas, electricity generation, transmission and distribution, cogeneration/waste heat recovery, workforce training, CNG/alternative fuels, energy efficiency, coal, regulatory reform, and renewables.

Figure 6.20 CHP Installations Capacity (megawatts) by Application Sectors in Ohio, 1980-2016

(Data Source: DOE's CHP Installation Database, accessed on July 2018)



6.6.3 Texas : Low Policy Entrepreneurship / High CHP Adoption

Texas has the largest capacity for CHP, accounting for 22% of the national CHP capacity in 2017. This large-scale investment in CHP came from the prevalence of large industrial facilities, including chemical manufacturing and refining, which require large electrical loads and thermal energy (see LQs by industry from Figure 6.9 and Tables 6.9 & 6.10). Under these economic bases, Texas has aggressively worked to develop energy efficiency goals to reduce energy demand. In 1999, like Ohio, Texas took on restructuring its energy market by deregulation. The passage of SB 7, codified as the Public Utilitiy Regulatory Act Sections 39 through 41, deregulated its electricity sector.

However, unlike Ohio, Texas ensured the cessation of integrated utilities performing generation, transmission, distribution, and retail functions at a single entity. The utilites were instead separated into three distinct entities: (1) power generation companies, (2) retail electric providers, which purchase electricity from the power generation companies and sell it to customers, and (3) transmission and distribution service providers, which are responsible for the delivery of electricity. Since 2002, transmission and distribution service providers were authorized to offer incentives to retail electric providers or energy services companies for qualifying energy efficiency measures (Bevill & Howell, 2017).

As part of the restructring process, Texas established a *Required Energy Efficiency Goal*, which was the first EERS in the United States. The Public Utilities Commission of Texas (PUCT) adopted the rules for IOUs to achieve at least a 10% reduction in their annual demand growth by 2004. However, since 1999, several states have surpassed Texas's energy efficiency goal. In order to maintain their lead, in 2008, Texas amended the efficiency rule to increase the goal from 10% of demand growth in 2007, to 15% in 2008, and finally to 20% in 2009 (House Bill 3693, 2007). Before this legislation, the largest IOU, Itron, assessed that the 10% goal was already in place, and could be increased to 20% or more (Bevill & Howell, 2017). The 2008 amendment also allowed utilities to earn a bonus if they exceeded the goals. The PUCT determined that utilities would be eligible to receive a bonus equal to 1% of the net benefits for every 2% the demand reduction goal was exceeded. In addition, the 2008 amendment specifically allowed for incentives to be provided for CHP systems.

In 2010, the PUCT adopted additional modifications to the efficiency rules, increasing demand reduction goals, ramping up from 20% reduction of demand growth in

2010 and 2011 to 25% reduction in 2012, and finally to 30% reduction for 2013 and thereafter (Senate Bill 1125). The calculation of the performance bonus was also modified along with the goal increase. SB 1125 required IOUs to reduce energy usage and demand to the point that such savings represent 30% of the annual growth in peak demand on each utility's system or if this standard was already met, up to 0.4% of each utility's peak demand thereafter. The Texas Efficiency website (texasefficiency.com) has posted utility programs and energy efficiency reports for each IOU since 2007.

In the overall process of evolving energy management programs, several non-profit partnerships and initiatives have played a significant role in spreading awareness of CHP benefits, technologies, and applications. In 2015, the Houston Advanced Research Center (HARC) was awarded a U.S. DOE's grant, allowing it to operate as the DOE's Southwest CHP Technical Assistance Partnership (CHP TAP). Prior to the CHP TAP, the Gulf Coast Combined Heat and Power Application Center had worked since 2005 with the U.S. DOE's funding support. The HARC assists end-users who consider and evaluate CHP for their facilities, providing support throughout project development processes by screening options, qualifying sites, analyzing feasibility and regulatory requirements, and working with engineers, architects, city planners, project developers, state agencies, and policymakers. Several non-profit associations, such as the Texas Combined Heat & Power Initiative (TXCHPI) and the South-Central Partnership for Energy Efficiency as a Resource (SPEER) also support increasing and accelerating the adoption of energy efficient CHP technologies and services. Their main objective is to provide education and resources for those interested in CHP.

Even though Texas took a bold step in developing energy demand management programs along with diverse support groups, their policy efforts might be underestimated when compared to other states. ACEEE scored Texas's energy efficiency policy efforts as average, ranking them as 27th of the states in 2016 (Berg et al., 2016). SPEER argued that this assessment did not reflect a unique market structure and competitive electricity retail services in Texas (Bevill & Howell, 2017).

As of 2018, Texas installed 130 CHP systems with a combined capacity of 17,611 MW. Between 2010 and 2016, 20 new CHP units were installed with a capacity size of 624 MW.

Figure 6.21 Number of CHP Installations by Application Sectors in Texas 1980-2016

(Data Source: DOE's CHP Installation Database, accessed on July 2018)

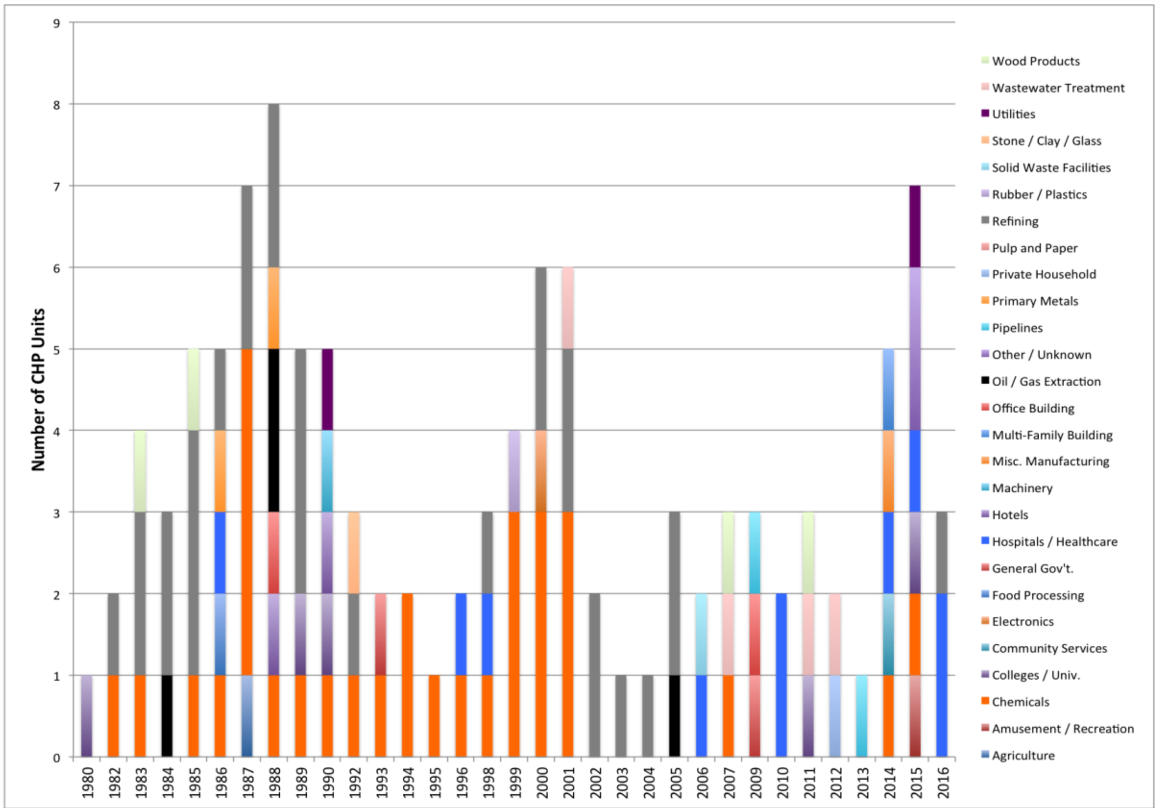
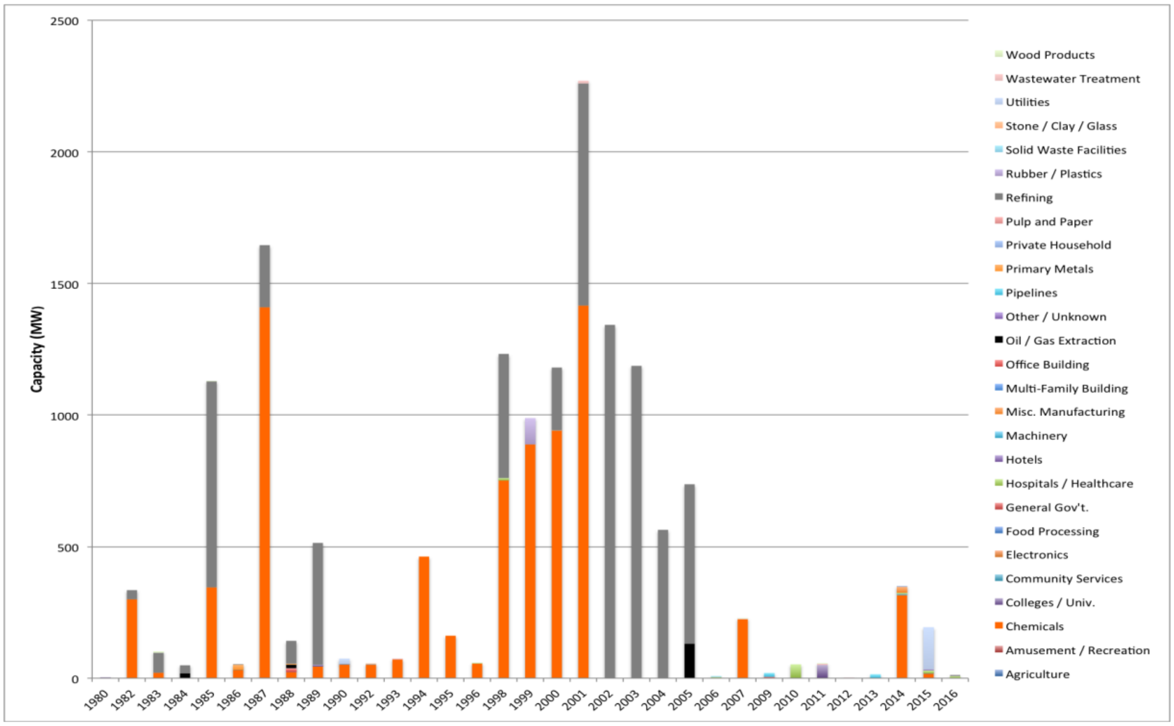


Figure 6.22 CHP Installations Capacity (megawatts) by Application Sectors in Texas, 1980-2016

(Data Source: DOE's CHP Installation Database, accessed on July 2018)



6.6.4 Wyoming : Low Policy Entrepreneurship / Low CHP Adoption

The state of Wyoming offers very unfavorable market conditions for not only CHP, but also other clean energy technologies. According to the CHP installation database, as of 2018, Wyoming installed only eleven units of CHP systems, accounting for 170 MW of capacity. The last CHP project installed in the state was in 2008 (Table 6.16).

Table 6.16 CHP Installations in Wyoming

(Source: DOE's CHP Installation Database, accessed on July 2018)

City	Facility Name	Application	Operation Year	Capacity (KW)	Prime Mover	Primary Fuel
Riverton	Amoco Oil Co.	Energy Management Services	2008	350	Backpressure steam turbine	Waste Steam
LaBarge	Exxon Mobil Shute Creek Plant	Oil / Gas Extraction	2004	108,000	Combustion turbine	Natural gas
Wheatland	Wyoming Premium Farms	Agriculture	2003	240	Reciprocating engine	Biomass - Digester gas
Cheyenne	East High School	Schools	2002	80	Microturbine	Natural gas
Rock Springs	SF Phosphates	Minerals	1986	11,500	Boiler/steam turbine	Other
Story	Orin R.Young Dba Young Electric	Misc. Manufacturing	1985	225	Reciprocating engine	Other
Beaver Creek	Beaver Creek Gas Plant	Refining	1983	5,000	Combustion turbine	Natural gas
Afton	Afton Generating Company LP	Wood Products	1982	7,000	Boiler/steam turbine	Wood
Green River	Soda Ash Plant	Chemicals	1968	30,000	Boiler/steam turbine	Coal
Sinclair	Sinclair Oil Refinery	Refining	1954	6,300	Boiler/steam turbine	Natural gas
Powell	Elk Basin Gasoline Plant / Winkelman Dome	Oil / Gas Extraction	1948	1,600	Boiler/steam turbine	Natural gas

The main reason for slow progress in Wyoming is the pre-existing economic structure. Wyoming is the least populous state in the nation, and has concerns about young generation losses (Figure 6.1). The main drivers of Wyoming's economy are mineral extraction and the tourism industry (Table 6.11 and 6.12). As the previous LQ analysis showed a LQ of 15.66 for the mining sector, the state is highly dependent on minerals. However, the coal industry is coming around to the fact that "hydraulic fracturing has changed the energy industry landscape at least for electricity generation.

[Wyoming] still produces 40% of coal-fired electricity but the pie is much smaller."[32] As seen in Figure 6.11, 84% of Wyoming's electricity was generated from coal-fired utilities, and 93% of coal-fired energy was consumed inside and outside of the state of Wyoming. As discussed above, Wyoming exported 61% of energy consumption out to other states (Figure 6.12).

ACEEE's study (Chittum and Kaufman, 2011) pointed out that the lower electricity rates in Wyoming could be the main barrier to increased CHP deployments. In addition, the natural gas prices are much higher than the national average (Table 6.14). The poor spark spread from the low electricity price and high natural gas price makes it difficult for industries and businesses to justify investing upfront capital in CHP or other alternative energy systems. However, more importantly, the existing industrial structure in Wyoming, which focused on single mineral extraction, could be a more significant explanation for the lack of support for both clean energy adoption and policy implementation.

Recent legislations in Wyoming focus on finding a solution to the question, *how can Wyoming diversify its economy?* The initial action was started by creating an *Economically Needed Diversity Options for Wyoming* (ENDOW) Initiative by Governor Matt Mead, on November 2016. Right after that, in January 2017, Governor Mead announced a 20-year economic strategic plan, and signed the ENDOW Initiative bill into law on March 2017 (Senate Bill 132). The ENDOW Executive Council was formed along

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[32] Quote from Rob Godby, Director of the Center for Energy Economics and Public Policy at the University of Wyoming, at a panel discussion in Powder River Basin Resource Council (PRBRC) on November 2017. The article is retrieved from Western Organization of Resource Councils (WORC) website, http://www.worc.org/wyoming-diversifying-economy-revenue.

with business and community leaders. According to their website postings of news and events (www.endowyo.biz), they have worked to host meetings, forums, and public hearings, tour successful sites on economic diversification and job creation, and submit a report of socioeconomic analyses. On March 2018, Wyoming legislature passed the bill package, authorizing ENDOW. The Executive Council proposed ten preliminary recommendations, including research and development of renewable and wind energy (ENDOW news release, 2018). Most recently, ENDOW held a meeting on July 2018, ahead of submitting recommendations to Governor Mead and the Wyoming legislature. The participants had panel discussions, and made a full recommendation list under nine key words—advanced manufacturing, agriculture, energy & natural resources, tourism & outdoor recreation, community health, technology & financial services, healthcare, workforce & education, and entrepreneurial ecosystem. The process is still ongoing.

6.7 Conclusions

A multi-case study of four selected states confirms distinct approaches to CHP policies developments and implementations, resulting in different degrees of CHP technology adoption. In states that have worked aggressively to remove barriers to CHP, CHP developers have been able to get information on regulatory requirements, technical consultants, feasibility analysis, and the benefits of CHP through offline meetings and online web resources. When active states created a goal of energy efficiency savings or renewable energy capacity, they also established a channel for tracking customers' performances in a regular schedule. For example, while California, a state with both high policy entrepreneurship and high CHP adoption, established a specific goal of GHG emissions reductions as well as a target of CHP capacity growth, the state's California Public Utility Commission has posted semi-annual performance reports on their website. The stringent air emission standards lead to increased CHP installations because compliance costs for permitting emissions controls tend to comprise a significant portion of the upfront cost of a CHP project (Chittum, Kaufman 2011). A variety of stakeholders and advocacy groups in public and private sectors have been involved in energy and environmental conservation performances. In addition, California's high electric prices make CHP and other forms of DG more economically attractive than in other parts of the country. Even so, the volatility of natural gas prices has made some CHP developers hesitant to move forward with new projects. In this context, strong policy supports of reducing rate-based barriers are important to make CHP projects more economically feasible. In Chapter 5, this finding is empirically confirmed by the most significant coefficients of utility rate policy (positive in Model 3) on CHP technology adoptions.

Overall, energy market of California has more diverse energy resources than in other parts of the nation (Figures 6.12 and 6.16). With lower energy intensity, California consumes less energy compared to the other states, such as Texas (Figures 6.11 and 6.13).

Energy market transformation in Ohio and Texas was spurred by deregulation of the electricity market in the late 1990s. In Ohio, a state with high policy entrepreneurship but low CHP adoption, energy plans were aimed to regulate electricity prices and only recently has the state relinquished control over its electricity prices. This slowed competitive market development, and as a result, Ohio is still dependent on coal and nuclear energy while natural gas consumption has risen in other parts of the country.

Even though RPS and EERS attempt to encourage renewable energy and energy efficiency as a resource, policy barriers seem to be high as seen in recent legistation for freezing the original RPS goal. Ohio is a state with high potential of CHP installation (Table 1.2) with its existing cluster of manufacturing industries. A study by Public Sector Consultants (2016) addressed that "[Ohio] now faces challenges related to how or if to maintain in-state generation and whether it wants to intervene to ensure the future of its energy supplies (p.6)."

Texas, a state with low policy entrepreneurship but high CHP adoption, is the most energy-intensive state with its reliance on chemical and refining industries. To reduce its energy burden, Texas has developed energy efficiency policies such as EERS. When Texas restructured its energy market by deregulation, they attempted to reduce utility monopoly and increase market neutrality by distinguishing functions in three distinct entities—electricity generation, retail service provider, and transmission and distribution service provider. Texas also strengthened its energy demand reduction goal from 10% to 30%. However, Texas's heavy industries demand more energy than in other states and also still rely on fossil fuel-based energy generation.

Wyoming, a state with low policy entrepreneurship and low CHP adoption, is significantly dependent on its mineral extraction industry. The existing economic structure makes Wyoming have little interest in alternative energy resources and energy efficiency. Not surprisingly, there are very few CHP projects. However, through recognition of a declining mining industry and young human power losses, the governmental leadership is recently making efforts to raise awareness of the need of economic diversification.

