UNIVERSITY OF BERGEN
*Department of Administration and Organization Theory*

# AORG351

**Master`s Thesis in Administration and Organizational Science**

# Carbon Pricing and Induced Small Business Innovation in California

## How the Global Warming Solutions Act Impacted Entrepreneurial Opportunities in Green Energy

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## Glossary of Acronyms

**Laws and Programs:**
ARRA – American Recovery and Reinvestment Act (2009)
EU-ETS – European Union Emissions Trading System
GGRF – Greenhouse Gas Reduction Fund
GWSA – Global Warming Solutions Act (2006) (also as AB 32)
SBIR/STTR – Small Business Innovation Research / Small Business Technology Transfer

**Government Agencies:**
CEC – California Energy Commission
CalEPA – California Environmental Protection Agency
CARB – California Air Resources Board
CAT – Climate Action Team
CPUC – California Public Utilities Commission
IPCC – Intergovernmental Panel on Climate Change
US-EPA – United States Environmental Protection Agency (also as just EPA)

**Technical Terms:**
CHP – Combined Heat and Power (also referred to as “cogeneration”)
GDP – Gross Domestic Product
LLC – Limited Liability Company

**Greenhouse Gases:**
CO2 – Carbon Dioxide
CH4 – Methane
N2O – Nitrous Oxide
SF6 – Sulfur Hexafluoride
HFC – Hydrofluorocarbons
PFC – perfluorocarbons
GHG – Green House Gases
MMTCO2e – Megatons CO2 Equivalent

**Other Pollutants:**
CFC – Chlorofluorocarbon
SO2 – Sulfur Dioxide

**Key Carbon Pricing Programs**

**European Union Emissions Trading System –** (EU-ETS) a cap-and-trade policy for the EU that has been operational since 2005.

**Global Warming Solutions Act (2006) –** (GWSA or AB32) is a California Law that established a cap-and-trade system for CO2 emissions in that state.

**Regional Greenhouse Gas Initiative –** (RGGI) a cap-and-trade type policy coordinated between ten states in the northeastern US.

**British Columbia Carbon Tax –** a carbon tax policy for the province of British Columbia, Canada.

**Energy Saving and Emission Reduction Plan –** (ESER) an environmental policy included in the past three Five Years Plans in the People's Republic of China that includes beneficial taxation schemes for economic activities that are deemed as "low emission" and pilot emissions trading systems in large Chinese cities.

**Dedication and Acknowledgements**

This Master's Thesis is dedicated to Mr. Pat Hughes for the lifelong encouragement to explore innovative ways to tackle the world's impossible problems, and to Prof. Michael Barnhart for inspiring me to find common ground with those who would rather see me dead than successful.

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**Abstract**

This is a study of the California Global Warming Solutions Act (GWSA) and the related laws passed to support it. The GWSA established a whole-economy cap on greenhouse gas emissions and established a series of emissions allowances which can be traded between companies and individuals on the private market. Using Limited Liability Company (LLC) registration data across 80 economic quarters spanning the years 1996-2016 inclusive, this study sought to test the theory that establishing a price on carbon emissions will induce innovation within the energy sector.

This study was conducted as a time-series observation study of the rate of successful new LLCs registered in either the green energy or carbon energy industries, controlled for the historic failure rate of businesses and specific federal and state grants such as funding through the Million Solar Roofs program, or the American Recovery and Reinvestment Act. The study found that there was a substantial increase, both in the raw number and in proportion of total new businesses, of successful green energy businesses after the passage of the GWSA. However, most of the new green energy LLCs were solar energy companies, which were likely bolstered by the US$3 billion in tax incentives and other subsidies from the Million Solar Roofs program. When non-solar green energy companies were regarded separately, the study found that the GWSA had only a modest positive impact on inducing small business innovation. This study concludes that a carbon price alone will probably not be sufficient to induce innovative solutions to achieve carbon neutrality goals, unless the revenues collected are used to directly subsidize green energy implementation.

## Chapter 1: Introduction

This thesis was written to explore the impact of carbon pricing policies passed by sub-national governments in North America on innovation, entrepreneurship, and the livelihood of citizens in those regions. As national and super-national governments struggle to pass comprehensive and effective policies to address climate change, there has been a growth in the number of individual cities and provinces passing their own climate legislation. This has been common in countries like the United States where partisan gridlock and disagreement over the nature and extent of human-made climate change in the federal government has to-date stifled a national-scale decarbonization effort.

In this chapter I will explain the problem I am addressing and my motivation for doing so, provide an overview of the history of carbon pricing policies in North America and beyond, state my research questions and variables to be tested before concluding the section with an outline of the structure for the rest of the study.

### 1.1 Statement of the Problem

It is impossible to tune into current events today without being confronted by the existential crisis of global climate change and its effects on everyday life. In 2020 alone, historic fires have ravaged Australia, Siberia, and the United States, destroying thousands of homes and killing hundreds of thousands of endangered animals; a record-breaking number of tropical cyclones formed in the North Atlantic Ocean, with the worst storms causing billions of dollars in damages (Podlaha et. al, 2020); and monsoon flooding in South-east Asia has destroyed crops and livestock, threatening food shortages in a region with a high population (Hollingsworth, 2020).

These issues are most keenly felt by the younger generations. In 2017, the Global Shapers Survey processed questionnaires from 25,000 people ages 18 to 35 from across the globe and found that a plurality of respondents (48.8%) believed Climate Change to be the most serious issue affecting the world today. Perhaps more frighteningly, a majority of respondents (55.9%) believe their views are not being considered during governmental decision-making processes

(Brodie, 2017). This is fueling disenchantment with liberal values such as democracy (Tidey, 2020) and capitalism (Riechers, 2019) that are the cornerstones of the current, historically peaceful, world order. Extremist voices on both the left and right in democratic nations have seized on these attitudes as well as new forms of media to grow their ranks, weaken democratic institutions, and encourage political violence. A recent survey showed a surprising and rapid increase in the number of US voters on both the left and the right who think political violence is justifiable (Kalmoe, 2020). This trend was shockingly demonstrated on January 6, 2021 when an insurrectionist mob stormed the US Capitol to attempt to stop legislature from certifying election results; the first time since 1860 that there was not a peaceful transition of presidential power in the world's most stable democracy.

Illiberal nations have also used the climate crisis to establish themselves as global leaders. Chinese President Xi Jinping drew a sharp contrast between himself and Former US President Donald Trump at the 2020 UN General Assembly gathering by promising to stop the growth of $CO_2$ emissions before 2030, and to have the world's largest country carbon neutral by 2060, to generally favorable reception (McGrath, 2020). The risk here is self-evident. At a time when skepticism of liberal values is high and increasing, an authoritarian superpower proving itself better positioned to address issues of concern to the global population while the so-called "leader of the free world" openly denies there is a problem at all could dramatically shift the world order towards one with little regard for human rights.

Thus, solutions to climate change must not only solve the issue of decarbonizing the economy to prevent extreme weather, collapsing ecosystems, food insecurity, and air pollution. They must also reinvigorate faith in market economies and democracy by increasing material wealth of the whole population and empowering citizens to make decisions for themselves that will have a noticeable positive impact on their well-being. Although this seems like a tall order, several policy proposals have been put forward in the last few decades that could achieve these goals. One such is carbon pricing.