Chapter 7 Conclusions and Implications

U.S clean energy policy has evolved from the bottom up, led by state governments and associated stakeholders in private and non-private sectors rather than federal leadership. This dissertation was written between 2013 and 2018, during the period of political transition from the previous Obama administration and to the current Trump administration. Because of that, we have seen that federal policy is often subject to political winds. For example, as shown by the Clean Power Plan case, complex interests can slow and impede policy innovations. In 2018, under the Trump admistration, which does not believe climate change is a priority concern and wants to expand oil and gas production, much uncertainty impedes the direction of low-carbon energy deployment and energy resource diversification. Yet, a number of states and cities are continuously moving forward to advance clean energy.

Since the Obama administration began, EBED has emerged and been expanded where energy is identified as a driver of regional and local economic development. After approximately a decade of state governmental leadership in clean energy and climate change policy, what have we learned about the impacts of state leadership in energy market and regional economic development? What other factors (or people) have been involved in EBED? How differently have state governments taken action to promote clean energy and regional economic development? What lessons would guide the future of EBED practice?

This dissertation sought to address these questions, and empirically evaluate clean energy policies by narrowly focusing on a CHP system as an innovative technology option of distributed generation and state-level supportive policies in the United States. The driving questions behind this dissertation have been raised due to skepticism in regard to a growing number of articles in the policy literature estimating green jobs creation in the absence of a clear definition of green economy.

To address the skepticism, this dissertation conducted three major analyses. The first portion of the dissertation identified types of state clean energy policy instruments, and scored the intensity of clean energy policy implementation by state, which was described in Chapter 4. This dissertation evaluated the impacts of clean energy policies, including (1) financial incentives such as utility rate policies, tax credits, tax exemptions, and financing assistance; (2) regulatory instruments such as environmental and energy regulations, renewable and energy efficiency portfolio standards, interconnection standards and net metering; and (3) information policies such as energy plans and climate change plans. This analysis provided explanatory variables of state clean energy policy entrepreneurship and its diffusion to be included in the empirical analyses.

The second portion of the dissertation provided empirical evidence under a main question: What are the drivers and barriers of innovative technology adoption? To measure the innovative technology adoptions, the total number of new CHP units and total size of new CHP capacity per GDP were used as dependent variables. In Chapter 5, internal determinants models with random-effects regression analyses were developed with a panel data set for 50 states and Washington D.C. from 1980 to 2014. In addition, a lagged-effects model is employed to test policy impacts at a later point in time.

The third portion of the dissertation was to provide a closer look that explains distinctions between states that have worked to develop CHP-friendly policies and states that have done little to nothing for CHP-friendly policies. A multiple-case study was applied by selecting four states: California as a representive state having high intensity of clean energy policy entrepreneurship and a high number of new CHP projects, Ohio as a state having high policy entrepreneurship but a low number of new CHP projects, Texas as a state having low policy entrepreneurship but a high number of new CHP projects, and Wyoming as a state having low policy entrepreneurship and a low number of CHP projects. The multiple-case study was conducted in four parts: (1) an economic base study to assess economic and demographic drivers and barriers in different states, (2) location quotient analysis to understand the existing industrial bases (clusters) in different locations, (3) energy market analysis to understand the different energy market footprints, and (4) CHP-supportive policies and legislation by exploring media, formal policy reports, state governments' documentation, and other website resources created by interest groups and associated stakeholders. In Chapter 6, the multi-case study of four selected states confirmed distinct approaches to CHP policy development and implementation, resulting in different degrees of CHP technology adoption and employment.

7.1 Scoring the Evolution of State Clean Energy Policies

As a measure of state policy entrepreneurship, a score was credited after the first year of each policy's implementation unless the policy was discontinued. The collection of state policy data itself provided lessons of state clean energy policy efforts.

First, some states have taken substantial action, others minimal action. Not all states have taken actions to aggressively engage with the practice of EBED. Scoring the intensity of state clean energy policies indicates a wide range from 1 (Alabama and Mississipi) to 17 (California). Each state has crafted its own combination of different policy instruments, and has updated or removed the tools over time.

Second, energy policies are not necessarily climate change policies. The majority of state clean energy policies is assumed to be a cost-effective and politically feasible way to achieve climate change policy objectives, such as greenhouse gas emissions reductions. Yet, the collection of state clean energy policies presents that most of clean energy policies do not directly address the market failures regarding climate change. Instead, energy policies have demonstrated objectives for economic development, including energy resource diversification, utilization of decarbonization technologies, energy efficiency improvement, demand-side management, standardized interconnection, financial barriers abatement, price-based feasibility, and job creation. Thus, energy policy implementations require multidimensional approaches regarding technology development, commercialization, research and development, entrepreneurship recruitment, financial support, coordination with the utility sector, and supportive information channels. A comprehensive approach is important to successful EBED practices.

Third, states are likely to emulate policy experiments from earlier movers (Walker 1969, Berry and Berry 2007). However, not all first movers are game changers. Some states adopted RPS standards or regulations earlier than other states, but made little progress (i.e. Iowa's RPS). The initial legislation can be effective when it continues to be reevaluated, updated and amended as a response to consumer demand and market availability for more diverse alternative energy sources. While Rabe (2008) argued that many state and local energy entities attempt to "be first movers" to gain an early market share, the benefit could be realized in those states with long-term efforts for policy implementation. These states have a tendency to strengthen or extend policy instruments over time. In addition, these states have pursued a democratic communication in policy processes, with openness to all stakeholders.

Fourth, location matters in policy diffusion. According to Figure 4.1 showing the geographic allocation of total policy scores, there are strong concentrations of scores in the northeastern region surrounded by New York, Connecticut, and Massachusetts, and in the west coast surrounded by California. In contrast, states in the southeast and midwest regions have relatively weak scores. This dissertation did not focus on measuring how much location plays a factor in a state's adoption of energy policy. However, we reviewed that location has been regarded as a factor of policy diffusion from the literature. Theorists have viewed policy diffusion as a mechanism of interregional economic competition between neighboring states. Since the availability of renewable energy resources varies by location, geographical location sets time-invariant contraints on how much renewable energy supply a state can pursue. A RE regression model was employed to control this time-invariant condition.

Fifth, political context strongly influences a state's adoption of a new energy policy. Theorists have dicussed policy diffusion as a function of internal determinants, including political context, fiscal health, problem severity/demand, and regulatory stringency. A general concensus from the literature was that political context is one of the most important determinants of clean energy policy diffusion. The multicase study in Chapter 6 described how the political capacity to address climate change can differ from state to state, and how it can or cannot help states jumpstart clean energy development. Future studies that consider political capacity as a determinant of CHP technology adoption will make great contributions to the existing literature.

Sixth, energy policies that support all ranges of CHP technologies without a limit on system size can be more effective to increase CHP users. In many states, CHP-friendly policies typically tend to be supportive to industrial customers that demand large-sized generation systems. However, deciding to adopt CHP systems in small-scale facilities could be more affected by the level of policy support. As regards the intensity of the clean energy policies for a RE model, an additional score was given based on whether interconnection standards and net metering allow all sizes and all fuel levels of CHP generation, which contribute to reduce barriers for consumers of small-scale CHP systems.

7.2 Consumers CHP Technology Adoption and State Clean Energy Policies

The results of the RE models suggest that state clean energy policies generally lead to increases in CHP installations in terms of the number of units. In Model 1, using the number of new CHP units, the coefficient of policy score is positively correlated with the number of CHP units. Model 2, using the size of new CHP capacity per GDP as a dependent variable, estimated that the coefficient of total policy score is insignificant as the large size of CHP capacity mostly in Texas does not correlate with state policy efforts, but rather their existing industrial bases. Therefore, Models 1 and 2 conclude that we can accept hypothesis #1, that industries are more likely to adopt CHP technologies where the state government provides a number of policy instruments. The small-scale CHP technology is generally installed in hospitals, colleges, hotels, waste management facilities, etc. Deciding to adopt innovative technology in these small-scale facilities could be affected by the level of policy support.

Models 3 and 4 used nine individual types of clean energy policies as its explanatory variables. In Model 3, in which the dependent variable is the number of new CHP installations, utility rate policies are shown to have the most significant effect on the growth of CHP units. In addition, the role of energy and climate change plans is also significant by lagging a few more years after enactment.

One interesting finding from RE models is that market structure matters in technology adoption. In all four models, the coefficient of electricity price is significantly positively correlated with the growth of CHP units while the coefficient of natural gas is significantly negatively correlated. Higher electricity prices and lower natural gas prices would therefore result in a favorable spark spread, which indicates long-term economic profitability for CHP customers. From this result, we can agree with hypothesis #2 that industries are more likely to adopt innovative technologies when energy prices favor profitability.

7.3 Comparing Socioeconomic Bases and Policy Efforts of California, Ohio, Texas, and Wyoming

A multiple-case study was employed to explain how different levels of CHP technology adoption and employment are affected by economic drivers and barriers in four representive states. Understanding the different paths of each state's economic performance, the composition of GDP and employment, industrial bases, human forces, and energy profiles provided evidence beyond the results of RE regression analyses.

First, state entrepreneurship is a critical factor in innovation development and adoption. California was selected as a High-High state with both the highest clean energy policy efforts and higher degrees of CHP deployment, compared to other parts of the nation. The economic base and energy market analyses confirmed that this High-High state possesses the policy-driven virtuous circle of EBED, and the status of the energy market amplifies the benefit. California has built its entrepreneurship based on more diverse sources of energy generation and consumption, more sources of zero- or low-carbon energy, expensive energy prices, and qualified labor forces. This is empirically confirmed by RE models with the positive coefficients correlating electricity prices with levels of CHP adoption, and the positive coefficients correlating utility rate policies with levels of CHP adoption (Tables 5.2). Taken together, findings from multiple-case studies and RE models add empirical evidence to confirm hypothesis #2, that firms are more likely to adopt innovative technologies when they can be convinced of economic profitability.

Second, people matter in innovation diffusion and regional economic development. According to an economic base study, the high policy entrepreneurship in California is likely to be driven by its quality of human factors, as shown by a growing population and higher ratio of working age with the quality of educational attainment and racial diversity. According to LQ industrial cluster analyses, California has enjoyed agglomeration economies by strengthening both its existing clusters of information, accommodation, and wholesale trade industries, as well as the emerging clusters of health care, construction, and transportation sectors. Based on these industrial bases, California has experienced steady growth both in real GDP and per capita real GDP, holding 14.3 percent of the U.S. GDP in 2017. As of 2018, California is the second largest state in CHP generation capacity (Figures 3.1, 6.17, and 6.18).

Third, CHP technology adoption is basically active where the state economic base consists of energy-intensive industries. In the beginning of the multiple-case study, Texas was selected as a high CHP adoption with low policy entrepreneurship. Texas is the top state in terms of CHP installation capacity, accounting for 17,611 MW of CHP capacity in only 130 CHP systems (Figures 3.1, 6.21 and 6.22). While the CHP capacity is the largest of any of the states, the number of CHP installations is relatively low compared to the number in California. This is because of Texas's industrial clusters of mining, oil and gas extraction, according to LQ analysis (Figure 6.9). The economic base study also confirmed that a dominant sector of GDP in Texas encompasses mining and manufacturing, which results in the largest size of CHP-installed capacity over time in the U.S. Texas has been holding the second-highest real GDP with 9.1% of the U.S. GDP in 2017 (Table 6.3).

In contrast, Ohio and Wyoming have shared a relatively low portion of the U.S. GDP and population. Ohio has heavily relied on manufacturing (Figure 6.8) while Wyoming has a long-standing cluster of mineral extraction industries (Figure 6.10). These two states are still dependent on primarily coal-fired electricity generation (Figures 6.11 and 6.12), and thus low amounts of renewable energy and CHP generation (Figures 6.15 and 6.16). However, Ohio is a state with high potential for CHP installation (Table 1.2) based on its existing clusters of manufacturing, although policy barriers seem to be high given recent legistation freezing the original RPS goal in Ohio.

Overall, the findings of economic base, industrial cluster, and energy market analyses allow us to confirm hypothesis #4, that "existing industrial bases, which are distributed differently state-by-state, would be a key determinant to clean energy technology development and job creation."

Fourth, active engagement of stakeholders and information sharing are key elements on enhancing EBED practices. Next, exploring states' EBED practices and legislation of clean energy plans and programs help to better understand the top entrepreneurial state's approach to CHP policy development and implementation. The most distinctive factors of California's policy-driven EBED practices are transparent communication channels, diverse stakeholders, and stringent energy plans. CHP developers in California have been able to get regulatory, technical, and economic information through offline meetings and online web resources. Ever since Governor Schwarzenegger initiated ambitious goals of GHG emission reductions, California has developed a channel of tracking customers' performance on a regular basis and sharing updated information on regulations and practices. This channes hasbeen created to be available both online and offline. For example, the California Public Utilities Comissioin website has uploaded and updated tracking reports of any additional CHP capacity and GHG reductions. A variety of stakeholders and advocacy groups in public and private sectors has been actively involved in energy and environmental conservation performance.

Texas, a Low-High state, also actively engages non-profit partnerships and initiatives in spreading awareness of CHP technologies, applications, and benefits for those interested in CHP. Texas has made efforts to develop energy-efficiency policies to cope with a heavy demand for energy from its large cluster of chemical and refining industries. However, its policy efforts are likely insufficient to avoid reliance on fossil fuel-based energy generation.

From exploring these cases, we can confirm hypothesis #3, that “industries are more likely to adopt innovative technologies when they are exposed to a communication channel of information sharing provided by state governments.”

Multi-case studies addressed how states demonstrate different policy objectives under different shapes of regional economy, and what kind of outcomes they have faced. Future research is needed, as this dissertation avoided a number of important issues, such as workforce diversity and quality of jobs, which may be an issue for local sustainable economic development. One suggestion is to develop a RE model by using QCEW employment survey data. The employment composition could be separated into categories based on levels of income and education, gender, and occupation. RE models of Chapter 5 could be employed with these distinct sets of employment data.

7.4 Implications

From all three sectors of analyses, this dissertation reaches one general conclusion that clean energy policies cannot be considered separately from economic development policies. Some states have been key players in the promotion of clean energy production and consumption with the additional intention of creating diverse jobs. These efforts are different from a traditional economic development strategy that focuses on net job growth. Conserving and diversifying a state's resource for energy as a way of addressing climate change requires comprehensive and multidimensional approaches involving technological innovation, market forces, entrepreneurial recruitment, electricity market decentralization, political support, and a variety of stakeholders engagement. It is also a process of building up existing bases of the energy portfolio, industrial bases, and human forces.

Yet, the outcomes and effectiveness of EBED strategies have not been entirely understood. This dissertation attempts to provide empirical evidence by seeking to identify factors affecting consumers' adoption of a mature clean energy technology, and presenting policy processes and associated stakeholders in case studies of selected states. This may provide a better understanding of comprehensive EBED considerations to policy makers and practitioners in the junction of planning for energy and economic development.

States continue to make efforts in seeking independence from fossil fuels, of driving the use of advanced, efficient, and clean energy, and in developing strategies for a sustainable economy. The transition to clean and sustainable energy will take efforts by other multiple actors including cities, national governments, and international organizations; by scientists, engineers, and entrepreneurs; by investors and financial institutions; by private corporations and non-profit organizations; by community organizations; by political activists; by consumers. Finding optimal policy instruments and reevaluating EBED strategies informed by empirical and theoretical research like this will be important to maintaining a more sustainable development path and to bringing a continual engagement of diverse stakeholders.

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Appendix I. ARRA Funds Allocation for Energy and Environment (in $ Billion)

Categories		**Funds Paid Out ($Billion)**
Total		**$62.537**
Tax Benefits		**$10.900**
	Residential Energy Credit	$11.000
	Residential Credit for Alternative Energy	$0.602
	Credit for Electricity Produced from Certain Renewable Resources	$0.647
	Extension of Commuter Transit Benefits / Transit Passes	$0.142
	Business Credits for Renewable Energy Properties	$0.144
	Electric Motor Vehicles Credit	$0.115
	Investment Credit or Productions Credit	$0.125
	Increased Credit for Alternative Fuel Vehicles Refueling Properties	$0.051
	Increased Limitation on Energy Conservation Bonds	$0.028
	Increased Limitation on Clean Renewable Energy Bonds	$0.004
	Carbon Dioxide Used as a Tertiary Injectant	$0.000
	Renewable Energy Grants vs Energy Investment Tax Credit*	-$2.000
Contract, Grant and Loan Programs		**$30.182**
	Department of Energy-Energy Efficiency and Renewable Energy, Recovery	$15.504
	Department of Energy-Deputy Administration for Defense Programs-Defense Environmental Clean-up Recovery	$5.105
	Department of Energy-Office of Emergency Operations-Electricity Delivery and Energy Reliability, Recovery	$3.971
	Department of Energy-Title 17 Innovative Technology Loan Guarantee Program	$1.328
	Department of the Interior-Bureau of Reclamation-Water and Related Resources, Recovery Act	$0.896
	Environmental Protection Agency-Hazardous Substance Superfund, Recovery Act	$0.624
	Department of Energy-Non-defense Environmental Clean-up, Recovery	$0.442
	Department of Energy-Office of Nuclear Security/National Nuclear Security Administration-Uranium Enrichment Decontaminati	$0.387
	Department of Energy-Energy Transformation Acceleration Fund	$0.354
	GSA-Office of the Federal Acquisition Service-Energy-Efficient Federal Motor Vehicle Fleet Procurement	$0.300
	Environmental Protection Agency-Leaking Underground Storage Tank Trust Fund Program	$0.190
	Department of the Interior-U.S. Fish and Wildlife Service-Resource Management, Recovery Act	$0.183

	Department of Housing and Urban Development-Green Retrofit Program (Grants) for Multifam Housing	$0.172
	Department of the Interior-Geological Survey-Surveys, Investigations, and Research, Recovery Act	$0.145
	Department of the Interior-National Park Service.-Operation of the National Park System, Recovery Act	$0.142
	Department of Housing and Urban Development-Office Healthy Homes and Lead Hazard Control-Lead Hazard Reduction, Recovery	$0.093
	Department of the Interior-Bureau of Land Management-Management of Lands and Resources, Recovery Act	$0.092
	Environmental Protection Agency-Environmental Programs and Management	$0.084
	Department of Housing and Urban Development-Green Retrofit Program (Loans) for Multifam Housing	$0.069
	Department of the Interior-Utah Reclamation Mitigation and Conservation Commission-Central Utah Project Completion Accoun	$0.050
	Department of Energy-Weapons Activities	$0.017
	Department of the Interior-National Park Service.-Historic Preservation Fund, Recovery Act	$0.015
	Department of Energy-Advance Technology Vehicles Manufacturing Loan Program	$0.010
	Department of Energy-Energy Efficiency and Renewable Energy	$0.009
	Southwestern Power	$0.000
	USDA-Conservation Operations	$0.000
Entitlement Programs		**$21.455**
	Grants for Specified Energy Property in Lieu of Tax Credits	$19.878
	Bonneville Power Administration Fund	$1.359
	Western Area Power Administration, Borrowing Authority	$0.218

* Received funds from Treasury

(Source: Recovery.gov, Date updates in 12/2012, accessed 10/04/2014)

Appendix II. Contents and Initial Enactment Years of State Clean Energy Policies

Appendix II - Table 4.1. List of State Energy/Climate Change Plans in 2016

(Plan name; Initial year of enactment; Main contents)

State	State Energy Plan	State Climate Change Plan
Arizona		Arizona Climate Change Action Plan; 2006; The plan contains 49 policy recommendations for reducing GHGs.
Arkansas	State of Arkansas Energy Assurance Plan; 2013; the plan will allow the state to make informed decisions about the power grid, enhance energy monitoring, and mitigate the consequences of energy disruptions.	Arkansas Governor's Commission on Global Warming, Final Report; 2008; The Commission agreed to policies to state-wide GHG emissions reductions by 2035 of 50% below 2000 levels.
California	2015 Integrated Energy Policy Report; 2012; It contains an assessment of the benefits and barriers to the CHP and the natural gas market. It also includes a renewed commitment to achieving the Governor's goal of 6,500 MW of new CHP capacity by 2030.	Climate Change Scoping Plan; 2008; AB32 calls for a reduction of greenhouse gas emissions to 1990 levels by 2020. The report recommends installing an additional 4,000 MW of CHP capacity by 2020. The first update in 2014, Governor Jerry Brown set a goal for 6,500 MW of additional CHP by 2030.
Connecticut	Comprehensive Energy Strategy for Connecticut; 2013; This strategy presents a series of policy proposals aimed at expanding energy choices, lowering utility bills, improving environmental conditions, creating clean energy jobs, and enhancing the quality of life in the state.	Connecticut Climate Change Action Plan; 2005; The goal is to reduce GHG emissions to 1990 levels by the year 2010 and an additional 10% below that by the year 2020.

Delaware	Delaware Energy Plan 2009-2014; 2009	
District of Columbia		Climate of Opportunity - A Climate Action Plan for the District of Columbia; 2011; The DC government set emissions reduction targets of 20% below 2006 levels by 2012, 30% below 2006 levels by 2020, and 80% below 2006 levels by 2050.
Hawaii	Hawaii Energy Strategy 2000; 2000;	
Idaho	2012 Idaho Energy Plan; 2012;	
Illinois	Governor Quinn's Comprehensive Energy Strategy; 2011;	
Iowa		Iowa Climate Change Advisory Council Final Report; 2008; The goal of CRE-11 is to deploy 7,500 MWh per year of new distributed renewable generation by 2010 and continuing each year thereafter. The goal is to achieve a 10% shift to renewable energy and/or CHP, as a percentage of retail sales.
Kentucky	Kentucky State Energy Plan; 2008; Kentucky's energy plan proposes that 25% of Kentucky's energy needs in 2025 be met by reductions through energy efficiency and the use of renewable resources.	
Maine	Maine Comprehensive Energy Plan Update; 2015;	Maine Climate Action Plan; 2004; The plan contains CHP incentive policies—such as developing uniform interconnection standards, utility back-up rate regulations, Renewable Portfolio Standard, and Maine's participation in the Regional Greenhouse Gas Initiative (RGGI) leading to CHP-supportive actions such as loans or grants using public benefit fund resources and measures under its state energy plan.

Maryland	EmPower Maryland Recommendations; 2013; The EmPOWER Energy Efficiency Act of 2008 set a target reduction of 15% below 2007 peak demand and electricity consumption levels by 2015.	Maryland's Plan to Reduce Greenhouse Gas Emissions; 2011; The plan includes several voluntary measures to facilitate the expansion of CHP units through education and outreach about the benefits of these systems and the enactment of incentives.
Massachusetts	Massachusetts Clean Energy and Climate Plan for 2020; 2010; This Plan was developed to help meet the State's greenhouse gas reduction goals, to reduce emissions to 25% below 1990 levels by 2020 and 80% below these levels by 2050.	
Michigan	Michigan's 21st Century Electric Energy Plan; 2007; The Michigan energy plan mentions modeling that "indicates a potential for at least 1,100MW and up to 2,700 MW of new electric power capacity development in Michigan from renewable resources with another 180 MW available from CHP."	Michigan Climate Action Plan; 2009; The plan set a goal for CHP facilities to account for up to 10% of annual electricity sales by 2020. This would be accomplished with a phase-in beginning in 2010, equivalent to installing 15% of in-state CHP technical potential (180-2,000 MW) at commercial and industrial facilities by 2020.
Minnesota		Minnesota Climate Mitigation Action Plan; 2008; The plan targets to achieve 50% of technical potential for CHP in order to reduce GHG emissions.
Missouri	Missouri Comprehensive State Energy Plan; 2015;	
Montana		Montana Climate Change Action Plan; 2007; The plan includes policy recommendation, incentives and barrier removal for CHP and clean DG.
New Hampshire	New Hampshire State Energy Strategy; 2014;	New Hampshire Climate Action Plan; 2009; The plan recommends the implementation of CHP where possible as a method of reducing GHG emissions, with regulatory changes, incentives, and portfolio standards as ways of encouraging the use of CHP.

New Jersey	New Jersey Energy Master Plan; 2011; The Plan sets a target to develop "1,500 MW of new DG and CHP" resources over the next decade.	New Jersey's Global Warming Response Act Recommendations Report; 2009; The report estimates GHG emissions reductions associated with a range of measures, including CHP.
New Mexico		New Mexico Climate Change Advisory Group Final Report: 2006; To reduce GHG emissions, The CCAG suggested direct subsidies or tax credits for purchasing/selling CHP systems and tax credits, exemptions, or feed-in tariffs for CHP operation.
New York	New York State Energy Plan; 2009; updated in 2015	New York State Climate Action Council Climate Action Plan Interim Report; 2010; The report estimates that these policy actions could lead to additional CHP generation capable of producing 890 GWh/year in 2020 and 4,600 GWh/year in 2030, and resulting in 7.1 MMtCO2e reductions through the use of CHP in the years 2011 to 2030.
North Carolina	North Carolina State Energy Report; 2010;	North Carolina Climate Action Plan Advisory Group Final Report; 2008; The goal is to implement 25%-33% of North Carolina's CHP potential by 2020.
Ohio	Ohio's 21st Century Energy Policy; 2014;	
Oklahoma	Oklahoma First Energy Plan: 2011;	
Oregon	Ten-Year Energy Action Plan; 2012;	Oregon Strategy for Greenhouse Gas Reductions: 2004; The plan includes several recommendations to improve the economic feasibility of CHP, which includes voluntary demand-response programs, PUC review of rules and tariffs, adaptation of standard tariffs and rates for renewable and CHP facilities under 10 MW. Those tariffs are now in place.

Pennsylvania	Pennsylvania Energy Development Plan: 2008	Pennsylvania Final Climate Change Action Plan: 2009; Promoting CHP technologies through tax benefits, attractive financing, utility rebates, and feed-in tariffs.Removing barriers to CHP development, such as utility rate structures that allow discounted electric rates to compete with CHP.Designing interconnection standards to facilitate economical and efficient CHP connection to the grid.Including CHP electricity in energy efficiency or renewables targets.Considering the economic and environmental benefits of CHP as a resource in each electric utility's Integrated Resource Plan.
Rhode Island	Energy 2035: Rhode Island State Energy Plan: 2015; The updated 2002 state energy plan set a goal of 400 MW of CHP by 2035.	Resilient Rhode Island Act of 2014: 2014, It creates a GHG gas reduction goal of 85% by 2025.
South Carolina		South Carolina Climate, Energy, and Commerce Plan: 2008; A plan to reduce emissions 5% below 1990 levels by 2020. It suggests incentives, resources, and regulatory reform to promote energy recycling.
Vermont	Vermont Comprehensive Energy Plan 2011: 2011; The plan sets three goals: 90% of Vermont's energy is to be renewable by 2050 (with intermediate goals), reduce energy consumption per capita 15% by 2025 and 33% by 2050.	Governors' Commission on Climate Change Final Report; 2007; This report outlines recommendations for meetings the Governor's and state legislature's goals of reducing GHG emissions by 25% of 1990 levels in 2012, 50% by 2028, and, if practical, 75% by 2050.
Virginia		A Climate Change Action Plan: 2008; The Executive Order created a GHG emissions target of 30% below business-as-usual emissions projections by 2025.

Washington	2012 Washington State Energy Strategy; 2011	Growing Washington's Economy in a Carbon Constrained World; 2008; The Department of Ecology published the state's comprehensive climate change action plan that will return emissions to 1990 levels by 2020 and will ultimately achieve reductions of 50% below 1990 levels by 2050.
West Virginia	2013-2017 West Virginia State Energy Plan: 2013	
Wisconsin		Wisconsin's Strategy for Reducing Global Warming: 2008, Cogeneration Incentives policy recommendations that will result in the deployment of 250 MW of CHP by 2020 and an additional 250 MW of CHP by 2030.

Appendix II - Table 4.2. Energy and Environmental Regulations in 2016

(Name; Initial year of enactment; Main contents)

State	Energy Regulation	Environmental Regulation
California	California Public Utilities Code Section 218 and 353; 2000; Allow CHP facilities to sell electrical power in "over-the-fence" transactions to not more than two other corporations on the same property or immediately adjacent properties.	California Emissions Performance Standard; 2007; requires base load generation (including from CHP systems) must come from generating plants with a corresponding emission rate of <1,100 lbs of CO2/MWh. Base load generation is defined as electricity generation from a power plant with >60% capacity factor. The EPS applies to power plants with "long-term financial commitments."
	Green Building Action Plan for State Facilities; 2005; State facilities must reduce grid-based energy purchases by 20 percent of 2003 level by 2018.	Distributed Generation Certification Regulation; 2001; The program establishes output-based emissions limits of NOX, CO, VOCs, and PM for

	New buildings and renovations occurring after 2025 must have net-zero energy consumption.	DG units that have a minimum energy efficiency of 60 percent may take a thermal credit of 1 MWh for every 3.413 MMBtu to meet the emission standard.
Connecticut		Connecticut Regional Greenhouse Gas Initiative (RGGI) CHP Set-Asides; 2009; The regulations hold 1.5 percent of the annual CO2 allowances for eligible CHP systems. The allowances are allocated on an output-basis and calculated using the equivalence approach. CHP systems are eligible with energy efficiency equal to or greater than 60% qualify under the set-aside.
Delaware		Control of Stationary Generator Emissions; 2006; The rule limits emissions of NOX, NMHC, PM, SO2, CO, and CO2 from stationary generators, including CHP. Eligible CHP systems can receive emissions credits based on the "avoided emissions" approach. To be eligible for an emissions credit, a CHP system must have a total overall efficiency of at least 55%, and at least 20% of the fuel's total recovered energy must be thermal and at least 13% must be electric corresponding to an allowed power-to-heat ratio between 4.0 and 0.15.
Louisiana	Louisiana Renewable Energy Pilot Program; 2010; Utilities can issue the RFP to develop a minimum of three projects following two options: Under the "self-build" option, utilities must develop their own renewable energy facilities (less than 300 kW but one project may be 5 MW, operational by the end of 2013) Under the standard offer tariff option, utilities can develop tariffs ($30/Mwh plus an	

	avoided-cost payment) and associated contracts to purchase renewable energy facilities.	
	Louisiana Senate Resolution 171; 2012; a resolution requesting that the DNR and the PUC establish guidelines to evaluate CHP feasibility for critical infrastructure facilities. To be considered an applicable facility, a facility must be operational 6,000 hours per year and have a peak electric demand >500 kW. CHP systems must be able to provide 100% of a facility's critical electricity needs and sustain emergency operations for at least 14 days. The energy savings from the CHP system must also exceed the costs of installation, operation, and maintenance over a 20-year period.	
Maine		Emissions from Smaller-Scale Electric Generating Resources; 2005; Maine's output-based regulation limits emissions of NOX, SO2, PM, and CO, and includes provisions for CHP. CHP systems can receive credit for heat recovery to comply with the emission standards using the equivalence approach at the rate of one MWh for each 3.4 MMBtu of heat recovered. CHP systems must be >50 kW. The design efficiency must be >55%.

		Regional Greenhouse Gas Initiative (RGGI) Implementation in Maine; 2007; As part of Maine's RGGI implementation, the Maine Department of Environmental Protection (DEP) sets aside a portion of the state's annual CO2 emissions allowances into an account for "carbon dioxide budget units" that are CHP units (equal to or greater than 25 MW of electrical output) located at "integrated manufacturing facilities."
Massachusetts		Industry Performance Standards for Combined Heat and Power; 2006; A CHP system that meets the eligibility requirements may receive a compliance credit against its actual emissions based on the emissions that would have been created by a conventional separate system used to generate the same thermal output - the "avoided emissions approach." The regulations establish output-based NOX, PM, and CO emission limits (in lbs/MWh) from engines and turbines that meet the size thresholds noted below and that are constructed, reconstructed, or altered on or after March 23, 2006. To be eligible for the emissions credit, a CHP system is required to meet the following requirements: The power-to-heat ratio must be between 4.0 and 0.15. The design system efficiency must be at least 55%. The engine has a rated power output >50 kW or the turbine has a rated power output <10 MW.

Minnesota	Minnesota Waste Heat Recovery Law (HF 729); 2013; HF 729 allows recovered waste heat that reduces demand side energy usage to be eligible to participate in utility conservation improvement programs and natural gas or electric energy savings goals.	
New Hampshire	2015 NH Statutes, Title 34, Chapter 374-G-To Encourage Utility Investment in CHP; 2008; Public utilities can make investments under this act in distributed energy systems with a capacity less than or equal to 5 MW that are located on the premises of a retail customer of the electric public utility. Utilities are limited in the total amount of distributed electric generation owned by or receiving investments from the utility to a cumulative maximum of 6% of the utility's total distribution peak load in megawatts.	Multi-Pollutant Emissions Regulations; 2002; outlines a cap and trade program for CO2, SO2, NOX, and Hg emissions from fossil fuel fired plants.
New Jersey	New Jersey CHP Sales Law, P.L. 2009, Chapter 240; 2010; Clarifies that a CHP facility is not a public utility. Clarifies, for purposes of electric or thermal sales, that the properties of the end-use customer and of the CHP facility are contiguous regardless of whether the customer is located across a street, easement, or utility right-of-way. Extends the sales tax exemption for sales of energy from CHP built after January 1, 2010.	General Permit (GP 021) for Combined Heat and Power Combustion Turbine(s); 2011; This General Permit allows for the construction, installation, reconstruction, modification and operation of: A single CHP combustion turbine, with or without duct burner, having a combined maximum heat input rate less than or equal to 65 million Btu per hour (MMBtu/hr) based on the higher heating value (HHV) of the fuel; or Multiple CHP combustion turbines, with or without duct burners, having a combined maximum heat input rate less than or equal to 65 MMBtu/hr based on the HHV of the fuel. This General Permit can be used only for CHP combustion turbine units with total design efficiency greater than or
	New Jersey Energy Resilience Bank; 2014; In response to Superstorm Sandy, the ERB is a resiliency financing initiative aimed at funding distributed energy technologies. CHP systems must have an efficiency of at least 65%.	

		equal to 65 percent.
New York	Community Risk and Resiliency Act; 2014; The purpose of which was to develop more resilient infrastructure systems in the wake of Hurricane Sandy.	
Oregon		Oregon Emissions Performance Standard: 2009: H.B. 3283 requires that all new base load gas-fired power plants have net emissions 17% below the most efficient base load plant in the United States. (The Oregon Energy Facility Siting Council currently sets the standard at 0.675 lbs CO2/kWh.) Under S.B. 101, facilities generating base load electricity, whether gas- or coal-fired, must have emissions < 1,100 lbs CO2/MWh, and utilities may not enter into long-term purchase agreements for base load electricity with out-of-state facilities that do not meet that standard.
Rhode Island		General Permits for Smaller-Scale Electric Generation Facilities: 2007; output-based CO2 limits, CHP must have a power-to-heat ratio b/w 4.0 and 0.15, must be >55% efficient
Texas	Energy Security Technologies for Critical Governmental Facilities: 2009; Prior to constructing to a government facility, ensure the entity in control of the facility obtains a feasibility study to consider the technical opportunities and economic value of implementing CHP. A facility must be operational 6000 hrs per yr and have a peak electric demand >500 kW. The energy savings from the CHP must also exceed the costs of installation, o&M over a 20yr period. CHP efficiency	Air Quality Standard Permit for Electric Generating Units (EGUs): 2001; Create a standard permit with Output-based Nox emission limits for EGUs. Small (<10MW) generators installed or modified after 06/2001. To qualify as a CHP unit, the heat recovered must represent >20% of total energy output by the unit.

	should be at least 60%. Texas CHP Sales Law Codified under Chapter 31 and 37 of the Utilities Code: 2013; Allow CHP to sell electricity and heat to any customer in proximity of the facility.	
Washington		GHG Emissions Performance Standard for Thermal Electric Generating Facilities: 2004; CO2 mitigation program requires new fossil-fueled thermal electric genertion facilities to mitigate >20% of CO2 emissions using "avoided emissions approach", accounting for the thermal output of the CHP system. Initial mitigation rate is $1.6/metric ton of CO2.