### 1.2 Motivation for the Study

I was fortunate to grow up in a world where democracy and capitalism were expanding, new technologies were bringing the world together, and prosperity was growing at unparalleled rates, allowing people the freedom to innovate. Through intelligent, bi-partisan policy decisions, the commercial Internet flourished and expanded at breakneck speeds, conveniently cataloging the whole of human knowledge and making it available to the masses. New companies went from dorm-room pet projects to household names seemingly overnight. Most critically, there was optimism for the future. Millions were being lifted out of extreme poverty worldwide every year, and countries were finally working together in unprecedented ways to address environmental issues – from reducing ozone-destroying CFCs and acid-rain generating SO2 to international summits such as Kyoto addressing the much larger problem of climate change.

In the last 20 years, though, a coalition of ideological opponents to liberalism, and populations that felt disenfranchised or abandoned by the sweeping societal changes of the late 20$^{th}$ century, have worked to undermine capitalism, stifle innovation, and roll back democratic values. For their part, the proponents of liberalism have largely failed to portray how their policies work and benefit the typical voter. Those who support carbon pricing policy as a driver of economic innovation, from academics like economist William Nordhaus to politicians like former California Governor Arnold Schwarzenegger, make a strong case for it in the abstract. There has been plenty of "real world" research on the impact of such policies on whole industries and large firms, but perilously little on the opportunities such policies present to average citizens outside of broad metrics such as jobs numbers. Thus, it is too often unclear how well, if at all, the theory translates into reality for the median voter. My goal as a researcher is to provide a critical assessment of one such policy so that its effects may be understood more fully, and lawmakers can make informed decisions about these policies as potential solutions to the climate crisis.

### 1.3 History of Carbon Pricing Initiatives in North America and Beyond

Prior to 1990, the idea that pollution could be reduced by fixing a cost to it was strictly academic, with support from economists on both right and left (Rabe, 2019: 5). The first such policies to be signed into law were aimed at sulfur-dioxide (SO2), an industrial pollutant that was making rain acidic and damaging both the environment and human-made structures. The Clean Air Act Amendments, signed into law by US President George H.W. Bush in 1990 established, among other things, a cap-and-trade program for SO2. The cap-and-trade program established an economy-wide budget for SO2 emissions and allowed polluting companies to negotiate for reductions[1].

The Clean Air Act Amendments served as the inspiration for the EU Emissions Trading System, which launched in 2005 and was the first successful multi-national cap-and-trade system specifically designed to reduce CO2. Cap-and-trade legislation for CO2 was also introduced to the US Congress several times in the 1990s and early 2000s, but none ever became law. Cap-and-trade policy for CO2 also failed to gain traction in the Canadian Parliament. However, despite the setbacks at the national level, 23 US states and 4 Canadian provinces either adopted CO2 cap-and-trade policies, or laid groundwork to implement them in the future during this time (Rabe, 2019: 45).

California governor Arnold Schwarzenegger signed the Global Warming Solutions Act[2] (GWSA) into law on September 27, 2006, vaulting California to the spotlight on the international stage for being a leader in climate change policy. The initial goal of this legislation was to reduce California's whole-economy CO2 emissions to 1990 levels[3] by the year 2020 with further goals of reducing it 40% below 1990 levels by 2030 (CARB, 2015). The GWSA regulates seven types of Greenhouse Gases across the economy through a combination of traditional regulations and market-based approaches. The Climate Action Team (CAT) was created by executive order and loops eighteen state agencies under the umbrella of the GWSA to ensure emissions targets are met and industry and government both have the support and resources to achieve these goals.

Following on the heels of California, the Canadian province of British Columbia instituted a carbon tax in 2008 covering roughly 70% of its economy. The tax started low, C$20/tonne of

[1] for example, by purchasing offsets from the government or another company.
[2] also referred to as AB 32, the ID number given to the bill in the California State Assembly, and by its acronym GWSA.
[3] Set to 431 megatons of CO2 equivalent.

$CO_2$, and was raised incrementally to its present-day rate of C$40/tonne of $CO_2$. Unlike the GWSA which uses the fees it collects to fund further regulations and public utility projects, British Columbia's carbon tax provides a Climate Action Tax Credit to every citizen (British Columbia, 2020).

In 2019, the Pan-Canadian Approach to Pricing Carbon Pollution went into effect across Canada. This plan sets minimum standards for individual provinces to develop their own carbon pricing plans while levying a federal tax on the residents and businesses located in those which do not develop their own plans. The "backstop" price set by the Canadian government was CA$50/ton of $CO_2$ equivalent (World Bank Group, 2020). Proceeds from this tax are returned as dividends to Canadian taxpayers to alleviate the increased costs of carbon-based fuels. At the time of writing, five provinces have their own policies on-line while the others have acquiesced to the federal tax (Government of Canada, 2019).

In 2020, the government of Mexico embarked on a three-year carbon emissions trading pilot impacting just shy of 40% of the national economy to stress test the design of the policy ahead of a full launch (World Bank Group, 2020).

Outside of North America, carbon pricing has found significant success in Europe, especially Nordic countries, with Finland and Sweden adopting carbon taxes in 1990, followed by Norway in 1991, and Denmark in 1992. Carbon taxation programs were also adopted in the Netherlands, Slovenia, Germany, and the United Kingdom in the late 1990s and early 2000s. As mentioned above, the EU-ETS went online in 2005. Despite some early mismanagement and insufficiently high market pricing in the early phases of the program rendering it largely ineffective as a pollution control tool, it has ultimately proven to be both a resilient and successful tool in reducing the carbon-intensity of the European economy[4]. Further, non-EU nations like Switzerland, Liechtenstein, Luxembourg, Norway, and the United Kingdom have either aligned or plan to align their own ETS markets with the EU's strengthening the legitimacy of those systems.

[4] In 2019, emissions from EU-ETS covered facilities dropped 9.1% (European Commission, 2020)

The People's Republic of China established the Energy Saving and Emission Reduction (ESER) plan as part of its 11th Five-Years-Plan in 2006 in an effort to decouple China's explosive economic growth from its pollution output. While much of the ESER focuses on strengthening traditional forms of environmental legislation, it also prominently features a reduction (or elimination) of tax rebates for exporter companies deemed to be high pollution or high energy consumption firms (Wang and Chen, 2010). This can be treated as a carbon tax because of the way it increases production costs on polluters at a set rate. Starting in 2013, China also began pilot programs for an emissions trading system of their own in cities around the country, perhaps most noteworthily in the Yangtze River Delta, to study the impacts and learn best practices for a forthcoming nation-wide system (World Bank Group, 2020: 11).

With South Africa's national carbon tax going into effect in 2019, there now exists some form of carbon pricing on every continent. As of fall of 2020, there is carbon pricing in 31 countries covering in total roughly 22% of global CO2 emissions. In 2019 these programs collectively raised nearly US$45 billion in revenues despite more than half of all covered outputs being taxed at less than US$10/ton CO2 equivalent, which is far lower than what most experts believe is the optimal rate to be to achieve the Paris Climate Agreement goals (World Bank Group, 2020: 20). This indicates that these policies will be incredibly lucrative for governments and – for those nations which adopt a climate dividend – a powerful wealth redistribution tool.

The COVID-19 pandemic has delayed the implementation or expansion of many carbon pricing policies worldwide, to avoid stressing the already burdened world economy. There is a real risk, as we saw during the economic downturn of 2007-9, for carbon pricing to fall out of favor among stakeholders again. However, the sharp reduction of travel and associated pollution has also sparked a renewed interest in climate legislation across the world. Therefore, it is vital that political scientists turn their attention to the economic and social impact of carbon pricing in areas already under such regimes, so that policymakers have the analyses needed to fine tune policies moving forward into the 2020s.