Appendix II - Table 4.3. State Interconnection Standards

State	Initial Year/Amendment Year	Capacity Limits
Alaska	2011	< 25 kW CHP systems powered by biomass, municipal solid waste, and landfill gas.
Arizona	2007	< 10MW
Arkansas	2001	Residential systems up to 25 kW and non-residential systems up to 300 kW.
California	2000 2012	All sizes are eligible. Systems connecting to an investor-owned utility's distribution grid, non-export generating facilities connecting to an investor-owned utility's transmission grid, and all net metered facilities in an investor-owned utility's service territory
Colorado	2015	< 10MW

Connecticut	2007	< 20MW
Delaware	2000	Renewable-energy systems up to 10 MW, and non-renewable systems up to 1 MW.
District of Columbia	2009	<10 MW
Florida	2008	Renewable-energy systems, including CHP, up to 2 MW. The customer-owned renewable generation must have a gross power rating that does not exceed 90% of the customer's utility distribution service rating.
Georgia	2001	Residential facilities up to 10 kW and non-residential facilities up to 100 kW. Only fuel cell systems are eligible.
Hawaii	2002	Renewably-fueled inverter-based systems up to 10 kW on the island of Kauai and up to 250 kW on all other islands. All sizes are eligible for standardized procedures.
Illinois	2008	< 10 MW
Indiana	2006	All sizes are eligible.
Iowa	2010	< 10MW Interconnection of larger facilities should take place using the Level 4 review process as a starting point.
Kansas	2009 2014	Up to 25 kW for residential customers, and up to 200 kW for non-residential customers for eligible systems prior to July 1, 2014. For eligible systems installed on or after July 1, 2014, capacity limits are set at 15 kw for residential, 100 kW for non-residential, and 150 kW for postsecondary educational institutions or any public or private schools which provide instruction for students enrolled in grade kindergarten or grades one through 12.
Kentucky	2009	Renewable-fueled (PV, wind, biomass, biogas and small hydro) retail electric suppliers up to 30 kW all in the state, excluding TVA utilities. A utility may negotiate a contract interconnection with a merchant or co-generation electric generating facility with a capacity of up to 10 MW.
Louisiana	2005	Residential systems up to 25 kW and commercial systems up to 300 kW

Maine	2010	All sizes are eligible.
Maryland	2008	< 10MW
Massachusetts	2007	All sizes are eligible.
Michigan	2003	All sizes are eligible.
Minnesota	2004	< 10MW
Mississippi	2016	< 2MW
Missouri	2007	Renewable energy systems including CHP up to 100 kW
Nebraska	2009	Renewable energy systems up to 25 kW
Nevada	2003	< 20 MW. CHP systems fueled by biomass are eligible.
New Hampshire	2001	Small customer-generators (up to 100 kW) and large customer-generators (between 100 kW and 1 MW). CHP systems that use natural gas, wood pellets, hydrogen or heating oil are eligible under the standards. Net-metered CHP systems that use natural gas, wood pellets, hydrogen, propane or heating oil are eligible for standardized interconnection, along with fuel cells using renewable fuels, and other renewably fueled systems. CHP systems <30 KW must have an efficiency of at least 80%. CHP systems between 30 kW and 1 MW must have a fuel system efficiency of at least 65%. In addition, CHP can only contribute up to 4 MW under the aggregate net-metering capacity limit of 50 MW.
New Jersey	2004	All sizes are eligible.
New Mexico	2008	Rule 569 applies to systems up to 80 MW. Rule 568 applies to CHP systems up to 10 MW.
New York	1999 2013	All systems >50 kW and up to 2 MW, and systems >50 kW and up to 300 kW that have not been certified and tested in accordance with UL 1741, applicants must use the basic, 11-step process for interconnection. As amended in 2013, systems up to 50 kW are eligible for a simplified or expedited 6-step process.
North Carolina	2008	All sizes are eligible.

Ohio	2007	< 20MW
Oregon	2007	Three categories of interconnection standards that apply to CHP, one for net-metered systems, one for non-net-metered small facilities, and then one for non-net-metered large facilities. Greater than 20 MW for large generators; Up to 10 MW for small generators; 25 kW for residential net metered; 2 MW for non-residential net metered.
Pennsylvania	2006	< 5MW
Rhode Island	2011	All sizes are eligible.
South Carolina	2006	Residential systems up to 20kW; Non-residential systems up to 100 kW
South Dakota	2009	Four levels of interconnection for systems <10MW
Texas	1999	Up to 10MW and connected at a voltage up to 60 kV.
Utah	2002	< 20 MW. Renewables-fueled CHP eligible for standardized interconnection.
Vermont	2006	Separated standards for net-metered systems up to 150 kW and DG systems that are not net-metered (no size limit specified).
Virginia	1999	Standards for net-metered (up to 20kW for residential, up to 500kW for commercial) and not net-metered systems (3 tiers up to 20MW).
Washington	2006	Revised standards provide three tiers by system capacity. Application fee vary, $100 for up to 25 kW, $500 for >25 kW ~ 500 kW, $1000 for >500 kW~20MW.
West Virginia	2010	Renewable-fueled CHP up to 25 kW (level 1)/ up to 2MW (level 2)
Wisconsin	2004	CHP up to 15MW is required interconnection
Wyoming	2001	Systems up to 25 kW that generate electricity using solar, wind, hydropower or biomass, including biomass CHP.

Appendix II - Table 4.4 Net Metering Rules

States	Initial Year/Amendment Year	Eligible Capacity Size	NEG Credits
Alaska	2010	Renewable energy systems, including biomass CHP, with a capacity up to 25 kW are eligible for net metering. Overall enrollment is limited to 1.5% of a utility's retail sales from the previous year.	
Arizona	2009	No limit on system size. Instead, systems must be sized to meet all or part of a customer's electric load, and the system "may not exceed 125% of the customer's total connected load". Additionally, the rules do not set an aggregate capacity limit for all net-metered systems in a utility's territory. The rules require that utility billing charges for net-metered facilities are assessed on a non-discriminatory basis.	
Arkansas	2001	Residential systems up to 25 kW, or 100% of the net metering customer's highest monthly usage in the previous 12 months. Non-residential systems up to 300 kW. No specified limit for aggregated capacity of net metered systems.	NEG credited at retail rate; credits do not expire
California	1996 2016		NEG credited at retail rate; credits do not expire
Colorado	2005	Investor owned utilities: Systems sized up to 120% of the customer's annual average consumption that generate electricity using qualifying renewable energy resources are eligible for net metering in IOU service territories. Municipal Utilities and Electric	NEG credited at retail rate; credits do not expire

		Cooperatives: Electric cooperatives and municipal utilities over 5,000 customers must offer net metering to residential systems up to 10 kW and non-residential systems up to 25 kW.	
Connecticut	1998 2013	Systems up to 2 MW are eligible for standard net metering (meaning renewably-fueled systems only). Systems up to 3 MW are eligible for virtual net metering (this includes all CHP that meets the 50% efficiency requirement, and that were developed on or after January 1, 2006)	
District of Columbia	2005	Residential and commercial customer-generators with systems powered by renewable-energy sources, CHP, fuel cells and micro turbines up to 1 MW in capacity (a 5 MW limit applies to community renewable energy facilities). There is no specified aggregate capacity limit of net-metered systems.	For systems up to 100 kW, NEG is credited to the customer's next bill indefinitely at the full retail rate, which includes generation, transmission, and distribution components. For systems with capacities >100 kW, NEG is credited to the customer's next bill at the generation rate.

Florida	2008	There is no stated aggregate capacity limit for net-metered systems.	NEG is carried forward at the utility's retail rate, as a kWh credit, to a customer's next bill for up to 12 months. At the end of a 12-month billing period, the utility pays the customer for any remaining NEG at the utility's avoided-cost rate.
Hawaii	2001	The maximum capacity for a net metered system is 100 kW. The aggregate capacity of net-metered systems is limited on a per-circuit basis to 15% per circuit distribution threshold for distributed generation penetration. Of this 15% in peak circuit demand capacity, 5% (or 0.75% of overall peak circuit demand capacity) will be reserved for residential or small commercial systems that are 10 kW or smaller. For customers of Hawaii Electric Light Company (HELCO) and Maui Electric Company (MECO), the maximum capacity allowed for a net metered system is 100 kW. The capacity limit vary by Island in Hawaii (For customers of Kauai Island, the eligible size is 50 kW.)	Note: On October 12th, 2015, the Hawaii PUC voted to end net metering in favor of three alternative options. Those options are a grid supply option, a self-supply option, and a time of use tariff.

Maine	1987 2009	Net metering had been available in Maine from 1987 to 1998 for qualified CHP and from 1987 until April 30, 2009 for other small power production facilities up to 100 kW. Micro-CHP systems are defined as a system that produces heat and electricity from one fuel input, without restriction to specific fuel or generating technology. Micro-CHP with an electric generating capacity rating of at least 1 kW and not more than 30 kW must achieve a combined electric and thermal efficiency of at least 80% or greater to qualify. In addition, micro-CHP 31 kW to 660 kW must achieve a combined efficiency of 65% or greater to qualify. IOUs are required to offer net metering to eligible facilities up to 660 kW. COUs are required to offer net metering to customers up to 100 kW, and are authorized, although subject to their discretion, to offer net metering to eligible facilities up to 660 kW. There is no limit on the aggregate amount of energy generated by net-metered customers. However, a utility must notify the PUC if the cumulative capacity of net-metered facilities reaches 1.0% of the utility's peak demand.	Credited to customer's next bill at retail rate; granted to utility at end of 12-month billing cycle. "Shared ownership" allows for community net metering, where several people invest in an eligible system and are therefore allowed to benefit. At its own expense, a utility may install additional meters to record purchases and sales separately.
Maryland	1997	1,500 MW (~8% of peak demand). System size is generally limited to 2 MW, except micro-CHP resources are limited to 30 kW.	Credited to customer's next bill at retail rate; reconciled annually at the wholesale energy rate
Massachusetts	1982	All systems except public facilities up to 2 MW are eligible to net-meter. Public facilities can be larger (up to 10 MW).	

Minnesota	1983	Systems <40 kW at municipal utilities and electric cooperatives are eligible to net-meter. Systems up to 1 MW at IOUs are allowed to net meter. For systems under 40 kW, each utility is required to compensate customers for any net excess generation (NEG) at the "average retail utility energy rate," defined as "the total annual class revenue from sales of electricity minus the annual revenue resulting from fixed charges, divided by the annual class kilowatt-hour sales." This rate is basically the same as a utility's retail rate. For systems 40 kW-1 MW at public utilities (IOUs), NEG is credited at the avoided cost rate, or customers may elect to be compensated in the form of a kWh credit. Excess credit will be reimbursed at the end of the calendar year at the avoided cost rate.	
Mississippi	2016	Residential systems up to 20 kW and non-residential systems up to 2 MW are eligible to net-meter. Systems are allowed to interconnect on a first-come, first-service basis until total systems add up to 3% of the utility’s total system peak demand recorded during its prior calendar year.	Electricity self supplied by the customer will be credited at full retail rate. This excess generation will be credited at utilities’ avoided cost plus additional Non-quantifiable Expected Benefits Adder of 2.5 c/kWh. This would value the excess generation at

			approximately 7 to 7.5c/kWh.
Nebraska	2009	Utilities are required to offer net metering to renewable energy systems up to 25 kW, including biomass CHP. Utilities are required to offer net metering until the aggregate generating capacity of all customer-generators equals 1% of the utility's average monthly peak demand for that year.	Any NEG produced by the qualifying facility during the month will be credited at the utility's avoided cost rate for that month and carried forward to the next billing period. Any credited NEG remaining at the end of an annualized period will be paid out to the customer-generator.
Nevada	1997 2015	Senate Bill 374 of 2015 changed the aggregate capacity limit for net metering under current tariffs from 3% of total peak capacity for all utilities to a flat cap of 235 MW. There is no aggregate capacity limit under the new tariffs. For net-metered systems up to 25 kW, utilities must offer the customer-generator a meter capable of registering the flow of electricity in two directions.For net-metered systems >25	All exported generation is credited at the avoided cost rate.

		kW, the utility may require a customer-generator to install -- at its own cost -- a meter capable of measuring generation output and customer load.	
New Hampshire	1998 2013	Customers who own or operate distributed generation systems up to 1 MW including landfill gas and CHP systems are eligible. The rules for net-metering distinguish between small customer-generators (up to 100 kW) and large customer-generators (greater than 100 kW and up to 1 MW). CHP systems up to 30 kW must have a system efficiency of at least 80% to be eligible. CHP systems greater than 30 kW and up to 1 MW must have a fuel system efficiency of at least 65%. Legislation enacted in May 2012 (HB 1296) allowed CHP systems to account for up to 4 MW of the state's aggregate net-metering capacity limit of 50 MW.	NEG credited at retail rate; credits do not expire Legislation enacted in 2013 extended net metering for shared systems, allowing a customer to become a group host for the purpose of reducing or otherwise controlling the energy costs of a group of customers who do not generate their own electricity.
New Mexico	2008	Utility customers < 80MW	Net-metered customers are credited or paid for any monthly net excess generation (NEG) at the utility's

			avoided-cost rate.
New York	1997 2010	Residential micro-CHP systems up to 10 kW are eligible to net-meter. Also potentially farm-based biogas CHP systems up to 1 MW, and up to 1.5 MW renewably fueled fuel cells are eligible to net-meter. The aggregate limit on net-metered PV, on-farm biogas systems, micro-CHP, fuel cell, and micro-hydroelectric systems combined is currently generally set at 6.0% of a utility's 2005 electric demand.	
North Carolina	2005	< 1MW	
North Dakota	1991	Both renewable-energy generators and CHP systems up to 100 kW	If a customer has net excess generation (NEG) at the end of a monthly billing period, the utility must purchase the NEG at the utility's avoided-cost rate.
Oklahoma	1988 2014	Customer-owned renewable-energy systems and CHP facilities up to 100 kW	a fixed charge to customer-generators who install net-metered distributed generation on or after November 1, 2014.

Pennsylvania	2006	Residential systems up to 50 kW, non-residential systems up to 3 MW and micro-grid systems up to 5 MW	Full retail rate
Rhode Island	2011	Systems up to 5MW are eligible. Any excess kWh generation that exceed 100% but limited up to 125% of the net-metering customers usage during the billing period will be paid excess renewable net-metering credits	Avoided cost rate
South Carolina	2015	First-come, first-serve basis until 2% of the 5yrs average retail peak demand	
Utah	2002	RE-fueled CHP, residential systems up to 25 kWh and nonresidential systems up to 2 MW	Retail rate
Vermont	1998	systems up to 500kW of RE fueled CHP. Net meter allows to micro-CHP up to 20 kW. For fossil-fueled CHP to qualify, at least 20% of its fuel's total recovered energy must be thermal and at least 13% must be electric, the design system efficiency must be at least 65%.	
Virginia	2000	Systems up to 20 kW for residential, 1MW for non-residential systems.	NEG credited at retail rate; credits do not expire
Washington	1998	< 100kW	
West Virginia	2010	Capacity limits vary based on IOUs' customer type and electric utility type.	NEG credited at retail rate; credits do not expire

Wisconsin	1982	CHP up to 20kW	
Wyoming	2001	Solar, wind, biomass and hydropower systems up to 25 kW, including biomass CHP	

Appendix II - Table 4.5 Renewable and Energy Efficiency Portfolio Standard

	Policy Name	Initial Year	Applicable Sectors	Goals
Arizona	Arizona Renewable Energy Standard	2006	Investor-Owned Utility, Retail Supplier	Increase renewable energy generation from 2.5% in 2010, to 5% by 2015, 10% by 2020, and 15% by 2025.
	Arizona Energy Efficiency Resource Standard	2010	Utilities (except for electric distribution cooperatives)	To achieve cumulative annual energy savings equivalent to 22% of their retail electric energy sales from 2009 by December 31, 2020.
Arkansas	Energy Efficiency Targets	2010	Investor-Owned Utility	Incremental Electric Sales Reduction targets began at 0.25% in 2011, ramping up to 0.9% annually for 2015 – 2018 and 1.00% for 2019.
California	California's Renewables Portfolio Standard	2002, 2006, 2008, 2015	all electricity retailers including publicly owned utilities (POUs), investor-owned utilities, electricity service	20% by 2013, 25% by 2016, 33% by 2020, 50% by 2030

			providers, and community choice aggregators	
	Energy Efficiency Resource Standard	2004	Investor-Owned Utility	The Assembly Bill 2021 of 2006 calls for a 10% reduction in forecasted electricity consumption within 10 years.
Colorado	Colorado Renewable Energy Standard	2004 2013	Investor-owned utility, municipal utilities, cooperative utilities	Investor-owned utilities: 30% by 2020 Electric cooperatives serving 100,000 or more meters: 20% by 2020 Electric cooperatives serving fewer than 100,000 meters: 10% by 2020 Municipal utilities serving more than 40,000 customers: 10% by 2020. For IOUs, there is a separate distributed generation (DG) carve-out, 3% of retail electricity sales in 2020 and one must come from either wholesale DG (< 30MW) or retail DG. At least half of the DG requirement must come from retail DG systems located on-site at customers' facilities. Co-ops that provide service to less than 10,000 meters at least 0.75% of its retail sales must come from DG by 2020. For Co-ops serving 10,000 meters or more, 1% of retail sales must come from distributed generation by 2020.

	Energy Efficiency Resource Standard	2007	Investor-Owned Utility	Black Hills follows PSCo incremental savings targets of 0.8% of sales in 2011, increasing to 1.35% of sales in 2015. For the period 2015-2020, PSCo must achieve incremental savings of at least 400 GWh per year.
Connecticut	Connecticut Renewable Portfolio Standard	1998	Investor-owned utility, local government, retail supplier	27% of its electricity load through renewable sources or energy efficiency by January 1, 2020
	Energy-Efficiency And Load Management Plan	2007 & 2013	Investor-Owned Utility	Average incremental savings of 1.51% of sales from 2016 through 2018. Utilities must pursue all cost-effective efficiency resources.
Delaware	Delaware Renewables Portfolio Standard	2005	Investor-owned utility, local government, retail supplier	25% by 2026
District of Columbia	Renewables Portfolio Standard	2005 2016	Investor-Owned Utility, Retail Supplier	50% by 2032
Hawaii	Hawaii Renewable Portfolio Standard	2003	Investor-Owned Utility	10% by 2010, 15% by 2015, 30% by 2020, 40% by 2030, 70% by 2040, and 100% by 2045
	Hawaii Energy Efficiency Portfolio Standard	2009	Statewide goal	4,300 GWh of energy savings by the year 2030.
Illinois	Illinois Renewable Portfolio Standard	2007	Large investor-owned electric utilities and	Require large investor-owned electric utilities and alternative retail electric suppliers to

			alternative retail electric suppliers. Electric cooperatives and municipal utilities are exempt.	source 25% of retail electricity sales from eligible renewable energy resources by 2025. Electric cooperatives and municipal utilities are exempt. Beginning in 2016, utilities are required to provide 1% from distributed generation. If possible, at least half of this should come from systems with less than 25 kW in capacity.
	Illinois Energy Efficiency Standard	2007	Investor-Owned Utility, Retail Supplier	Electric sales reductions from the preceding year began at 0.2% for 2009 and grow to 2.0% by 2016. Natural gas sales reductions began at 0.2% in 2012 and grow to 1.5% in 2019. From 2019 onward, utilities must reduce their total natural gas delivered by 1.5% from the preceding year.
Iowa	Energy Efficiency Standard	2009	Investor-Owned Utility, Local Government, Municipal Utilities, Cooperative Utilities, Retail Supplier	Incremental savings targets vary by utility from ~1.1-1.2% annually during 2014-2018. Utilities must target peak demand reductions 436~504MW by 2018
Indiana	Indiana Clean Energy Portfolio Standard	2011	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities, Retail Supplier	A voluntary goal of 10% clean energy by 2025. CPS allows for up to 30% of the goal to be met with CHP systems, net-metered distributed generation facilities, clean coal technology, nuclear energy, C systems, and natural gas that displaces electricity from coal.

Kansas	Kansas Renewable Energy Standard	2009 2015	Investor-Owned Utility	A voluntary goal for 20% by 2020
Maine	Maine Renewable Portfolio Standard	2000	Investor-Owned Utility, Retail Supplier	40% by 2017. Providers must supply at least 10% of total sales using eligible new Class I renewables and 30% of eligible existing Class II resources. (CHP systems <100 MW are eligible under Class II.)
	Energy Efficiency Targets	2009	Statewide goal	Electric savings of 20% by 2020, with incremental savings targets of ~ 1.6% per year for 2014-2016 and ~2.4% per year for 2017-2019. Efficiency Maine operates under an all cost-effective mandate.
Maryland	Maryland Renewable Energy Portfolio Standard	2004 2017	Investor-Owned Utility, Local Government, Retail Supplier	25% by 2020 (On February, 2017, the lawmakers voted to increase the RPS from 20% by 2022 to 25% by 2020.)
	Empower Maryland Efficiency Act	2008 2015	Investor-Owned Utility, Municipal Utilities, Retail Supplier	15% per-capita electricity use reduction goal by 2015 (10% by utilities, 5% achieved independently). 15% reduction in per capita peak demand by 2015, compared to 2007. After 2015, targets vary by utility, ramping up by 0.2% per year to reach 2% incremental savings.
Massachusetts	Massachusetts Renewable Energy Portfolio Standard	1997	Investor-Owned Utility, Retail Supplier	Class I (New Resources): 15% of by 2020 and an additional 1% each year thereafter Class II (Existing Resources): 5.3% in 2014 (1.8% renewables and 3.5% waste-to-energy) and 5.5% in 2015 (2.0%

				renewables and 3.5% waste-to-energy)
	Massachusetts Alternative Energy Portfolio Standard	2008	Investor-Owned Utility, Retail Supplier	5% of supplier (both regulated distribution utilities and competitive suppliers) retail sales must come from alternative energy sources by December 31, 2020.CHP and other eligible projects can receive credits, referred to as "APS Alternative Energy Certificates (AECs)," for 1 MWh of electrical energy output or for thermal output (using a conversion factor of 3,412 thousand Btus = 1 MWh). Massachusetts APS credits were priced around $21 in 2012. Systems must also meet a net CO2 emissions rate of 890 lbs./MWh
	Massachusetts Energy Efficiency First Fuel Requirement	2008	Investor-owned utilities	1) A statewide electricity savings target of 2.93% for the years 2016-2018, which is expected to save the State 2,744,075 MWh annually. 2) A savings target of 25% of electric load by the year 2020 with demand side resources, including "energy efficiency, load management, demand response and generation that is located behind a customer's meter including a CHP system with an annual efficiency of 60% or greater with the goal of 80% annual efficiency for CHP systems by 2020."
Michigan	Michigan Renewable Energy Portfolio Standard	2008 2016	Investor-Owned Utility, Municipal Utilities,	All utilities: 15% by 2021, Consumers Energy: 200 MW of new renewables by 2013 and 500 MW by 2015,

			Cooperative Utilities, Retail Supplier	Detroit Edison Electric: 300 MW of new renewables by 2013 and 600 MW by 2015
	Energy Optimization Standard	2008 2016	Investor-Owned Utility, Retail Supplier	1.0% annual reduction of previous year retail electricity sales (MWh)
Minnesota	Minnesota Renewable Energy Standard	2007 2013	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities	Public utilities, generation and transmission electric cooperatives, municipal power agencies, and power districts: 25% by 2025, State's nuclear utility Xcel Energy: 30% by 2020, Other public and non-public utilities: 20% by 2020
	Minnesota Energy Efficiency Resource Standard	2007	Investor-Owned Utility, Retail Supplier	1.5% reduction in annual average retail sales (for both electric and gas utilities) beginning in 2010
Missouri	Missouri Renewable Energy Standard	2008	Investor-Owned Utility	15% by 2021
Montana	Montana Renewable Resource Standard	2005	Investor-Owned Utility, Retail Supplier	15% by 2015. Public utilities and competitive electricity suppliers servicing 50 or more customers must derive 15% of retail electricity sales from renewable resources. Utilities and suppliers can earn renewable energy credits (RECs) by joining long-term contracts with renewable energy providers and by purchasing RECs separately.
Nevada	Nevada Energy Portfolio Standard	1997	Investor-Owned Utility, Retail Supplier	20% in 2015 through 2019, 22% in 2020 through 2024, and 25% in 2025 and thereafter. The contribution from energy efficiency measures to meet the EPS is capped at 25% of the total standard in 2013 and 2014 and this percentage

				decreases every 5 years thereafter until 2025 when energy efficiency can no longer be used to help meet the standard. The EPS includes a Portfolio Energy Credit (PEC) trading program.
New Hampshire	New Hampshire Renewable Portfolio Standard	2007	Investor-Owned Utility, Cooperative Utilities, Retail Supplier	24.8% by 2025 Class I (new renewables including RE-fueled CHP and thermal energy): 15% by 2025 Only the biomass share will count toward the RPS. There is no size limit on renewable-fueled CHP systems, but waste heat-to-power system must be <15 MW. Thermal Energy: 2% by 2023 New Solar-Electric: 0.3% by 2014 Existing Biomass: 8% by 2017 Existing Hydro: 1.5% by 2015
	Energy Efficiency Resource Standard	2016	Investor-Owned Utility, Cooperative Utilities	0.8% incremental savings in 2018, ramping up to 1.0% in 2019 and 1.3% in 2020
New Jersey	New Jersey Renewables Portfolio Standard	1999	Investor-Owned Utility, Local Government, Retail Supplier	20.38% by 2021 plus solar 4.1% by 2028
New Mexico	New Mexico Renewable Portfolio Standard	2004	Investor-Owned Utility, rural electric cooperative utilities	Investor-owned utilities: 20% by 2020 Rural electric cooperatives: 10% by 2020. A distributed generation carve-out (which does not include wind and solar, which have their own carve-outs) requires 3% of the renewable energy to come from distributed generation.

	Energy and Energy Efficiency Resource Standard	2008 2013	Investor-Owned Utility	5% of 2005 total retail kWh sales by 2014 8% of 2005 total retail kWh sales by 2020
New York	New York Clean Energy Standard	2004, 2016	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities, Retail Supplier	50% by 2030 (2004 RPS goal was 29% by 2015, expired on 2016.)
	Energy Efficiency Resource Standard	2008 2016	Investor-Owned Utility	Utilities have filed efficiency transition implementation plans (ETIPS) with incremental targets varying from 0.4% to 0.9% for the period 2016–2018.
North Carolina	North Carolina Renewable Energy and Energy Efficiency Resource Standard	2008	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities	Investor-owned utilities: 12.5% by 2021. Municipal utilities and electric cooperatives: 10% by 2018. Energy efficiency is capped at 25% of target, increasing to 40% in 2021 and thereafter
North Dakota	North Dakota Renewable and Recycled Energy Objective	2007	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities	10% by 2015
Ohio	Ohio Alternative Energy Portfolio Standard	2008, 2012, 2014	Investor-Owned Utility, retail supplier	0.25% by 2009 0.5% by 2010 1.0% by 2011 1.5% by 2012 2.0% by 2013 2.5% by 2014

				3.5% by 2017 (2 yrs delayed by SB 310 in 2014) 4.5% by 2018 5.5% by 2019 6.5% by 2020 7.5% by 2021 8.5% by 2022 9.5% by 2023 10.5% by 2024 11.5% by 2025 12.5% by 2026
	Ohio Energy Efficiency Portfolio Standard	2009	Investor-Owned Utility, Electric distribution utilities	A cumulative, annual energy savings in excess of 22% by 2025. SB 310 freezes savings at 2014 levels (2.5%) through 2016 before continuing the 1% savings increase each year until 2021 when savings increase 2% annually, reaching the 22% annual energy savings by 2027. Electric distribution utilities: 7.57% peak demand reduction by 2020.
Oklahoma	Oklahoma Renewable Energy Goal	2010		15% by 2015 Systems <5MW are eligible.
Pennsylvania	Pennsylvania Alternative Energy Portfolio Standard	2005	Investor-Owned Utility, Retail Supplier	18% by 2021 Compliance is based on accumulating alternative energy credits (AECs), and banking of excess credits is allowed for up to 2 years.
	Energy Efficiency and Conservation Requirements for Utilities	2004 2008	Utilities with over 100,000 customers	Varies by utility, electricity savings range from 2.6% to 5%. Phase III begins from June 1, 2016 through May 31, 2021 EERS includes peak demand targets. Energy efficiency measures may not exceed an established cost-cap.

Rhode Island	Rhode Island Renewable Energy Standard	2004 2016	Investor-Owned Utility, Retail Supplier	38.5% by 2035 (in 2016, extended from 14.5% by 2019 to 38.5% by 2035)
	Rhode Island Energy Efficiency Resource Standard	2006 2012	Investor-Owned Utility, Municipal Utilities	EE targets, 2.5% in 2015, 2.55% in 2016, 2.6% in 2017.
South Carolina	South Carolina Distributed Energy Resource Program: portfolio program	2014		A voluntary standard 2% aggregate generation from RE by 2021. Carve-out of no-less than 0.25% for systems under 20kW
South Dakota	South Dakota Renewable, Recycled and Conserved Energy Objective	2008		10% of all retail electricity sales from RE and waste heat-to-power (recycled energy) by 2015
Texas	Texas Renewable Generation Requirement	2000	Investor-Owned Utility, Retail Supplier	5,880 MW of RE energy installed by 2015 and set a target for 10,000 MW by 2025
	Required Energy Efficiency Goals	1999 2000	Investor-owned utilities	30% of annual growth in peak demand or up to 0.4% of each utility's peak
Utah	Utah Renewables Portfolio Goal	2008	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities	20% of adjusted retail sales by 2025 The goal applies to "adjusted retail electric sales," defined as the total kWh of retail electric sales reduced by the kWh attributable to nuclear power plants, demand-side management measures, and fossil fuel power plants that sequester their carbon emissions.
Vermont	Vermont Renewable Energy Standard	2015	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities, Retail Supplier	55% of retail electricity sales from RE by 2017. Will increase 4% every 3 yrs until 75% by 2032. Distributed generation: 1% of elec sales from DG RE by 2017 and increase to reach 10% in

				2032
	Energy Reduction Goals	2000	Investor-Owned Utility, Local Government	Annual Incremental Net Savings: 321,800 Summer peak kW savings: 41,300 Winter peak kW savings: 53,700
Virginia	Voluntary Renewable Energy Portfolio Goal	2007	Investor-Owned Utility	15% of base year (2007) sales by 2025
Washington	Washington Renewable Energy Standard	2006	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities	15% of electric load from new RE by 2020.
	Energy Efficiency Resource Standard	2006	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities	Biennial and Ten-Year Goals vary by utility. Law requires savings targets to be based on the Northwest Power Plan, which estimates potential incremental savings of about 1.5% per year through 2030 for Washington utilities.
Wisconsin		1999	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities	Statewide target of 10% by 2015; requirements vary by utility
	Energy Efficiency Standard for Focus on Energy	2011	Investor-Owned Utility, Municipal Utilities, Cooperative Utilities	Focus on Energy targets include incremental electricity savings of ~0.81% of sales per year in 2015-2018.

Appendix II - Table 4.6 Utility Rate Policies

State	Policy Names	Initial Year	Rate Policies
Arizona, California, Nevada	Southwest Gas Rate for Power Generation	2011	Southwest Gas offers discounted gas rates for customers using natural gas for on-site power generation. Discounts only apply to gas used for electricity generation.
California	California Departing Load Charge Exemption	2001	On April 3, 2003, the CPUC issued Decision 03-04-030, outlining a mechanism for granting a range of distributed generation customers from paying power surcharges known as "exit fees" or "cost responsibility surcharges" (CRS). The following systems are exempt from the exit fee rules: Systems <1 MW that are net metered and/or eligible for CPUC or Energy Commission incentives for being clean and super clean are fully exempt from any surcharge; including solar, wind, and fuel cells. Ultra-clean and low-emission systems (defined as generation technologies which produce zero emissions or emissions that meet or exceed 2007 Air Resources Board (ARB) emission limits) >1 MW that meet Senate Bill 1038 requirements to comply with CARB 2007 air emission standards will pay 100% of the bond charge, but no future Department of Water Resources (DWR) charges or utility undercollection surcharges. All other customers will pay all components of the surcharge

			except the DWR ongoing power charges. When the combined total of installed generation reaches 3000 MW (1500 MW for renewables), any additional customer generation installed will pay all surcharges.
	California Standby Rates	2001	An exemption from standby rates for CHP systems was established in Senate Bill 1-28 (SBX 1-28) and expired on June 1, 2011. Since then, standby rates are now addressed in each utility's general rate case. While the standby rate design of each utility will differ, the utilities are instructed to enact rates that account for the actual costs and benefits of distributed energy resources. The CPUC also specified that in establishing standby rates, a utility should ensure that customers with similar load profiles within a customer class will be subject to the same utility rates, regardless of their use of distributed energy resources.
Connecticut	Connecticut DG Backup Rate Waiver	2006	Customers who install DG after January 1, 2006 will not be required to pay backup power rates as long as their generation is not higher than their peak load, and their generation is available during peak periods.
	Connecticut Natural Gas Rates	2006	CHP systems that use natural gas are eligible for a rebate of gas delivery charges from the gas distribution company. The Connecticut Department of Public Utility Control (DPUC) oversees these programs. Customers shall be rebated for

			an amount equivalent to the customer's retail delivery charge for transporting natural gas from the local gas company to the customer's project. The costs associated with the rebates will be recouped through federally mandated congestion charges.
	DEEP CHP Pilot Program	2013	DEEP is establishing a pilot program to promote CHP systems by limiting the demand charge electric companies impose on them. A qualifying project selected to participate in the pilot program shall not be required to pay the demand charges pursuant to the distribution demand-ratchet provision of firm service due to an outage of service of such project. If the project experiences an outage longer than 3 hours, the demand charge must be based on daily demand pricing pro-rated from standard monthly rates.
Hawaii	Hawaii Standby Rates	2008	The PUC issued an order that made standby rates optional for 10 years for customer-sited generators who install CHP and other forms of distributed generation power systems. If CHP customers choose not to take standby service, they remain on the otherwise applicable rate schedule. Hawaii Electric Company's (HECO) tariff, for instance, includes a reservation fee and calculates demand charges based upon the contract demand or the highest 15-minute backup demand amount, whichever is lesser. Additionally,

			customers taking standby service have the option of waiving their demand (due to an unscheduled outage) for billing purposes once a year. There is no demand ratchet in place.
	Hawaii Gas: Gas and Propane Rates	2012	Hawaii Gas (The Gas Company) offers favorable dedicated propane rates for CHP projects. The list includes resorts, hospitals, military facilities and retirement homes totaling 2.2 MW of operational CHP and 1.4 MW in development.
New Jersey	New Jersey Standby Charge Law	2012	Under the law, the NJBPU must establish criteria for fixing rates associated with the study assessment and require public utilities to file tariff rates according to the new criteria. The NJBPU must ensure equity between distributed generation customers and other electric public utility customers.
	New Jersey Natural Gas Rates	2012	Under the pricing plans, residential customers can save up to 40% on their gas delivery charges and a commercial customer can save up to 50% on delivery charges.
New York	New York Standby Rates	2001	The guidelines require that the investor-owned utilities in New York make their standby rates reflective of actual costs.
	New York Natural Gas Rates	2003	New York customers using natural gas for distributed generation including CHP may qualify for discounted natural gas delivery rates.

Pennsylvania	PGW Gas Rate for CHP	2014	PGW offers a discounted gas rate for customers using CHP.