**1.4 Research Questions:**

Is there evidence that California's carbon cap-and-trade might have induced small business innovation in bringing green energy products to market viability?

*Subquestions:*

1. Which power sources (ex. Solar, natural gas), saw the biggest expansion in innovation, if any?
2. Which power sources saw the biggest decrease in innovation, if any?
3. Is there evidence that other state and federal legislation might be correlated to expanded innovation in California?

**1.5 Hypothesis**

This Masters Thesis will test the hypothesis that a carbon pricing policy can spur economic innovation while also reducing $CO_2$ emissions. This is a relatively new field of study, with the idea that a price on carbon first being pioneered in the 1980s by economists, although theories that government can induce desirable societal change through policy dates back many decades before that. The theory behind taxation spurring innovation will be explored in Chapter 2 of this thesis.

**1.6 Units of Analysis**

In order to test the hypothesis, I will be looking predominantly at the change in the number of successful new businesses registered within the energy industry. This will be achieved through three layers of analysis in increasing detail: the proportion of new energy businesses relative to all new businesses across the study period, the proportion of new "Green" energy businesses relative to all new energy businesses across the study period, and the proportion of new "Green" energy businesses across individual sources of energy (ex. Solar, Wind). In order to focus this study more towards how these policies present opportunities to average citizens, I chose to focus on the registrations of a specific type of business, the Limited Liability Company (LLC). This is due to its tax and legal structure, which is the best, if imperfect, measure of middle-class innovation available when looking at entrepreneurship. The reasons for this will be elaborated on further in Chapter 3.

**1.7 Significance of Study**

The study of carbon pricing as a mechanism to spur innovation is a field that has only recently developed as interest in decarbonization across the globe has increased. In April 2021, US President Joe Biden released a detailed statement committing to a 50% reduction in greenhouse gas emissions[5] by 2030, including an ambitious investment in blue collar jobs[6] and research and development (The White House, 2021). While the plan itself makes no mention of a carbon tax, US Climate Envoy John Kerry (McCormick, 2021) and US Treasury Secretary Janey Yellen (Geman, 2021) have both indicated Biden supports a carbon price to help pay for his program. This comes on the heels of the government of Canada instituting its own carbon tax in 2019. Policymakers in these countries should be working with political scientists to try to develop a complete picture of the impact of these ambitious targets and look to understand how to raise the revenues needed for their investment goals. Understanding how carbon pricing and investment of those revenues impacted entrepreneurship in a North American context, such as this study of the California Global Warming Solutions Act aims to, will be vital for policymakers to make these ambitious climate targets a reality.

**1.8 Structure for the Rest of the Study**

Chapter 2 will cover the theoretical underpinnings of carbon taxation and policy-induced innovation in the private sector before establishing the specific definitions of terms used throughout this thesis and concluding with a review of other studies on the effects of carbon pricing policy. Chapter 3 will establish how this study will select its cases, measure its variables, and establish both internal and external validity. It will also discuss in detail the procedures used to prepare the dataset for testing. This chapter will provide the reader background on the

[5] Measured by the output in 2005.
[6] Blue-collar work is a nebulous phrase, but in this context typically refers to jobs in the skilled trades, such as construction.

different environmental laws passed in California, and at the federal level, as well as information on how California's energy market works. Chapter 4 will discuss the details of the data this study will use to draw its conclusions, where it is sourced from, and the results of the cleaning procedures detailed in Chapter 3, as well as quirks in the data that must be adjusted for. Chapter 5 will discuss the testing of the hypothesis and the results of those tests by looking at trends within the California LLC market. Finally, Chapter 6 will draw final conclusions on the hypothesis and provide suggestions for follow-up studies.

Citations will follow the MLA8 standard and be found in-text in parentheses. Throughout this thesis I will include footnotes for clarifications or asides that are not strictly necessary for understanding the core concepts of the thesis but nonetheless may provide useful context for readers unfamiliar with the study area.

## Chapter 2: Theoretical Framework and Literature Review

Chapter 2 will start by defining technical terms as they will be utilized for this thesis, establishing also the ontological and epistemological frameworks for this study. Next it will provide an overview of the theory of carbon pricing and how it relates to induced innovation, as well as an alternative theory of how government directly funds innovation in ways that are overlooked by economic theories on induced innovation. Then it will present a review of previous studies done on existing carbon pricing programs to provide context as to where this master's thesis will sit within the body of political science work on this topic. Chapter 2 will conclude by establishing the specific hypotheses this thesis will test.

### 2.1 Use of Theories and How They Connect to This Study

Since most of the theories behind carbon pricing policies are borne from economics, which often prefers to think of individuals and institutions as fully rational actors, I have chosen to take a rationalist approach to studying the real-world impacts of such policies. Rationalism "is a normative and a descriptive model that speaks to how governments should thoroughly plan and critically analyze each policy decision, in terms of clearly stated objectives, goals, and outcomes.

Once decisions are taken, the subsequent program activity associated with the policy decision must be evaluated and analyzed." (Mills et al., 2012: 118).

From its inception, California's Global Warming Solutions Act (GWSA) was framed in rationalist ways. According to a 2006 press release on the legislation, "the emissions limit will stimulate new business opportunities, and provide new 'clean-tech' jobs" with one such entrepreneur quoted as saying "'venture capitalists and entrepreneurs are waiting for the market signal that now is the time to invest and innovate.'" (EDF, 2006) As you can see, advocates for this policy were making the assumption that business owners and investors were rational actors waiting for the right conditions to take financial risks. As such, it is sound practice to test the outcomes of this policy in the same manner.

After establishing key definitions for terms I will be using throughout this theses, I will look at why Governor Schwarzenegger and his allies framed their support for the GWSA in this manner. To do so, I will provide an overview of two key concepts -- carbon taxation and induced innovation -- that provide the theoretical underpinning for the passage of this law. These theories are both rooted deeply in the field of economics, but there has been little concrete political science study of these policies as they have only just begun to be adopted by governments worldwide. This section will touch on the work of economists like William Nordhaus who pioneered the idea of pricing the effects of climate change into economic models, and the political science work of researchers like Barry Rabe.

From there I will explore the theoretical backing to the idea that carbon taxation can be a driver of innovation, called "induced innovation." I will provide a brief overview of the economic theory first posited by Hicks, with looks at other key works from Kennedy, Nordhaus, and Atkinson and Stiglitz, before moving to a deeper theoretical economic study specific to carbon taxation by Wang et al (2019). Following this, I will discuss the alternate theory of government as an entrepreneur that does more than just correct market failures in order to progress ideas through the innovation chain and to market, discussing some of the work of Marianna Mazzucato and a case study on the Port of Rotterdam. Next, I will provide an overview of studies done to measure the impacts of carbon pricing policies including economic studies on carbon pricing policies in North America, Europe, and China, and studies on the impact to $CO_2$ emissions rates of carbon pricing policies to provide context for where this thesis fits within the growing body of work in this field. Using these theories and previous experiments, I will establish a hypothesis to test in this study.

### 2.2 Critical Definitions

**Carbon Pricing –** any policy that applies a price per unit penalty on the emission of $CO_2$ (and in some cases other greenhouse gas emissions) by polluters. There are two primary ways by which this price is determined – either through government policy directly setting it (Carbon Tax) or allowing market forces to determine the price (Cap-and-Trade). Carbon pricing is typically measured in a currency amount per carbon dioxide weight in tons (Nordhaus, 2007: 30).