Appendix II - Table 4.7 Financial Incentives

States	Incentive Types	Program Names	Initial Year	Key Incentives
Alabama	Loan	SAVES Revolving Loan Program	2010	1% interest rate for a maximum of 10 years for retrofitting existing facilities
Alaska	Production Incentive	Sustainable Natural Alternative Power (SNAP) Program	2006	Based on the amount (kWh) of renewable electricity generated by each producer
	Grant	Renewable Energy Grant Program	2008	The initial allocation plan recommended that 20% of the funding go to reconnaissance, feasibility and resource studies, and the remaining 80% be awarded to final design, permitting and construction projects.The grant program is intended to provide assistance to utilities, independent power producers, local governments and tribal governments.
	Loan	Power Project Loan Fund	2004	Designed for the development or upgrade of small-scale power production facilities, conservation facilities and bulk fuel storage facilities less than 10MW
Arizona	Rebate	Southwest Gas Corporation's CHP Program	2010	Funding ranging from $400 to $500 per kW (depending on efficiency) - and up to a maximum of 50% of the installed cost of any project
	Tax Credit	Renewable Energy Business Tax Incentives	2010	Income tax credits and property tax incentives (up to 10% of the investment) for RE companies. Different incentive levels are available depending on how many full-time jobs are created.
	Tax Exemption	Energy Equipment Property Tax Exemption	2009	Incentive includes 100% of increased value.
Arkansas	N/A	N/A	N/A	N/A

California	Public Benefit Funds	Electric Program Investment Charge Program	2012	The California Energy Commission (CEC) and the three investor-owned utilities (Southern California Edison, Pacific Gas and Electric Company, and San Diego Gas & Electric) administer the EPIC Program funds. The EPIC surcharge averages about $0.0008/kWh for all customer classes
	Feed-in-Tariff	California Feed-in Tariff	2007	The FIT price is tied to natural gas prices adjusted by the time of day and season.
	Commercial PACE	CaliforniaFIRST	2012	The programs allow property owners to finance the installation of energy and water improvements and pay the amount back on their property tax bill. The financing is based on the value of the property and provides fixed interest rates.
		FIGTREE PACE, mPower Placer (PACE), Los Angeles County - Commercial (PACE), City of San Francisco - GreenFinanceSF (PACE)	2010	
		City of Palm Desert - Energy Independence Program (PACE), Sonoma County - Energy Independence Program (PACE)	2008	
	Grant	Energy Innovations Small Grant Program	2013	The program provides up to $95,000 for hardware projects and $50,000 for modeling projects.
	Rebate	Self-Generation Incentive Program	2003	The following technologies will receive the corresponding incentives:

				Renewable and Waste Energy Recovery: Wind Turbine: $1.02/W, Waste Heat to Power: $1.02/W, Pressure Reduction Turbine: $1.02/W Conventional CHP projects fueled with non-renewables: Internal Combustion Engine (CHP): $0.42/W, Microturbine (CHP): $0.42/W, Gas Turbine (CHP): $0.42/W, Advanced Energy Storage: $1.31/W, Biogas Adder: $1.31/W, Fuel Cell (CHP or Electric Only): $1.49/W
	Loan	Anaheim Public Utilities - Low Interest Energy Efficiency Loan Program	2010	Loan terms include a low interest rate (5% in 2016) and a maximum repayment term of 8 years. Collateral will be required on all loans
		Energy Efficiency Loans	1981	State Assistance Fund for Enterprise, Business and Industrial Development Corporation (SAFE-BIDCO) offers loans up to $350,000 or 10 times the amount of estimated annual savings, whichever is less.
	Tax Credit	Sales and Use Tax Exclusion	2010	The state of California's Sales and Use Tax Exclusion for Advanced Transportation and Alternative Energy Manufacturing Program offers a 100% sales and use tax exclusion (STE) on property for eligible projects.
Colorado	Production incentives	Carbon Fund	2008	Funding for all projects is provided by donations from private businesses, organizations, and individuals who wish to support quality, innovative Colorado-based projects which reduce greenhouse gas emissions. Offsets are purchased from selected projects and then retired by The Climate Trust on behalf of these donors to the Colorado Carbon Fund.
		Recycled Energy Program	2014	Waste heat to electricity projects may be eligible to receive $500 per kW for a span of 10 years.Individual projects are limited to 10 MW.
	Tax Credit	Renewable Energy Property Tax Assessment	2009	Property tax for utility-scale electric-generating facilities is based on installed cost. Renewable energy facilities installed are assessed property taxes as though their installed costs were comparable to those of non-renewable energy facilities. The incremental value of the renewable facilities above the non-renewable facilities is disregarded.
	Tax Exemption	Property Tax Exemption for Renewable Energy	2007	Counties and municipalities offer property or sales tax rebates or credits.

		Systems		
Connecticut	Public Benefit Funds	Connecticut Clean Energy Fund	1998	The CEEF is funded by a surcharge of $0.003/kWh on electric bills and focuses on efficiency projects, including but not limited to conservation and load management programs, research, development and commercialization of products or processes which are more energy-efficient than those generally available, and certain demand-side technology programs -- all of which could be supportive of CHP. Funding for the CCEF comes from a surcharge of $0.001 per kWh on certain electricity sales and can be invested in various renewables, including "usable electricity from combined heat and power systems with waste heat recovery systems." These charges only apply to investor-owned utilities in the state.
	Commercial PACE	Connecticut PACE (C-PACE)	2012	C-PACE allows property owners to access 100% upfront, long term financing for energy efficiency and clean energy improvements on their properties through a special assessment on the property tax bill, which is repaid over a period of years (up to 20 years). Although there is no financing minimum, C-PACE is best suited for capital improvements over $150,000.
	Grant	CHP Capital Grant Program	2013	DEEP's CHP Capital Grant Program awards qualifying CHP projects a capital grant of $200/kW of nameplate capacity, 1MW or less
		Microgrid Grant and Loan Program	2012	Requires DEEP to establish a $15 million Microgrid Grant and Loan Program to support distributed energy generation at critical facilities.The loans are to be used for the cost of design, engineering, and interconnection of microgrid systems.
	Loan	Clean Energy On-Bill Financing	2014	CEFIA will develop a residential clean energy on-bill repayment program. The program will be financed by third-party, private capital and managed by CEFIA. The program will prioritize projects by cost-effectiveness, and the repayment term of any project cannot exceed the expected life of the improvements. Monthly payments cannot exceed the amount of the customer's bill before the project was installed.

		Low-Interest Loan Program	2005	Low-interest loans for $1 million or more are available for CHP Projects in Connecticut through Bank of America at a subsidized interest rate of 1% below the applicable rate or no more than the prime rate. Loans will be collateralized by way of equipment, or other collateral or credit enhancements required by Bank of America. 0.05 to 65 MW
	Tax Credit	Renewable Energy Property Tax Exemption	2007	The state of Connecticut provides a 100% property tax exemption for owners of "Class I" renewable energy systems that generate electricity for private residential use and are installed on or after October 1, 2007.Beginning in October 2014, commercial and industrial systems (meeting the same technology requirements as above) are also eligible for the property tax exemption. The exemption is available for properties installed on or after January 1, 2014, and the nameplate capacity cannot exceed the load for the location where the system is installed.
Delaware	Public Benefit Funds	Green Energy Fund	1999	Funds for the public benefit programs are collected from Delmarva Power and Light customers (the state's only investor-owned utility). Prior to July 2007, the Delmarva fund collected $0.000178 per kWh (0.178 mills/kWh) to fund renewable energy and energy efficiency incentive programs but collections were increased to $0.000356 per kWh (0.356 mills/kWh) by S.B. 35 of 2007. This money is collected and distributed through the Green Energy Fund.
		Delaware Electric Cooperative- Green Energy Fund	2005	Under the 2005 Delaware RPS legislation, electric cooperatives were allowed to opt out of the RPS schedule if they met certain requirements. One such requirement was that they contribute to the existing Green Energy Fund for investor-owned utilities or create their own green energy fund supported by an equal surcharge (i.e. $0.000178/kWh).The Delaware Electric Cooperative, the state's lone cooperative, opted out of the RPS requirements and established its own green energy fund. Based on 2012 retail electricity sales data from the DEC annual report, the fund has an annual income of approximately $214,000. The surcharge for the investor-owned utility fund was doubled in 2007 through legislation, but the surcharge for

				the Cooperative's fund was not affected.
	Loan	Efficiency Plus Business Program	2013	The Revolving Loan Fund Objective is to encourage the adoption and installation of end-user energy efficiency measures and customer-sited renewable generation that result in savings that can lower customers' bills and reduce the environmental impacts of energy production, delivery, and use.
District of Columbia	Commercial PACE	D.C. PACE Commercial	2010	The District of Columbia offers financing through a commercial PACE program in which the participant agrees to pay a special assessment on the property, collected in the same manner as real property taxes, for the purpose of repaying the loan. The special assessment constitutes a lien on the property senior to all other liens except real property taxes, with similar penalties for non-payment. This program permits PACE loans to be used to finance renewable energy projects, as well as a wide variety of energy efficiency improvement projects. Installations of renewable energy sources must be done in conjunction with energy-efficiency improvements that result in an ENERGY STAR score greater than 75 or, for properties that are not supported by ENERGYSTAR, reduce energy consumption by more than 10%.
	Tax Credit	Cogeneration Personal Property Tax Credit	2012	The District of Columbia has created a 100% personal property tax exemption for cogeneration facilities within the District.
Florida	Tax Credit	Renewable Energy Production Tax Credit	2010	This annual corporate tax credit is equal to $0.01 per kilowatt-hour (kWh) of electricity produced and sold by the taxpayer to an unrelated party during a given tax year. For new facilities (placed in service after May 1, 2012) the credit is based on the sale of the facility's entire electrical production.
	Tax Exemption	Solar and CHP Sales Tax Exemption	1997	The state of Florida has created a permanent sales and use tax exemption for CHP systems. The exemption applies to owners of machinery and equipment used at a fixed location for the purpose of producing electrical or steam energy resulting from the burning of boiler fuels other than residual oil. However, such energy must be primarily used for manufacturing, processing, compounding or producing for sale items of tangible personal property in Florida. In

				facilities where machinery and equipment are necessary to burn both residual and non-residual fuels, the exemption is prorated.
		Miami-Dade County-Targeted Jobs Incentive Fund	2005	Miami-Dade County will provide a qualifying company a property tax credit up to 1.7% of total real property capital investment or 1.15% of the tangible personal property capital investment. All incentive disbursements will occur after jobs are created, capital investments are made and a qualifying company has paid taxes.
Georgia	Tax Credit	Biomass Sales and Use Tax Exemption	2006	The state of Georgia has a 100% exemption for biomass materials from the state's sales and use taxes.
Hawaii	Public Benefit Funds	Hawaii Energy	2006	From 2013 onwards, the PBF will have a projected target budget of 2% of total projected revenue. The PUC engages in rulemaking to set the target percentage for the total projected revenue each year. All utilities in Hawaii, with the exception of KIUC, collect this surcharge on utility bills. In addition, as amended by the 2013 legislation, the Department of Business, Economic Development, and Tourism can issue Green Infrastructure Bonds in order to raise funds for renewable energy and energy efficiency projects. Revenue from the bonds will be used for on-bill financing and loan programs offered by the state and bondholders will be repaid with PBF funds.
	Bond	Green Infrastructure Bonds	2013	The bond proceeds will be used to fund the on-bill financing program being developed by the Public Utilities Commission. Bondholders will be repaid with funds collected from the state Public Public Benefits Fund.
	Tax Credit	City & County of Honolulu - Real Property Tax Exemption for Alternative Energy	2009	In 2009 the Honolulu City Council passed Bill 58, making alternative energy property installed on a building, property or land exempt from 100% of property taxes for 25 years.

Idaho	Bond	Renewable Energy Project Bond Program	2005	Independent (non-utility) developers of renewable energy projects in Idaho are eligible for financing opportunities, even if facilities are not "qualifying facilities" under the federal Public Utility Regulatory Policies Act of 1978 (PURPA).
	Loan	Low-Interest Energy Loan Programs	1995	Loans are available to commercial, residential, school, local government, state government, agricultural, institutional and hospital properties for retrofit only, with the exception of some renewable resources.
Illinois	Grant	Illinois Clean Energy Community Foundation Grants	1999	Foundation funding for biomass projects is limited to the purchase and installation of project hardware needed to convert the biomass into useful energy through processes including combustion, gasification and anaerobic digestion.
Indiana	Production incentive	City of Bloomington - Sustainable Development Incentives	2006	The City of Bloomington provides bonuses and allowances for buildings developers, not individual residents. Projects should build on the city's four goals, which include: renewable on-site energy sources
Iowa	Loan	Alternate Energy Revolving Loan Program	1996	The AERLP provides 50% of the total loan at 0% interest, up to a maximum of $1 million. Non-rate regulated electric and gas utilities are limited to 1 loan every 2 years with a maximum loan of $500,000. The remainder of the loan is provided by a lender at market rate. The maximum loan term allowed for the AERLP funds is 20 years. As of May 2012, the AERLP has reportedly provided loans of more than $28.2 million in support of 193 renewable energy projects. As the loans are paid back to the Iowa Energy Center, those funds are cycled back into the program and made available to new applicants.,
		IADG Energy Bank Revolving Loan Program	2011	The Iowa Economic Development Authority in partnership with the Iowa Area Development Group (IADG) is offering low interest loans for energy efficiency improvements, renewable energy projects, energy management and implementation plans. Loans will have terms of up to 10 years and range from $50,000-$300,000 with a 1% or higher interest rate.

	Tax Credit	Energy Replacement Generation Tax Exemption	2008	the state of Iowa provides a 100% exemption for self-generators and landfill gas systems. Iowa imposes a replacement generation tax of $0.0006 per kWh on various forms of electricity generated within the state. This tax is imposed in lieu of a property tax on generation facilities.
	Tax Exemption	Renewable Energy Production Tax Credit	2005	The State of Iowa offers a production tax credit of $0.015 per kWh for energy generated by eligible renewable energy facilities. In addition, Iowa offers $4.50 per million BTUs of biogas used to generate either electricity or heat for commercial purposes, or $1.44 per thousand cubic feet of hydrogen fuel generated and sold by an eligible renewable energy facility. These credits may be applied toward the state's personal income tax, business tax, financial institutions tax or sales and use tax and last for a 10-year period.
Kensas	Tax Credit	Renewable Energy Property Tax Exemption	1999	Owners of renewable energy equipment are 100% exempt of property taxes on their energy equipment in the state of Kansas.
	Tax Exemption	Waste Heat Utilization System Income Tax Deduction (Corporate)	2007	Kansas taxpayers may claim a deduction on adjusted gross income from the amortizable costs of a new waste heat utilization system. This deduction is equal to 55% of the facility's amortizable costs for the first year in operation, then 5% for the next nine taxable years.
Kentucky	Loan	Energy Efficiency Loans for State Government Agencies	2010	The eSELF Revolving Loan is a loan for energy efficiency projects costing between $50,000 and $225,000 that will result in at least a 20% energy reduction. Improvement projects funded under this loan will be managed directly by the state agency. The Hybrid Revolving Loan is for energy efficiency projects costing between $50,000 and $600,000. An energy audit or engineering analysis is required as well as a design and development package. The state agency is responsible for procuring materials and service. The cost of the audit/engineering analysis may be rolled into the loan. The ESPC Revolving Loan is for comprehensive energy efficiency projects costing more than $600,000 and that use an Energy Savings Performance Company (ESPC) or Energy Service Company (ESCO). A

				detailed industrial energy audit as well as cost-benefit analysis is required. The cost of the audit/engineering analysis may be rolled into the loan.
	Tax Credit	Incentives for Energy Independence	2008	For companies that work on renewable energy facilities incentives may include the following: A tax credit that allows approved facilities to receive a credit up to 100% of Kentucky income tax and the limited liability tax for projects that construct, retrofit or upgrade facilities that generate power from renewable resources. A sales tax incentive of up to 100% of the Kentucky sales and use tax paid (on or after the activation date) on materials, machinery and equipment used to construct, retrofit or upgrade an eligible project. Approved companies may also require that employees whose jobs were created as a result of the associated project, as a condition of employment, agree to pay a wage assessment of up to 4% of their gross wages. Employees will be allowed a Kentucky income tax credit equal to the assessment withheld from their wages. Advanced disbursement of post-construction incentives. The maximum recovery for a single project from all incentives, including the income and liability entity tax credit, sales tax refund and the wage assessment, may not exceed 50% of the capital investment.

Louisiana	N/A	N/A	N/A	N/A
Maine	Public Benefit Funds	Efficiency Maine Trust	1999	The total collection cap for utilities is 4% of total retail electricity, transmission, and distribution sales in the state. Previous to July 2015, the fixed amount of assessment was $0.00145/kWh, which generated revenues for this fund of between $13 million and $14 million per year. There is also a natural gas system benefit charge which generated nearly $900 thousand in 2013.,
		Energy Efficiency and Renewable Resource Fund	1997	This fund was originally known as the Renewable Resource Fund (now it is part of Efficiency Maine Trust).The fund supports grants for energy efficiency, renewable-energy demonstration, and research and development projects to Maine-based nonprofits, consumer-owned electric transmission and distribution utilities, community-based nonprofit organizations, community action programs, municipalities, quasi-municipal corporations or districts, and school administrative units.
Maryland	Production Incentive	BGE Smart Energy Savers Program	2012	Incentives include: Design incentive ($75/kW): Subsequent to signed commitment letter and acceptance of Minimum Requirements Document. Installation incentive ($275/kW for projects under 250kW; $175/kW for projects 250kW or greater): Subsequent to commissioning of CHP system and BGE inspection. Production incentive ($0.07/kWh for 18 months): Three payments subsequent to review of metering data at the end of the 6th, 12th and 18th months, respectively. Capacity and design incentives are capped at $1.25 million and production incentives are capped at $1.25 million.,
		Delmarva Power Combined Heat & Power Program	2012	Incentives include: Capacity incentive: $350/kW for projects under 250kW; $250/kW for projects 250kW or greater Production incentive: $0.07/kWh for 18 months.,

		FirstEnergy (Potomac Edison) - Combined Heat and Power Incentives Program	2015	Incentives include: Design incentive: $75/kW Installation incentive: $275/kW for projects under 250kW; $175/kW for projects 250kW or greater Production incentive: $0.07/kWh for 18 months. Three payments subsequent to review of metering data at the end of the 6th, 12th and 18th months, respectively.,
		Pepco Combined Heat & Power Program	2012	Incentives include: Capacity incentive: $350/kW for projects under 250kW; $250/kW for projects 250kW or greater Production incentive: $0.07/kWh for 18 months.
	Grant	Maryland CHP Grant Program	2014	Individual grants range in size from up to $425/kW to up to $575/kW based on the size of the CHP system, with a maximum per project cap of $500,000.
	Loan	Jane E. Lawton Conservation Loan Program	2013	Borrowers can use cost savings of added improvements to repay the loans.
Massachusetts	Public Benefit Funds	Energy Efficiency Fund	1997	Support energy efficiency programs, including demand-side management (DSM) programs and low-income energy programs. It is funded by several sources: a non-bypassable surcharge of $0.0025 per kilowatt-hour imposed on customers of all investor-owned electric utilities in Massachusetts; amounts generated under the Forward Capacity Market program administered by ISO-NE; cap-and-trade pollution-control programs, including the Regional Greenhouse Gas Initiative (RGGI) and the NOx Allowance Trading Program; and other sources approved by the Massachusetts Department of Energy Resources (DOER), the Energy Efficiency Advisory Council and the Department of Public Utilities (DPU).
	Production Incentive	Massachusetts Renewable Energy Trust Fund	1997	The Massachusetts Renewable Energy Trust Fund is supported by a non-bypassable surcharge of $0.0005 per kWh imposed on customers of all investor-owned electric utilities and competitive municipal utilities in Massachusetts. The eligible project size is Less than 0.06 MW.