**Carbon Tax –** a policy passed by the government that sets a monetary cost for emitting carbon dioxide or other greenhouse gasses into the atmosphere and collects money from polluters. This operates in a similar fashion to sales tax, where it is only levied on a particular activity. Often it is easiest for governments to tax companies and allow them to distribute the cost of the tax to the customers through price increases, though in some cases, such as with gasoline taxes, the government collects the tax at the point of sale instead.

**Cap-and-Trade –** According to the World Resources Institute a “Cap-and-Trade” system operates differently from a carbon tax because in this system, the government sets a specific limit called a cap on $CO_2$ emissions and allows companies that have polluted less than the limit to sell “carbon credits” on an open market to other companies (Metzger, 2008). In a Cap-and-Trade system, the price of carbon is not set by the government, but instead fluctuates based on the laws of supply and demand. Cap-and-Trade pricing systems for $CO_2$ emissions are typically based on the United States’s 1990 Clean Air Act, meant to reduce $SO_2$, and was widely regarded as successful in its goal (Rabe, 2018: 5).

**Provincial/State Government –** the United States and Canada are comprised of a tightly-knit federation of individual territories that operate as semi-sovereign entities, but are ultimately tied together by the supreme power of the national government. These units are called “Provinces” in Canada and “States” in the US. Provinces/States have less power than national governments, but often pass legislation that is different, or in direct opposition to, the national government, allowing quite a bit of variation in laws depending on which area of a country a person lives.

**Innovation –** Baregheh et al (2009), based on an extensive literature review of over 60 academic papers on the nature of innovation, define innovation as “the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace.” (Baregheh et al, 2009: 1334). This definition encompasses six key pillars: a systematic methodology by which innovation is created and adopted, the social entity (organizations, individual actors, teams/groups, etc.) employing this process, the means by which they are able to create and adopt innovation (technological advances, ideas, a consumer demand), the nature of the innovation itself (how it improves upon or solves a problem), the type of innovation (a new product or service), and the aim of the innovation (solve a problem, differentiate from similar innovations by competitors). This definition will be more concretely operationalized in Chapter 3.

**Induced Innovation –** Innovation that is created, encouraged, or otherwise subsidized by governmental policy. More discussion on this can be found further on in Chapter 2.

**Energy Category –** for brevity’s sake, this paper will classify energy as two broad categories, either “Green” or “Carbon”, depending on fuel type.

**Green Energy –** There is, unfortunately, no concrete definition for what constitutes “green” energy among scientists or policymakers, as all energy sources have some negative impact on the environment. Since this study is about a set of policies that specifically targets greenhouse gases, it will use the most straightforward definition for Green Energy: energy that is produced without byproducts that will be taxed under a carbon emissions tax. The specific energy sources that are considered Green Energy for the purpose of this study will be discussed further in Chapter 3.

**Carbon Energy –** The antonym for Green Energy as discussed above. Carbon Energy will be considered all energy sources that produce greenhouse gases as byproducts that will be taxed under a carbon emissions tax. Specifics will be discussed in Chapter 3.

**Fuel Type –** The specific fuel that is used to generate electricity (ex. Solar, natural gas). Each energy type will be classified based on the fuel type they specialize in. Table 3.1 details how the fuel types were used to categorize companies.

### 2.3 Carbon Pricing Theoretical Overview

Market based solutions like carbon pricing are widely considered by both scientists (Rosenberg et al., 2009) and economists (Sylvan, 2015) to be an effective and efficient means of reducing pollution with minimal impact to economies. There are two primary ways to price carbon for the purpose of controlling emissions. Governments may control CO2 either through a price approach whereby a carbon fee (or tax) is levied for emissions and emissions rates will naturally decrease to a point where the costs of emission reduction are balanced with the benefits, or through a quantitative approach where governments choose the acceptable rate of emissions in tons of CO2 and allow a market to develop for emissions permits (Nordhaus 2007: 30). This is commonly referred to as cap-and-trade.

A key benefit of carbon pricing programs is the way in which they frame CO2 emissions in terms of budgets. The concept of a ‘carbon budget’ is gradually gaining mainstream acceptance, starting with the publication of the IPCC’s Fifth Assessment Report which reframed how policymakers should approach climate goals. Instead of focusing goals on more esoteric metrics like global temperature gain or atmospheric concentration that tracks to an “acceptable” level of warming that finds the economic balance between catastrophic climate change and the heavy costs of mitigating it, the IPCC instead creates a “carbon budget” which represents the cumulative CO2 emissions of all human activity and sets a definitive cap at which all human activity must have a net-zero carbon output to avoid catastrophic climate change (Lahn, 2020). This type of framing allows policy-makers to more easily identify the ideal price for emissions, because it measures exactly how much of the resource (in this case carbon output) remains.

A Carbon Tax is, at its core, an excise tax just like other “sin taxes” on products like alcohol and tobacco which have been effectively implemented by governments to reduce consumption. These types of taxes can be traced back to economist Adam Smith who posited that a government could increase the price of goods by applying a tax to them (Rabe, 2018: 2). Taxes of this sort specifically designed to stop negative externalities[7], such as the carbon tax, were first theorized by economist Arthur Pigou in 1920. They function as a price correction mechanism for “the divergence between ‘social and private net product’, for example production activities generating smoke from factory chimneys that create adverse consequences for consumers in the form of damage to buildings[…]” (Sandmo, 2008). Put more simply, the money raised from the tax on pollution would be used by the public to offset the costs of the damage caused by pollution incurred by those who were not directly responsible for the pollution.

The Nobel winning economist William Nordhaus pioneered the idea of specifically pricing carbon emissions as a way to address the negative externalities of greenhouse gas pollution. By imposing a regulation or tax on polluting activities, governments can equalize the marginal cost of pollution with its social cost (Nordhaus, 2010).

A Carbon Tax avoids the volatility of prices caused when emissions permits are traded on an open market, and revenues can be returned by reducing taxes on other goods or through a dividend program thus mitigating deadweight loss (Nordhaus, 2007: 39). Carbon taxes are also much easier to coordinate between countries, through the same mechanisms by which trade and tariff negotiations happen today, to achieve policy unification needed to solve global issues.

There are some drawbacks to carbon taxes. It is difficult to measure the precise impact of the tax as individual laws could have loopholes or exemptions for trans-national polluters that would weaken or muddle them (Victor, 2001: 86). When setting rates, countries would have to estimate how much they would need to reduce emissions through esoteric economic formulas that may not be intuitive to the voting public. The introduction of new taxes is also a difficult thing in any democracy, even if the money would be returned through other channels. Consumption-based

[7] according to the New Palgrave Dictionary of Economics, a negative externality is a cost of economic activity that is imposed on a party not directly involved with that activity (Laffont, 2008)

taxes are regressive taxes because they will raise the price of consumer goods which disproportionately impacts the budgets of poorer citizens.

Whereas carbon taxes indirectly choose the "acceptable" level of greenhouse gas emissions, a cap-and-trade system directly chooses the "acceptable" level of emissions and allows market forces to select the price for exceeding that level (called the cap) through the sale of emissions allowances (Nordhaus, 2007). The advantage to this is that it allows environmental scientists to recommend a stable, long-term phasing down of carbon emissions directly and not have to rely on complex, and potentially wrong, economic models to estimate the correct "price" needed to hit emissions goals. A long-term timetable for the emissions cap also eliminates the risk associated with the "unknown" factor, making large-scale capital investments in carbon-free technology more palatable for investors and entrepreneurs[8].

The primary drawback to cap-and-trade is the trading mechanism itself. By allowing for market forces to control the price of carbon emission allowances, cap-and-trade systems can be prone to extreme volatility. This makes it difficult for businesses and consumer to do long-term financial planning around the carbon price, because it can change rapidly. For example, in the span of one month of 2006, the price per ton of allowances on the EU-ETS dropped more than 70% (Nordhaus, 2007: 37). Cap-and-trade programs are also more susceptible to corruption and what economists call rent-seeking behavior[9] which can weaken their efficacy (Nordhaus, 2007: 39).

In an econometrics modeling study comparing a cap-and-trade policy with a carbon tax one, Y. Chen et al (2020) demonstrated that a cap-and-trade policy resulted in lower overall emissions rates and higher rates of energy innovation than a carbon tax system. However, this conclusion only holds true to a certain point. The authors show that if a cap allocation is too high, the system will not work to reduce carbon at all. Thus, they conclude, policymakers "must rationally

[8] For example, if an energy company knows the carbon emissions cap will be 0 in 2045, and knows that a new natural gas plant will take 20 years to pay off at current operating costs, breaking ground on it in 2026 is not a smart financial decision.

[9] activities that reduce economic efficiency and pull money out of systems without adding value back, such as financial institutions purchasing carbon credits and reselling to manipulate the energy market.

allocate carbon caps and to determine total carbon cap based on the social target." (Y. Chen, 2020: 4)

A third method also exists that is a hybrid of these two approaches, wherein a government could cap the price of emissions permits on an open market with the government selling additional permits at a set price, acting effectively as a tax (Nordhaus, 2007: 35-6).

**2.4 Carbon Taxes and Induced Economic Innovation**

The theory of induced innovation first appeared in economics literature in John R. Hicks's 1932 book *The Theory of Wages.* In it, he proposes that "change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind—directed to economising the use of a factor which has become relatively expensive" (Hicks, 1963: 124). In other words, innovation will occur when it becomes too expensive *not* to innovate. Hicks's theory mostly revolved around the price of labor increasing to induce production process innovation, requiring less input of labor. This theory was expanded upon in the 60s by Charles Kennedy who stated that labor costs are not the only factor that can induce innovation. Factors such as capital costs might be more effective from the standpoint of profit-maximizing. He states that an entrepreneur will "search for the improvement that reduced his total unit cost in the greatest proportion" such that "if capital costs are high, relative to labour costs, he will search for a capital-saving innovation." (Kennedy, 1964: 543). We can see the early seeds of the logic behind the theory of induced innovation as it pertains to a carbon price forming – after all, if a company will save more by adopting carbon-reducing technology to avoid paying a tax or purchasing offsets than it would by reducing labor cost, it would logically choose the carbon-reduction strategy.

Atkinson and Stiglitz (1969) posit two interesting points that are ultimately relevant to this study on induced innovation. First, that in the case where the benefits of switching to a new technology or process are largely external from an individual firm or industry, as reducing greenhouse gas output in power generation most certainly is, government should intervene to ensure firms are switching to the correct technology for a long-term horizon. Second, they state that a firm will consider adopting a more expensive technology sooner if it expects prices to rise in the future, regardless of present costs (Atkinson & Stiglitz, 1969). With this note, we begin to see some of the significant reasons why the California legislature and executive offices structured the GWSA as they did: providing stable, long term horizons on the carbon cap allowing businesses to estimate the future cost of emissions credits for budget planning, and directing money collected from those dividends to renewable energy projects. This will be detailed more in Chapter 3. This article is an important step towards understanding how induced innovation, which is at its core a microeconomic theory[10], relates to whole economies. That in turn forms the basis for how a specific cost increase, for instance a price on carbon, would impact innovation across an industry.

Getting to more specific theoretical research on carbon prices, a study by the Carnegie Institution for Science indicates that carbon taxes would spur innovation to find cheaper alternatives for power generation, making this a lucrative prospect for both developed and developing economies alike looking to carve a niche for themselves in our globalist society. According to this study, government policies that increase the price of carbon fuels have a direct effect in inducing development of, and investment in, energy saving tools. “The induced efficiency improvements not only help the economy grow more rapidly, delivering a higher standard of living than would otherwise be predicted, but also reduce the amount of energy consumed and carbon dioxide emitted per dollar of output.” (R. Wang et al., 2019).

### 2.5 The Innovation Chain and The Entrepreneurial State

However, there is also criticism of this idea, especially from a business perspective. Interviewees in Gianoli and Bravo’s (2020) study of carbon pricing in the Port of Rotterdam stated that a carbon price could be a double-edge sword, motivating companies in low energy-intensive industries to invest in cleaner energy, but leaving high energy-intensive companies with less money to invest in cleaner technologies. Cleaner tech for energy-dense industry, they found, is also not readily available. Since modern businesses are typically rational actors seeking to maximize profit, an insufficiently high carbon price could simply be written off by a firm as a

[10] one that focuses on trying to explain why and how single firms take certain actions.

cost of doing business whereas one that is too large could cause firms to invest in, or relocate plants to, a lower-regulation area. Both cases could potentially stifle investment in new technology.

Mariana Mazzucato echoes this line of thinking, stating that "profit-maximizing companies invest less in basic research and more in applied research [because] there are greater and more immediate returns from the latter" (Mazzucato, 2011: 134). This results either in carbon and investment leakage as described in Gianoli and Bravo (2020) or in incremental change that would be insufficient to meet urgent climate goals. Mazzucato argues instead that the predominant neoliberal perspective with regards to innovation focuses too much on government policy correcting market failures[11] and overlooks a lot of what public money is being used for in the innovation chain. She posits that induced innovation literature should shift focus to the government engaging in market *creation* through targeted R&D investment, a process that is overlooked in market failure literature.

In this viewpoint, the innovation chain is not simply sustained by correcting a market failure, but by a series of state and private agencies bridging the gap between segments of a five-stage process starting with frontier scientific research to practical use conceptualization, prototyping and concept demonstration, product development, and finally bringing the invention to market. "In sum, the patterns we see in public financing for innovation in renewable energy, and clean tech more generally, are very far removed from the indirect policies recommended by a market failure approach." (Mazzucato and Semieniuk, 2017: 41). In Figure 2.1, below, we can see an illustration of this concept, where Mazzucato and Semieuk have identified agencies, both public and private, that contribute to each stage of the innovation chain.

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[11] in the case of climate change, this would be fixing the market failure of greenhouse gas pollution in the energy market by taxing the emissions, thus directing the market to invest in ostensibly cheaper clean energy.