	Grant	Community Clean Energy Resiliency Initiative	2014	Massachusetts municipalities, regional school districts, regional water districts, regional sewerage districts, and regional planning agencies are eligible to apply.
		Funding for Clean Energy Projects at Drinking Water and Wastewater Facilities	2014	Municipal or district facilities treating or pumping drinking water or wastewater are eligible. Municipal or district facilities that are contract-operated are also eligible.
	Rebate	Massachusetts Municipal Commercial Industrial Incentive Program	2010	Certain municipal utilities in Massachusetts, in cooperation with Massachusetts Municipal Wholesale Electric Company, have begun offering energy efficiency incentives. There are several programs offered, generally these include commercial and industrial retrofit programs, lighting programs and new construction programs. ,
		MassSAVE - Utility Energy Efficiency Program (CHP)	2008	There are three tiers of incentives for utility customers considering energy efficiency measures in conjunction with installing a CHP system: Level 1 - Basic, Level 2 - Moderate, Level 3 - Advanced. Level 1: $750 per kW for systems 150 kW or less. Level 2: Up to $950 per kW for units larger than 150 kW or $1,000 per kW for units 150 kW or less. Level 3: Up to $1,100 per kW for units larger than 150 kW or $1,200 per kW for units 150 kW or less. All owners of CHP are eligible, but the best applications are typically those with high annual hours of operation with near full use of the thermal output, including process industry (24/7) operation, as well as commercial applications such as hotels, hospitals, nursing homes, schools, colleges, laundries, health facilities and multi-unit apartments.
Michigan	Commercial PACE	City of Ann Arbor (PACE)	2011	The City of Ann Arbor offers Property Assessed Clean Energy (PACE) financing for energy efficiency and/or renewable energy projects, including CHP, that range in size from $10,000 to $350,000. Financing will be conducted by pooling the assessments and issuing a bond once the pool reaches $1 million. The interest rate is expected to be less than 5%.

		Lean & Green Michigan	2012	Lean & Green Michigan is a Commercial PACE program, which allows property owners to borrow money for energy improvements and repay the borrowed funds through an assessment on the property over a number of years.
	Tax Credit	Nonrefundable Business Activity Tax Credit	2002	The credit is equal to the lesser of (1) the amount by which a business's "tax liability attributable to qualified business activity" for the tax year exceeds the business's "baseline tax liability attributable to qualified business activity," or (2) 10% of the amount by which the business's "adjusted qualified business activity" performed in Michigan, outside of a "Renaissance Zone," for a tax year exceeds such activity for the 2001 tax year. Under either formula, a business may not claim the credit for any tax year in which its "tax liability attributable to qualified business activity" did not exceed the "baseline tax liability attributable to qualified business activity" in 2001.
	Tax Exemption	Refundable Payroll Tax Credit	2002	Businesses in Michigan may be eligible to claim a tax credit equal to their qualified payroll amount multiplied by their income tax rate for that year. If the credit exceeds the tax liability of the business for the tax year, the portion of the credit exceeding the tax liability will be refunded.
Minnesota	Production Incentive	Renewable Energy Production Incentive	2001	The state of Minnesota offers a payment of \$0.01 to \$0.015 per kilowatt-hour (kWh) for electricity generated by on-farm anaerobic manure methane digesters. The Hydro and Anaerobic Digesters program has a budget of \$1.5 million and is funded through the state's Renewable Development Fund.
	Grant	Minnesota Power Grant Program	2015	Grants up to \$50,000 to its commercial, industrial, and agricultural customers who use innovative technologies, improve manufacturing processes, undertake renewable electric energy projects or who need project design assistance

		Xcel Energy - Renewable Development Fund Grants	1999	The Xcel Renewable Development Fund provides grants periodically through a Request for Proposals (RFP) process to promote the start up, expansion and attraction of renewable energy projects and companies in the Xcel Energy service area, as well as stimulate research and development in renewable energy technologies. In RDF Cycle 4, more than $42 million was awarded to 29 projects.
	Loan	Value-Added Stock Loan Participation Program	1994	The Value-Added Stock Loan Participation Program is designed to help farmers finance the purchase of stock in certain types of cooperatives, limited liability companies or limited liability partnerships that will produce a "value-added agricultural product."
Mississippi	Loan	Energy Investment Loan Program	1989	The interest rate is 2% below the prime rate, with a maximum loan term of 10 years. Loans range from $15,000 to $500,000 per business.
Missouri	Loan	Energy Loan Program	1989	Loan available for energy efficiency and renewable energy projects for public and governmental buildings and structures.
Montana	Tax Credit	Alternative Energy Investment Tax Credit (Corporate)	2002	Commercial and net metering alternative energy investments of $5,000 or more are eligible for a tax credit of up to 35% against individual or corporate tax on income generated by the investment.
	Tax Exemption	Generation Facility Corporate Tax Exemption	2001	New electricity generating facilities built in Montana are exempt from property taxes for 5 years after operation begins.
		Property Tax Abatement for Production and Manufacturing Facilities	2007	Eligible facilities and equipment are assessed at 50% of their taxable value for the construction period and the first 15 years after the facility commences operation, not to exceed 19 years. These types of facilities are categorized as "Class 14" property, which is taxed at 3% of the property's market value. A facility that qualifies for the 50% property tax abatement is therefore subject to property tax equal to 1.5% of the property's market value. Additionally, all renewable energy research and development equipment up to $1 million in value may qualify for a 50% property tax abatement if it is placed into service after June 30, 2007.

		Renewable Energy Systems Exemption	2005	Montana's property tax exemption may be claimed for 10 years after installation of the property. The 100% exemption is allowed for up to $20,000 in value for single-family residential dwellings and up to $100,000 in value for multi-family residential dwellings or non-residential structures. This property is class 4 property and otherwise would be taxed at 3.01% of assessed value.
Nebraska	Commercial PACE	Nebraska PACE	2016	The Property Assessed Clean Energy Act was signed on April 13, 2016 and allows municipalities to create clean energy assessment districts. Municipalities that create such districts may enter into contracts with qualifying property owners and (if participating) third-party financiers to provide financing for energy efficiency and renewable energy projects on the qualifying property. The loans are paid back through assessments on the owner's property taxes. PACE bonds are capped at $5 million unless approved by referendum.
	Tax Credit	Sales and Use Tax Exemption for Renewable Energy Property	2013	Nebraska provides a 100% refund for the sales and use taxes paid for a renewable energy system used to produce electricity for sale. This refund does not apply to the first 1.5% of sales tax charged by a municipality.

Nevada	Rebate	NV Energy (Northern NV Gas) - SureBet Business Energy Efficiency Rebate Program	2003	Prescriptive rebates are available for the following: Boiler Reset Control: $500. Boiler Tune-up: $300. High Efficiency Furnaces Input MBH $1. Commercial Water Heaters Unit: $150. Condensing Unit Heaters Input MBH $1. Programmable Thermostat: $50. Infrared Heaters Input MBH $1. Steam Trap Repair/replacement Trap: $50. Pipe Wrap-Hot Water or Steam Boiler Linear Foot $4. Domestic Hot Water Pipe Wrap Linear Foot $2. Hotel Guest Room Energy Management System (Gas Heat): $35. High-Efficiency Pool Heater Input MBH $1.50. Process Boiler Tune-Up: $400. Domestic Water Heater Tune-Up Boiler: $150. Water Heater Systems: $1000 - $1800.
New Hampshire	Public Benefit Funds	System Benefits Charge	1996	For low-income residents, the efficiency fund, which took effect in 2002, is funded by a non-bypassable surcharge of 1.8 mills per kilowatt-hour ($0.0018/kWh) on electric bills (a separate surcharge of 1.5 mills per kWh ($0.0015/kWh) supports low-income energy assistance programs).
	Commercial PACE	New Hampshire Commercial PACE	2010	Enable municipalities to create special assessment districts so that owners of commercial buildings can finance energy efficiency upgrades or install renewable energy systems using financing secured by special assessment liens. CHP systems are eligible under this program.
	Grant	Enterprise Energy Fund	2010	Supported by State Energy Program (SEP) funds and the federal American Recovery and Reinvestment Act (ARRA). While primarily a revolving loan program, the Enterprise Energy Fund provides a limited amount of funding for grants. Grants are typically used to lower costs for non-profits that provide "essential services," and to support eligible commercial entities that invest in renewable energy systems

				to lower the payback period.
New Jersey	Grant	Clean Energy Solutions Large Scale CHP-Fuel Cells Program	2012	The project-based grant award cannot exceed $3 million per project with the maximum percent of project cost capped at 30% for CHP and 45% for fuel cells.Grant amounts are as follows: CHP systems greater than 1.0 and up to 3.0 MW: $0.55 per watt. CHP systems greater than 3.0 MW: $0.35 per watt.
	Loan	Energy Efficiency Revolving Loan Fund (EE RLF)	2012	Support up to 80% of tatal eligible project costs, not to exceed $2.5 million or 100% of total eligible project costs from all public State funding sources.,
	Tax Credit	Cogeneration Tax Exemption	2009	A sales and use tax exemption for the purchase of natural gas and utility service for on-site cogeneration facilities and the amendments allow the ability to "wheel" power to district energy thermal customers through CHP.
	Tax Exemption	Property Tax Exemption for Renewable Energy Systems	2008	New Jersey enacted legislation exempting renewable energy systems used to meet on-site electricity, heating, cooling or general energy needs from local property taxes.The exemption is equal to 100% of the value added by the renewable energy system.
New Mexico	Bond	Clean Energy Revenue Bond Program	2005	Up to $20 million in bonds, backed by the State's Gross Receipts Tax.The bonds are exempt from taxation by the state.
	Production Incentive	El Paso Electric Company - Small and Medium System REC Purchase Program	2009	EPE purchases RECs from its New Mexico customers. Up to 1MW. RECs will be measured by a separate REC meter and purchased by El Paso Electric on a monthly basis.
	Rebate	Xcel Energy (Electric) - Commercial Energy Efficiency Rebate Program	2010	CHP projects are eligible for custom rebates. Custom rebates are worth up to $400/ kW saved and efficiency studies for large commercial and industrial customers can cover up to 75% of the study cost. Customer contribution is limited to $7,500 with Xcel covering all costs above $30,000.

	Tax Credit	Advanced Energy Gross Receipts Tax Deduction	2010	New Mexico has a gross receipts tax structure for businesses instead of a sales tax. Businesses are taxed on the gross amount of their business receipts each year before expenses are deducted. Revenue generated by the sale and installation of a "qualified generating facility" may be deducted from gross receipts before the gross receipts tax is calculated. The deductions are allowed for a 10 year period starting the year construction begins. The maximum incentive is $60 million. 1.0 MW or greater
		Alternative Energy Product Manufacturers Tax Credit	2006	The total amount of the credit is approved by the Taxation and Revenue Department and is not to exceed 5% of the taxpayer's qualified expenditures.
		Renewable Energy Production Tax Credit (Corporate)	2002	A tax credit against the corporate income tax of $0.01 per kilowatt-hour for companies that generate electricity from biomass and wind. 1 MW or greater
	Tax Exemption	Advanced Energy Tax Credit	2009	A 6% tax credit against gross receipts and certain other state taxes. Any unused credit may be carried forward for up to 10 years. The tax credit amount is capped at $60 million. 15 MW or less.
		Biomass Equipment & Materials Compensating Tax Deduction	2005	allow businesses to deduct the value of biomass equipment and biomass materials used for the processing of biopower, biofuels or biobased products in determining the amount of Compensating Tax due. The rate is 5.125% on certain property used in New Mexico and 5% on certain services used in New Mexico.
New York	Public Benefit Funds	New York System Benefits Charge	1996	The SBC is a surcharge on the customer bills of New York's six investor-owned utilities. Funding for CHP projects provided by these resources would be found under related dCHPP incentive types (e.g., loan, grant, or rebate).

	Production Incentive	Combined Heat and Power Performance Program	2013	The NYSERDA funding provides Incentives are performance-based and correspond to the summer-peak demand reduction (kW), energy generation (kWh), and fuel conversion efficiency (FCE) achieved by the CHP system on an annual basis over a two-year measurement and verification (M&V) period. Systems will receive: Upstate: \$0.10/kWh + \$600/kW. Downstate: \$0.10/kWh + \$750/kW. Base CHP Incentives are capped at the lesser of \$2,600,000 per CHP project or 50% of total project cost. Owners of CHP systems with an aggregate nameplate greater than 1.3 MW that provide summer on-peak demand reduction and are located in New York.
	Grant	CHP Acceleration Program	2013	Provide incentives for the installation of grid-connected CHP systems at customer sites that pay the System Benefits Charge (SBC) on their electric bill. Systems less than 1 MW, must use the Catalog Approach. The Custom Approach is only available for projects 1MW and larger in size, but these larger projects can also use the Catalog Approach.
		Manufacturing Assistance Program (MAP)	2010	Provide fianancing for Interested NY State manufacturers must employ between 50 and 1,000 workers, and at least 30% of their production must be exported beyond the immediate region or to a prime manufacturer that exports beyond the region.
	Rebate	Custom Measures Commercial and Industrial Rebate Program	2010	Customers can receive rebates from the NYSERDA or their utility, but not from both NYSERDA and their utility for the same measure. Measures must be cost-effective (total resource cost of at least 1.0 to be confirmed by rebate processor). eligible an electric load of 100 kW or greater.

		National Grid (Gas) - Commercial Energy Efficiency Rebate Programs (Metro NY & Upstate NY)	2011	The program provides support services and incentives to commercial customers who install energy efficient natural gas related measures. All firm commercial rate customers are eligible to participate. Energy Efficiency Engineering Study: 50%. Custom and Large Industrial Gas Incentives: $50%. Furnaces: $200 or $400. Condensing Unit Heater: $500. Infrared Heaters: $500. Steam Boilers: $700. Hydronic Boilers: $5,000. Condensing Boilers: $15,000. Indirect Water Heaters: $100 or $300. Integrated Water Heater/Boiler: up to $1,600. ENERGY STAR Programmable Thermostats: $25/unit. Steam Traps: 25% of cost. Boiler Reset Controls: $150-$250/unit (two unit max). Pipe Insulation: $1.50/ft.
	Loan	Linked Deposit Program (LDP)	1994	The Linked Deposit Program helps New York state firms obtain reduced-rate financing (2-3% interest rate).
		NY Green Bank	2013	Rather than providing loans directly to the companies for pre-construction operations, NY Green Bank works in partnership with the participating financing entities, including banks and other private sector participants.
	Tax Credit	Tax-Exempt Equipment Leasing Program (TELP)	2000	TELP is a financing program that changes the traditional two-party lease structure to include a financing organization as a third party. Eliminate taxes on the interest portion of a lease payment.
North Carolina	Loan	Local Option - Financing Program for Renewable Energy and Energy Efficiency	2009	Low interest loans

	Tax Credit	Renewable Energy Tax Credit	2016	North Carolina offers a tax credit equal to 35% of the cost of eligible renewable energy property placed into service in North Carolina. There is a maximum credit of $10,500 per installation for CHP systems or certain other renewable-energy systems used for a non-business purpose.
North Dakota	Tax Credit	Sales and Use Tax Exemption for Electrical Generating Facilities	2011	Electrical generating facilities are 100% exempt from sales and use taxes in North Dakota.
Ohio	Rebate	AEP Ohio - Commercial Custom Project Rebate Program	2010	AEP Ohio offers $0.08/kWh (for one year energy savings) plus $100/kW for AEP's demand reduction (at summer peak). The maximum incentive is 50% of cost, up to $300,000 per project.
	Loan	Energy Loan Fund	2011	Priority will be given to projects with an energy savings payback of 1 to 4 years. Projects must result in energy savings of at least 15% and must be installed in Ohio.
	Tax Credit	Air-Quality Improvement Tax Incentives	1978	OAQDA can provide a 100% exemption from the tangible personal property tax (on property purchased as part of an air quality project), real property tax (on real property comprising an air quality project), a portion of the corporate franchise tax (under the net worth base calculation), and sales and use tax (on the personal property purchased specifically for the air quality project only) as long as the bond or note issued by OAQDA is outstanding. Furthermore, interest income on bonds and notes issued by OAQDA is exempt from state income tax (and may be exempt in certain cases from the federal income tax).
	Tax Exemption	Energy Conversion and Thermal Efficiency Sales Tax Exemption	2004	Ohio may provide a 100% sales and use tax exemption for certain tangible personal property.
Oklahoma	Loan	Community Energy Education Management Program	2009	Funding for the program comes from oil overcharge restitution funds. Loans offered have a 3% interest rate for up to 6 years.

Oregon	Public Benefit Funds	Energy Trust of Oregon	1999	Collect a 3% public-purpose charge from their customers to support EE and RE through 2026. Oregon's renewable portfolio standard legislation (SB 838), enacted in June 2007, established a goal that by 2025 at least 8% of Oregon's retail electrical load come from small-scale renewable energy projects with a capacity of 20 megawatts (MW) or less. To support this goal, the legislation modified the public purpose charge for renewables to require that funding be used to support only smaller projects of 20 MW or less. Furthermore, the sunset date on the original 10-year public purpose charge was extended through 2025.
	Grant	Custom Renewable Energy Projects	2002	part of two Energy Trust programs
	Loan	Small-Scale Energy Loan Program (SELP)	1980	Low interest loans
	Tax Credit	Local Option	2005	Rural Renewable Energy Development Zones: Cities, counties, or several contiguous counties in Oregon can set up Rural Renewable Energy Development (RRED) Zones. eligible for a 3 to 5 year local property tax exemption.
Pennsylvania	Production Incentive	PECO Non-Residential Energy Efficiency Rebate Program	2016	CHP projects are eligible for up to $1 million, or no more than 50% of total costs, through a combination of performance and capacity incentives. The performance incentive for CHP projects is $0.02/kWh based on the actual electricity generated. The capacity incentive, based on the installed system capacity, is equal to: $300 per kW - up to 0.5 MW $150 per kW - 0.5 MW to 1.5 MW $75 per kW - 1.5 MW to 10 MW
	Grant	Alternative and Clean Energy Program	2009	Loans, Grants, Loan Guarantees are available.
		Metropolitan Edison Company SEF Grants (FirstEnergy Territory)	2000	Any organization, governmental entity, individual or corporation may apply for grants under this program.