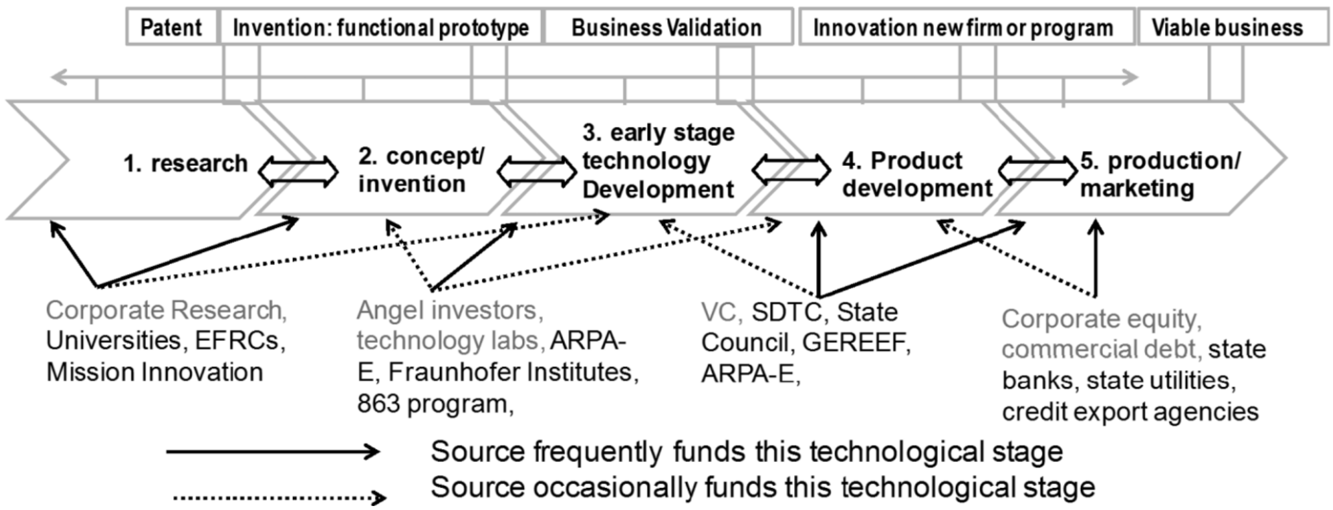


*Figure 2.1 Mission-oriented finance along the entire innovation chain in the renewable energy sector. (Mazzucato and Semieuk, 2017: 37)*

As I will discuss further in Chapter 3, this study will focus mostly on the last two links in the innovation chain, product development and marketing. In choosing to focus on innovations in bringing existing technologies to market viability (stages 4 and 5) *in California specifically* we take for granted the innovation process bringing alternative energy to the point of product development. We seek to prove that cap-and-trade is sufficient in and of itself to spur innovation in opening a market for new technology[12].

**2.6 Similar Studies**

During my literature review, I found several similar studies that helped inspire the methodology used for this thesis. Most of these studies are conducted by economists, and there is a stark whitespace for political science studies. While the post-Cold War consensus in government has coalesced around the idea of blurring economics and politics, it is still important to look beyond econometrics and understand if the economic and innovation opportunities promised by carbon pricing are accessible to the individual persons, instead of just broad national or sectoral interests.

[12] This process is not a given even once a certain tech has developed to “Stage 3. Early-stage technology development”. For example, in the pharmaceutical industry, Mazzucato estimates that only 1 in every 10,000 compounds conceptualized to have a medical benefit will make it to market (Mazzucato, 2011).

In one study, Calel and Dechezlepretre utilized the European Patent Office (EPO)'s relatively new "low-carbon patent" designation to study the impact of the EU Emissions Trading System (EU ETS) on the number of emissions-reduction patents awarded to large firms directly impacted by EU ETS regulations. They found that the EU ETS accounted for a 9.1% increase in low-carbon patents among regulated firms, or an approximately 1% increase in low-carbon patents economy-wide that could be attributed directly to the regulation (Calel and Dechezlepretre, 2016).

Agnolucci (2009) took an industry-specific approach to impacts on energy consumption and employment in both the UK and Germany. He found that the biggest decreases in energy consumption in both countries occurred in the electrical and optical equipment sector while having minimal effect on employment within the sector, indicating that innovation in energy reduction might be more effective or feasible in certain industries than in others. Martin et al (2014) looked at the impacts of the UK's carbon tax on British manufacturing plants across the three-year period when the carbon tax was in effect, but the EU-ETS was not (2001-2004) with the goal of comparing outcomes between fully-taxed plants and those eligible for reductions under the UK Climate Change Levy. The study found that the Levy resulted in a strong reduction in energy usage, with resulting CO2 emissions decreases of between 8.4 and 22.6%, with a more pronounced effect at the largest plants (Martin et al, 2014). The study authors conclude that there is no strong evidence to support the idea that CO2 emissions reductions in these plants was not the result of switching fuel sources and indicate that further studies should be done to determine how the plants achieved these reductions.

Weigt et al (2013) in a simulation study using real fuel-consumption data in the Germany electricity sector, sought to understand the compounding effects of the carbon price instituted by the EU-ETS and renewable energy regulations specific to Germany. They found that a carbon price alone would cause the electric utilities to switch power generation away from coal plants to more modern gas-powered plants as well as renewable energy, whereas the combined carbon-price and renewable energy support showed a more universal shift from carbon-based power to non-carbon. This study shows that in a study on renewable energy innovation, I must be cognizant of other policies such as renewable-energy subsidies that may have a stronger impact on new businesses and patents than a carbon price alone.

In a longitudinal study of ten industrial sectors across the three Scandinavian nations[13], Enevoldsen et al (2007) found both an overall decrease in energy demand in high-energy requirement sectors and evidence of industrial plants shifting to alternative fuels that are less carbon-intensive in the years following the implementation of carbon taxes in those countries. The study also indicated that the failure to reduce CO2 emissions in specific industrial sectors with economic prospects that declined during the study period could be the result of competitive pressures and the new carbon taxes making it more difficult to make expensive investments in energy efficiency. This would indicate there potentially exists limits to the ability of carbon pricing policy alone to induce innovation.

While the study of national and international carbon pricing is a nascent field, with a small but growing body of good work, independent academic studies on impacts to the economy of carbon pricing at the subnational level remain rare. Fang, Guochang et al offer a study of a pilot carbon tax program in the Yangze River Delta urban agglomeration[14] indicated that ESER goals could be better achieved through carbon taxes or carbon trading in certain (wealthier) districts (Fang, Guochang et al, 2016) but offered no indication on how such a program impacts specific industries.

Gianoli and Bravo (2020) concluded a qualitative case study on energy intensive industry in the Port of Rotterdam and the impacts on business operations and innovation of the proposed Dutch National Climate Agreement, which includes a high carbon tax. They found through conducting interviews that while carbon leakage[15] was not likely due to enormous costs of exit and long timeframes to realize the cost of such a move, investment leakage[16] was because the marginal cost of upgrades would be greater in the context of the lower profit margins already caused by

[13] Norway, Sweden, and Denmark.
[14] a region that includes the major cities of Nanjing, Hangzhuo, and Shanghai.
[15] companies moving polluting plants to lower regulation areas.
[16] choosing to upgrade existing plants in areas not subject to the carbon tax and allowing plants affected by the tax to fall into obsolescence, thus disproving the theory of induced innovation entirely.

the carbon tax. This study also found that a carbon tax alone is not sufficient to induce the implementation of new technologies in energy intensive industry, although the tax *does* provide critical long-term variable stability in the form of solid information about what the price of carbon will be year into the future. In addition to the tax, the study authors conclude that some form of subsidy or regulation to make investments in "green" technology is necessary.

### 2.7 Establishing a Hypothesis for This Study

This study is a time-series observational study of California's GWSA, to determine if the passage of this act, and the cap-and-trade program of carbon pricing that came with it, produced the necessary conditions to induce innovation in bring green energy technology to market. If the theory of induced innovation in green energy by carbon pricing is to be true, then we should expect to see a marked, and statistically significant, growth in this stage of the innovation chain for green energy, even when controlled for outside programs.

## Chapter 3: Methodology

Chapter 3 will be dedicated to describing the methodology for this study in detail. It will begin with an overview of the research design in the abstract, establishing the type of study, the methodological approach, and the research strategy. Next there will be an overview of how and why I selected California's energy market and Global Warming Solutions Act to study the impact of carbon pricing on small business innovation, including detailed background information on California's business culture, and the specifics of how its energy industry has operated since privatization. Next there will be a section on how innovation will be operationalized and within that context how "green" innovation will be operationalized, including subsections establishing the limitations and validity of these measures.

The concluding three sections of Chapter 3 will discuss data collection and sources. The first section will be about how the data was sampled and categorized in preparation for testing. The second section will discuss the data analysis strategy and tests to be conducted on the data. The third and final section will discuss the limitations to the data set and the approach to analysis and establish how the data can be generalized.

### 3.1 Research Design

As stated in chapter 2, this study will be utilizing the behavioralist approach to research, rooted in the foundationalist ontological position and the positivist epistemological school. In laymen's terms, this study seeks to test a specific theory of behavior as empirically and objectively as possible. To do so, the study must seek to establish a causal relationship between an independent variable and dependent variables in a manner that can be replicated both within the region of study itself, and for other regions with similar independent and dependent variables.

Sanders writes that for a behavioralist study any theory which claims to explain a cause of a phenomenon must be capable of being tested against an observation and must also be falsifiable (Sanders, 2010). The theory of induced innovation, as detailed in Chapter 2 fits this, as it establishes a cause (introduction of one or more pieces of legislation to establish a price on carbon), and measurable effect (innovation increases) and it can easily be falsifiable proving that there was no change in innovation related to a carbon price going into effect. Research of this design also seeks to develop explanatory and predictive models, with a methodology that is generalizable and repeatable (Furlong and Marsh, 2010: 192), as this study hopes to.

### 3.2 Research Approach

This study will employ a predominantly quantitative approach to research, utilizing statistical methods to show and explain a relationship between two variables in a way that is logical and consistent, and building on the methodologies employed by previous empirical studies (John, 2010: 275). As reviewed in Chapter 2, this study will be joining a group of studies that seeks to quantify innovation and measure the impact of carbon pricing on such. Whereas the broadly subjective nature of what does and does not qualify as "innovation" can lend itself to either a qualitative or quantitative study, the choice to focus on how the energy industry has changed over time by measuring new business registration as the chosen definition of innovation is inherently a quantitative measure.

One feature of the quantitative approach is the fact that this methodology, perhaps more so than others, makes inherent assumptions about its test cases (Furlong and Marsh, 2010: 192). The reason for this is because the empirical method, as employed in the natural sciences, requires controlled conditions to isolate the effect on the dependent variable as caused by the independent variable. Trying to replicate laboratory conditions in the social sciences is difficult if not impossible, and thus quantitative positivist studies are open to criticisms regarding potentially overlooked causes, such as cultural factors, ulterior motives for actors, or other plausible causes why an assumed rational actor might behave in a certain way. To address this, I will present and respond to some potential criticisms of the methodology, results, and conclusions throughout the body of this study as well as build several validity tests when presenting results.

### 3.3 Research Strategy

Fortunately, there are also ways to emulate a controlled scientific experiment through what is called an observational study. An observational study is useful for testing a hypothesis when it is impossible for a researcher to apply an independent variable, such as determining what impact a specific economic policy has on a segment of the economy. As stated above, there is a concern about confounding variables lowering confidence in any causal result this study might find. However, Kellstedt and Whitten state that "if sufficient attention is paid to accounting for all of the other possible causes of the dependent variable that are suggested by current understanding, then we can make informed evaluations of our confidence that the independent variable does cause the dependent variable." (Kellstedt and Whitten, 2018: 93). How I will go about accounting for alternative causes in this study will be detailed later in this chapter.

This study will be designed as a time-series type of observational study, which is a kind of study tracking one metric across multiple time periods. It will focus on variation in the rate of registration of new energy LLCs in California over a twenty-year timespan, divided into 80 quarters, from the 4$^{th}$ quarter of 1996 to the 4$^{th}$ quarter of 2016, inclusive. More specifically it will be looking at the rate at which new businesses in each of two energy categories, green and carbon-based, changed over this time with a specific focus on the change in the growth rate of each category in the 40 quarters after Q4 of 2006 (when the GWSA was signed into law) relative to the 40 quarters before.

### 3.4 How and Why I Chose to Study the Global Warming Solutions Act

*It is an interesting study area with an abundance of good, easily accessible, data.*

As stated in Chapter 1, this research thesis will be studying the impacts of a carbon-pricing policy of a sub-national government in North America. One unique advantage of North American style federalism is the ability to use certain states or provinces as “laboratories for democracy” and test how policies might work on a national scale. One of the more famous examples of this was the creation of the Affordable Care Act[17], which was largely based off a similar system that had been working in Massachusetts. Thus, taking the time to study state-level programs can be profoundly useful for policymakers in the national legislatures to learn from best practices and how to avoid policy pitfalls when crafting new laws.

When selecting the policy for study, I established the following rules based on a combination of personal interest and what I thought would provide the most robust results:

1. the policy MUST be a whole-economy carbon pricing program, either cap-and-trade or a carbon tax.
2. the policy MUST have been passed exclusively by one state or province in North America.
    - cities or counties with carbon pricing were not to be considered.
    - regional collective cap-and-trade agreements like the RGGI in the Northeast United States were also excluded due to many confounding variables and differences between state economies.
3. the policy MUST have been in effect for at least 10 continuous years at the time of writing, to establish a sufficient long-term trend after passage.

[17] colloquially ‘Obamacare’.

4. the policy MUST have been proven to reduce GHG emissions with verifiable scientific data.
5. there MUST NOT be a national carbon price policy supplanting or supplementing the sub-national one at any point in the study.
6. the state or province in question MUST have easily accessible business registration data, including date of registration, industry, and whether the business was still active.

These 6 rules narrowed down my choices to British Columbia and California from which I chose California. California is the largest state in the United States by population, and third largest in landmass and it has a carbon pricing program called the Global Warming Solutions Act (GWSA) (1), which has been in effect since 2006 (3). The GWSA also includes a traditional carbon tax, called a fee, on a select number of polluters, mostly those using or distributing fossil fuels for energy as well as concrete manufacturers, making it particularly interesting for its mixed-method approach at funding its own enforcement. California's GWSA to date has not been uploaded or otherwise combined into a regional system, despite earlier intentions to do so through the creation of the Western Climate Initiative (WCI)[18] (2).

As I will detail below, the GWSA exceeded its 2020 GHG reduction goal in 2018 (4) and an executive order set further reduction targets for 2030 and 2050, meaning follow up studies to this one can be done in the future. California's cap-and-trade system remains the oldest in the United States, and no national policy has received serious consideration in Congress in the last 20 years (5). Finally, California's Secretary of State maintains a database of all companies registered in the state since 1859, including business descriptions and whether the company remains in good standing (6). This data was made available to the public at no cost through a Freedom of Information Act request by the Los Angeles Times in 2018.

*California is a leader in policy and business.*

California is, by all standards, a massively influential state. Its population is greater than that of the whole nation of Canada's, and its GDP is larger than that of India (Saha, 2016). California is

[18] It is worth noting that several states in the WCI have since either aligned their climate targets to California's or passed their own carbon pricing systems, but there is still no regional cap-and-trade system at the time of writing.

the birthplace of many internationally known companies like Google, Tesla, and Disney as well as the home state of the current Vice President Kamala Harris, and the Speaker of the House Nancy Pelosi. This influence has resulted in something economists and political scientists call the "California Effect", which is the tendency for businesses to create products that match the regulatory standard of the strictest area in which they operate, especially in major economies. One study of the automotive industry found a ratcheting-up effect of environmental standards from countries with lower regulations that did significant business in areas with stronger environmental regulations (Perkins and Neumayer, 2012).