		The Pennsylvania Electric Company Sustainable Energy Fund	2000	FirstEnergy Funds will be distributed as loans or equity investments.
	Rebate	PGW - Residential and Commercial Construction Incentives Program	2012	Rebates to reduce gas consumption >10% to <20% more efficient than code = $13 Per First Year MMbtu Saved. >20% to <30% more efficient than code = $24 Per First Year MMbtu Saved. >30% more efficient than code = $40 Per First Year MMbtu Saved.
	Loan	Small Business Pollution Prevention Assistance Account Loan Program	1999	Loans for 75% of project costs up to $100,000 within any 12 month period, 2% interest rate of up to 10 yrs
		West Penn Power SEF Commercial Loan Program	2010	WPPSEF will seek out loan proposals that may not be currently bankable but are acceptable credit risks.
Rhode Island	Public Benefit Funds	Commerce RI Renewable Energy Fund	1996	Funded by a $0.0003/kWh surcharge. REF provides grants and loans for RE projects. (20%)
	Commercial PACE	Commercial Property Assessed Clean Energy (RI C-PACE)	2016	Financing provided by private capita providers at competitive rates
	Production Incentive	National Grid Electric's CHP Program	2014	A combination of EE, performance rebates, and advanced gas tech incentives for maximum 70% of total project cost. $900/kW per net kW for projects w. 55%-59.99% EE, $1000/kW for 60% or greater EE, A 25% bonus to facilities that have implemented EE measures in the previous 5 yrs that have reduced on site energy use by at least 5%. Projects 1 MW or larger are eligible for a performance incentive of $20/kW-year for metered load reduction.
	Loan	Energy Revolving Loan Fund	2014	funded by money from ARRA.
South Carolina	Loan	ConserFund Loan Program	2000	covering up to 100% of eligible project costs, (1) SouthCarolinaSAVES Green Community Loan Program: 2014
	Tax Credit	Biomass Energy Tax Credit (Corporate)	2007	allowed a credit against the income tax and/or license fees for 25% or the costs incurred by the purchase and installation. Limited to

				$650,000 tax credit and may not exceed 50% of a liability.
South Dakota	Tax Credit	Renewable Energy Facility Sales and Use Tax Reimbursement	2013	Allow for a reinvestment payment up to 100% of sales and use taxes paid for certain new or expanded RE systems and upgrades.
	Tax Exemption	Renewable Energy System Exemption	2010	A local property tax exemption for RE. the first $50,000 or 70% of the assessed value of the RE property. Less than 5 MW eligible.
Tennessee	Loan	Commercial Energy Efficiency Loan Program	2011	Below-market loans for EE and RE improvements. From $20,000 to $5 million. Allows to pay off the loan over a 10 yr with 50% of the money going to RE and EE projects, while retaining the remaining 50% through energy savings to pay off the loan. 2% fixed interest rate for terms up to 5 yrs and 5% fixed for b/w 5 and 10 yrs.
	Tax Credit	Sales and Use Tax Credit for Emerging Clean Energy Industry	2009	The Sales and Use Tax is reduced to 0.5% for clean energy technology manufacturers. The taxpayer must submit a claim for credit and documentation that the sales and use tax has been paid on qualified tangible property.
Texas	Grant	City of Houston - Energy Efficiency Incentive Program	2011	Incentives to offset 20% of the upfront costs, from $20,000 to $500,000. Available to existing bldg owners in the city
Utah	Bond	Local Option - Industrial Facilities and Development Bonds	2013	counties, municipalities, and state universities in Utah issue Industrial Revenue Bonds or Industrial Development Bonds.
	Tax Credit	Utah Renewable Energy Systems Tax Credit	2004	25% (up to a maximum of $2000) ITC for residential systems, 10% ITC (up to $50,000) for commercial systems, >600 kW or greater for PTC of $0.0035 per kWh for a first 4 yrs.
		Alternative Energy Manufacturing Tax Credit	2009	post-performance non-refundable tax credit for up to 100% of new state tax revenues
	Tax Exemption	Utah Alternative Energy Development Incentive	2009	post-performance tax credit for 75% of new state tax revenue for 20 yrs or the life of the project. 2 MW or greater
Vermont	Public Benefit Funds	Efficiency Vermont	2000	funding mechanism from "volumetric charge." The fund provides technical ssistance and financial incentives for EE to reduce the size of future power purchases and GHG emissions, limiting the need to

				upgrade state's T&D infrastructure and minimizing the costs of electricity. ,
		Vermont Clean Energy Development Fund	2005	D infrastructure and minimizing the costs of electricity. , - Vermont Clean Energy Development Fund: 2005,
	Production Incentive	Biomass Electricity Production Incentive	2004	Green Mountain Power purchases RECs for up to $0.04 per kWh. Farmers sell the electricity as a separate commodity.
	Loan	Agricultural Energy Loan Program	2013	Loan program to agriculture or forest-related business,
		Business Energy Conservation Loan Program	2010	loan from $5000 to $150,000, up to 75% of a project's cost. Interest rate is equal to VEDA's Small Business Index minus 1.5% for 5 yrs and then adjust to a variable Small Business Loan Program Index Rate.
		Commercial Energy Loan Program	2013	commercial entities,
		Energy Loan Guarantee Program	2013	up to 75% of the lender's loan, loans to businesses for EE improvements,
		Small Business Energy Loan Program	2013	
	Tax Credit	Investment Tax Credit	2016	ITC for RE installations, 24% of the Vermont property portion of the federal business energy tax credit from 2011 to 2016. For CHP, the credit is a 2.4% state-level tax credit for systems place in service on or before 2016.
	Tax Exemption	Renewable Energy Systems Sales Tax Exemption	1999	100% tax exemption for 250 kW or less systems using eligible RE sources, 20kW or less for micro-CHP systems.
Virginia	Grant	Clean Energy Manufacturing Incentive Grant Program	2011	maximum $36million up to 6 yrs grant.
	Loan	Commonwealth's Energy Leasing Program	2011	Financing for the EE equipment purchase,
		Energy Project and Equipment Financing	1984	Financial assistance for EE/RE projects

		VirginiaSAVES Green Community Loan Program	2015	subsidized financing to eligible borrowers including local gov, non-profit institutional and com and ind businesses with sufficient credit
	Tax Credit	Local Option - Renewable Energy Machinery and Tools Property Tax Exemption	2015	
Washington	Production Incentive	Renewable Energy Cost Recovery Incentive Payment Program	2006	The incentive amount paid to the producer starts at a base rate of $0.15 per kilowatt-hour (kWh) and is adjusted by multiplying the incentive by a factor of 1.0 for electricity produced using an anaerobic digester.
		Okanogan County PUD - Sustainable Natural Alternative Power Program		
	Loan	WSHFC Sustainable Energy Program	2015	low-cost financing for EE upgrades and RE projects; EE projects must achieve a minimum of 10% efficiency gains over existing conditions
	Tax Credit	Renewable Energy Sales and Use Tax Exemption	2006	75% exemption
West Virginia	N/A	N/A	N/A	N/A
Wisconsin	Public Benefit Funds	(0-point to loan, rebate, PACE) Focus on Energy	2007	investor owned utility is required to spend 1.2% of the latest 3-yr average of its gross operating revenue on EE/RE programs.
	Commercial PACE	City of Milwaukee - Energy Efficiency (Me2) Business Financing (PACE)	2011	Clean Energy Financing Program repay property owners' improvement costs over 10-20 yrs.
	Rebate	Renewable Energy Competitive Incentive Program	2012	maximum $250,000 for businesses on woody biomass, biogas etc.,
		City of Madison - Green Madison Business Incentives	2012	$0.10/kWh savings, $300/kW savings, $1/therm savings from EE improvements in businesses;

		Multifamily Energy Savings Program	2012	Rewards exceeding $10,000-$200,000 for one-for-one replacements or substitutions for specific equipment. Rewards up to $400,000 for efficiency improvements
	Loan	City of Milwaukee - Small Business Energy Efficiency (Me2) Program	2012	Milwaukee EE (Me2) & Focus on Energy Small Business Program provides financings to help small businesses afford EE projects b/w $5000 and $20000; eligible size less than 100kW
	Tax Exemption	Renewable Energy Sales Tax Exemptions	2011	100% sales and use tax exemption for biomass
Wyoming	N/A	N/A	N/A	N/A

Appendix III. Correlation Matrices

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             | TotalC~P Policy~e CoalSh~e  NGShare NucShare  REShare TotalGen CoalPr~e AvrEle~e  NGPrice Person~a Wagean~t CO2per~a
-------------+---------------------------------------------------------------------------------------------------------------------
TotalCHPCa~P |   1.0000
 PolicyScore |  -0.1057   1.0000
   CoalShare |  -0.0316  -0.2460   1.0000
     NGShare |   0.1232  -0.0852  -0.0181   1.0000
    NucShare |  -0.0441   0.1263  -0.3068  -0.3622   1.0000
     REShare |  -0.0367   0.1698  -0.4658  -0.4446  -0.1915   1.0000
    TotalGen |   0.1177  -0.0402   0.3455   0.4695  -0.3060  -0.4075   1.0000
   CoalPrice |  -0.0889   0.4993  -0.2241  -0.1533   0.2239   0.1439  -0.1431   1.0000
AvrElecPrice |  -0.0964   0.5911  -0.3397  -0.1678   0.1695   0.2693  -0.1673   0.5049   1.0000
     NGPrice |  -0.1212   0.3699  -0.1448  -0.2381   0.0854   0.3453  -0.2369   0.2774   0.7301   1.0000
PersonalIn~a |  -0.1378   0.6427  -0.2072  -0.1661   0.1633   0.1171  -0.0290   0.5381   0.6098   0.4219   1.0000
Wageandsal~t |   0.0190   0.2881  -0.0628   0.0404   0.2041  -0.1767   0.3060   0.0963   0.1167  -0.0425   0.1070   1.0000
CO2percapita |   0.0998  -0.3071   0.4990   0.2412  -0.3491  -0.4306   0.5626  -0.2454  -0.2919  -0.2763  -0.1572  -0.2556   1.0000
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             | TotalC~P Energy~n Enviro~g Interc~d NetMet~g EEPort~d REPort~d Utilit~y RETaxC~t TaxExe~n CoalSh~e  NGShare NucShare
-------------+---------------------------------------------------------------------------------------------------------------------
TotalCHPCa~P |   1.0000
EnergyClim~n |  -0.0787   1.0000
Environmen~g |  -0.0202   0.2761   1.0000
Interconne~d |  -0.0812   0.4624   0.4268   1.0000
 NetMetering |  -0.0546   0.1869   0.0325   0.2142   1.0000
EEPortfoli~d |  -0.0347   0.4851   0.3193   0.4510   0.2887   1.0000
REPortfoli~d |  -0.0571   0.4115   0.2035   0.3705   0.1827   0.4627   1.0000
UtilityRat~y |  -0.0335   0.2858   0.3753   0.3063   0.0345   0.3090   0.1717   1.0000
 RETaxCredit |  -0.0802   0.3687   0.0446   0.2476  -0.0506   0.1862   0.2297   0.2878   1.0000
TaxExemption |  -0.0684   0.1569  -0.0899   0.1613  -0.0028   0.1809   0.1718  -0.0230   0.4076   1.0000
   CoalShare |  -0.0316  -0.1269  -0.1956  -0.1065  -0.1302  -0.1689  -0.1284  -0.1399  -0.0139  -0.0249   1.0000
     NGShare |   0.1232  -0.0688   0.0152  -0.0405  -0.0657   0.0257   0.0122  -0.0921   0.0616   0.0637  -0.0181   1.0000
    NucShare |  -0.0441   0.1134  -0.0249   0.1217  -0.0312   0.0107   0.0974   0.1148   0.0522   0.1017  -0.3068  -0.3622   1.0000
     REShare |  -0.0367   0.1175   0.1204   0.0219   0.2653   0.1239   0.0407   0.0731  -0.0834  -0.1502  -0.4658  -0.4446  -0.1915
   CoalPrice |  -0.0889   0.4114   0.3179   0.4313   0.2223   0.2426   0.2991   0.2235   0.1799   0.0716  -0.2241  -0.1533   0.2239
AvrElecPrice |  -0.0964   0.4046   0.3149   0.4110   0.2701   0.3923   0.4258   0.5082   0.1729   0.0751  -0.3397  -0.1678   0.1695
     NGPrice |  -0.1212   0.2944   0.0866   0.2850   0.2549   0.2392   0.3336   0.3196   0.1383   0.0334  -0.1448  -0.2381   0.0854
PersonalIn~a |  -0.1378   0.4417   0.3129   0.5090   0.3357   0.3882   0.4842   0.3173   0.2233   0.1000  -0.2072  -0.1661   0.1633
Wageandsal~t |   0.0190   0.0680   0.4398   0.3092  -0.1605   0.2370   0.0561   0.3905   0.1144   0.0320  -0.0628   0.0404   0.2041
CO2percapita |   0.0998  -0.2254  -0.1548  -0.1315  -0.0598  -0.2305  -0.1740  -0.1709  -0.1169  -0.1015   0.4990   0.2412  -0.3491
```

```
             |  REShare CoalPr~e AvrEle~e  NGPrice Person~a Wagean~t CO2per~a
-------------+---------------------------------------------------------------
     REShare |   1.0000
   CoalPrice |   0.1439   1.0000
AvrElecPrice |   0.2693   0.5049   1.0000
     NGPrice |   0.3453   0.2774   0.7301   1.0000
PersonalIn~a |   0.1171   0.5381   0.6098   0.4219   1.0000
Wageandsal~t |  -0.1767   0.0963   0.1167  -0.0425   0.1070   1.0000
CO2percapita |  -0.4306  -0.2454  -0.2919  -0.2763  -0.1572  -0.2556   1.0000
```

```
             | TotalC~t Policy~e CoalSh~e  NGShare NucShare  REShare TotalGen CoalPr~e AvrEle~e  NGPrice Person~a Wagean~t CO2per~a
-------------+---------------------------------------------------------------------------------------------------------------------
TotalCHPCo~t |   1.0000
 PolicyScore |   0.3117   1.0000
   CoalShare |  -0.1217  -0.1836   1.0000
     NGShare |  -0.0293  -0.0303  -0.0616   1.0000
    NucShare |   0.0851   0.1374  -0.3254  -0.3417   1.0000
     REShare |  -0.0455   0.0843  -0.4832  -0.4542  -0.1438   1.0000
    TotalGen |   0.0930  -0.0193   0.2925   0.4726  -0.3114  -0.4357   1.0000
   CoalPrice |   0.1610   0.4810  -0.2644  -0.1401   0.2214   0.1580  -0.1089   1.0000
AvrElecPrice |   0.2774   0.6202  -0.3102  -0.1079   0.2152   0.1726  -0.1265   0.5261   1.0000
     NGPrice |   0.0734   0.5374  -0.1412  -0.1903   0.1220   0.2748  -0.1994   0.3271   0.7434   1.0000
PersonalIn~a |   0.1811   0.7271  -0.1574  -0.0494   0.1760   0.0273  -0.0022   0.4216   0.6303   0.6215   1.0000
Wageandsal~t |   0.5981   0.2587  -0.0491   0.0440   0.1908  -0.1853   0.3208   0.1092   0.1785   0.0255   0.1616   1.0000
CO2percapita |  -0.1231  -0.1952   0.4533   0.2483  -0.3465  -0.4345   0.5221  -0.2430  -0.2432  -0.2250  -0.0618  -0.2405   1.0000
```

```
             | TotalC~t Energy~n Enviro~g Interc~d NetMet~g EEPort~d REPort~d Utilit~y RETaxC~t TaxExe~n CoalSh~e  NGShare NucShare
-------------+---------------------------------------------------------------------------------------------------------------------
TotalCHPCo~t |   1.0000
EnergyClim~n |   0.1413   1.0000
Environmen~g |   0.3958   0.3281   1.0000
Interconne~d |   0.2622   0.5466   0.4705   1.0000
 NetMetering |  -0.0109   0.2511   0.0952   0.3085   1.0000
EEPortfoli~d |   0.2034   0.5469   0.3689   0.5412   0.3318   1.0000
REPortfoli~d |   0.0785   0.4952   0.2731   0.5023   0.2693   0.5417   1.0000
UtilityRat~y |   0.4926   0.3242   0.3989   0.3486   0.0829   0.3463   0.2274   1.0000
 RETaxCredit |   0.0858   0.4001   0.1001   0.3286   0.0424   0.2521   0.3024   0.2978   1.0000
TaxExemption |  -0.0336   0.2397  -0.0205   0.2775   0.0890   0.2638   0.2718   0.0288   0.4236   1.0000
   CoalShare |  -0.1217  -0.1021  -0.1437  -0.0932  -0.1466  -0.1293  -0.1051  -0.1047  -0.0046  -0.0337   1.0000
     NGShare |  -0.0293  -0.0300   0.0238   0.0014  -0.0370   0.0384   0.0326  -0.0592   0.0453   0.0630  -0.0616   1.0000
    NucShare |   0.0851   0.1093   0.0006   0.1219   0.0507   0.0377   0.1026   0.0999   0.0835   0.0979  -0.3254  -0.3417   1.0000
     REShare |  -0.0455   0.0631   0.0737  -0.0096   0.1848   0.0665   0.0065   0.0433  -0.0814  -0.1163  -0.4832  -0.4542  -0.1438
   CoalPrice |   0.1610   0.4097   0.3168   0.4330   0.2380   0.2737   0.3275   0.2290   0.2016   0.1225  -0.2644  -0.1401   0.2214
AvrElecPrice |   0.2774   0.4457   0.3388   0.4856   0.3309   0.4390   0.4821   0.4819   0.2251   0.1699  -0.3102  -0.1079   0.2152
```

```
     NGPrice |   0.0734   0.3988   0.1836   0.4591   0.3467   0.3634   0.4637   0.3395   0.2454   0.1797  -0.1412  -0.1903   0.1220
PersonalIn~a |   0.1811   0.4911   0.3364   0.6290   0.4154   0.4725   0.5705   0.3046   0.3247   0.2806  -0.1574  -0.0494   0.1760
Wageandsal~t |   0.5981   0.0848   0.3570   0.2602  -0.0779   0.2091   0.0833   0.3177   0.1451   0.0536  -0.0491   0.0440   0.1908
CO2percapita |  -0.1231  -0.1556  -0.1113  -0.0778  -0.0475  -0.1582  -0.1123  -0.1253  -0.0831  -0.0688   0.4533   0.2483  -0.3465

             |  REShare CoalPr~e AvrEle~e  NGPrice Person~a Wagean~t CO2per~a
-------------+---------------------------------------------------------------
     REShare |   1.0000
   CoalPrice |   0.1580   1.0000
AvrElecPrice |   0.1726   0.5261   1.0000
     NGPrice |   0.2748   0.3271   0.7434   1.0000
PersonalIn~a |   0.0273   0.4216   0.6303   0.6215   1.0000
Wageandsal~t |  -0.1853   0.1092   0.1785   0.0255   0.1616   1.0000
CO2percapita |  -0.4345  -0.2430  -0.2432  -0.2250  -0.0618  -0.2405   1.0000
```