*California's energy market is open for entrepreneurs.*

Since deregulation, California's energy market has been rife with opportunity for entrepreneurs and established businesses alike. In addition to privatizing previously state-owned power plants, there has been ample opportunity for new energy technologies, small-scale power plants, and land leases for fuel like natural gas drilling and bio-digestors.

### 3.5 Background Information on The Global Warming Solutions Act

*What it is.*

The Global Warming Solutions Act of 2006 (GWSA), referred to also by its legislative name Assembly Bill 32 (AB32), was signed into law on September 27, 2006 by Governor Arnold Schwarzenegger at a highly publicized ceremony on San Francisco's Treasure Island. This law was followed up by Executive Order S-3-05 that set a longer-term goal of an 80% reduction of GHG from 1990 levels by 2050 (CARB, 2008: ES-2), while also reorganizing eighteen existing agencies governing California's environment into the Climate Action Team (CAT) under the oversight of the Secretary of the California Environmental Protection Agency (CalEPA) (CARB, 2008: 6). This law was built on claims that it would spur job growth and investment in new energy, and shortly after it was passed, that seemed to be coming true. In Q2 of 2008 alone, California firms vacuumed up US$800 million in clean technology venture capital (CARB, 2008: ES-11).

*How it Works*

According to the 2008 scoping plan set forth by the California Air Resources Board (CARB), the GWSA's primary goal is to reduce the greenhouse gas emissions of the Californian economy to no more than 431 million metric tons of CO2 equivalent, which would represent a 15% reduction from 2008 levels (CARB, 2008: ES-1), and establish standards by which to track GHG emissions. The GWSA recognizes six such greenhouse gases. Carbon dioxide (CO2) is obviously the largest contributor to climate change, but methane (CH4), nitrous oxide (N2O), sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are also regulated under this law (CARB, 2008: 11).

The primary mechanism through which the GWSA seeks to reduce CO2 emissions is a cap-and-trade program. As stated in Chapter 2, cap-and-trade puts a regulatory cap on total emissions from sources covered by the law. In California that amounts to approximately 85% of all GHG emissions. The CARB scoping plan recommended the cap for 2020 be set at 365 MMT (CARB, 2008: 21). The declining cap and establishing a price on carbon emissions is meant to "tilt decision making toward cleaner alternatives" (CARB, 2008: 18).

Recognizing that markets are imperfect and barriers, both financial and informational, exist that impede the adoption of new technology, the CARB plan to achieve the GWSA's GHG emissions reduction goals also included several specific initiatives of interest to the scope of this study. In 2008, the Board recommended targeting 33% of California's energy generation portfolio come from renewables, which was signed into law in 2011. Pursuit of 33% renewable power was already being bolstered by a program signed into law the same year as the GWSA called "Million Solar Roofs", alongside increasing methane capture at landfills and large dairies, coupled with building efficiency measures such as increasing the use of combined heat and power[19]. (CARB, 2008: 17)

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[19] using combustion sources, such as natural gas, to generate electricity while ALSO using the exhaust heat to warm buildings or water.

The GWSA has been funded, since 2010, by the AB 32 Cost of Implementation Fee Regulation which is collected annually on a per gallon basis on fossil fuels, working effectively as a carbon tax. Currently 250 companies are subject to paying this fee (CARB, 2018). The GWSA also receives funding in part through the Greenhouse Gas Reduction Fund (GGRF), which is responsible for auctioning of carbon allowances to companies who need to exceed a continually decreasing cap on CO2 emissions for their operations.

*Carbon Reduction Results*

To successfully address the problem of climate-change through a market-based solution, a carbon pricing policy must foremost actually reduce GHG emissions. Fortunately, this study has been done already. California's emissions dropped substantially since the law was passed, as tracked by CARB. According to a press release, as of 2018, total annual greenhouse gas emissions in California was 425.3 million tons per CO2 equivalent, which was already below the initial 431 million ton goal for 2020. More critically, the GHG emissions per capital rate was at 10.7 tons CO2 equivalent, down from the peak of 14.0 tons in 2001 (Young and Clegern, 2020). Among US states in 2018, California has the 2$^{nd}$ largest amount of CO2 emissions for energy production, despite being the largest in population[20] (EIA, 2021).

*Other Laws Passed to Bolster or Supplement the GWSA for the Energy Sector*

**Senate Bill 1368 – GHG performance standards for long-term investments in electricity generation (California Energy Commission)** Limits which power plants can be invested in by the publicly owned utilities based on GHG emissions, including building new plants or purchasing existing ones or capital improvements to utility-owned plants. While this law does not impact privately owned plants, these standards ensure the government is playing on the same field as the private sector with regard to emissions standards as well as push the publicly owned utilities towards contracting power projects from companies that specialize in renewable energy and thus would have an impact on the results of this study.

[20] Texas is number one by far, emitting nearly *twice* the CO2 for energy as California, despite having 10 million fewer residents.

**Senate Bill X1-2 – Renewables Portfolio Standard** Passed in 2011 on the recommendation from the CARB Scoping Plan, this law requires the amount of electricity generated per year by the state to be at least 33% of retail electric sales in California by December 31, 2020. Law makes this a requirement of electricity sellers, not producers, to procure the renewable energy, thus directing investment directly into power generation innovation. This law also establishes the long-term goal of a "fully competitive and self-sustaining supply of electricity generated from renewable sources." (Senate Bill Number 2: 7). As this law was passed on recommendation from CARB for the successful implementation of the GWSA, it will be considered as part of the overarching law for the purpose of this study.

**Senate Bill 535 – Disadvantaged Communities** While the original GWSA does require the legislature appropriates 25% of funds in the Greenhouse Gas Reduction Fund towards disadvantaged communities, and 10% of the funds to energy projects located in disadvantaged communities, there was no clear definition in the bill as to what constitutes disadvantaged. Senate Bill Number 535, passed in 2012, rectifies this. While this bill does not directly impact the overall goal of broadly understanding small business innovation, several small businesses identified during data analysis were owned by people of color and women. Further study would be needed to see the specific impacts of California's climate legislation on expanding opportunities in social justice. Regardless, SB 535 can for the purpose of this study be considered as part of the GWSA.

**Assembly Bill 811 – Contractual Assessments: Energy Efficiency Improvements** Allows cities in California to enter into agreements with private property owners for the purpose of building renewable energy generation for the purpose of distribution to the municipality. It also allows the construction of the new renewable energy generators to be financed through municipal loans. This can provide needed startup capital for small-time businesses looking to get into the energy industry and thus is a vital piece in understanding the results of this study.

### 3.6 Operationalizing Economic Innovation

Innovation is a broad term that can mean different things depending on context, and the person using the phrase. In the definition I listed in Section 2.2 above, Baregheh et al focus predominantly on business firms creating new or improved products, processes, and services, based on 6 pillars[21]. They acknowledge that different people will choose to focus on specific pillars based on their background or interest. As an academic researcher, this is double-edged sword. On one hand, there is no “wrong” answer for how to operationalize economic innovation; any measure of innovation that I choose can be justified by the underlying theory. On the other hand, there is an overwhelming number of directions my research project can take, and it can be difficult to keep a narrow scope on my research.

My first step towards operationalizing innovation was to narrow down the dependent variables to one specific economic sector. Carbon pricing is unique in that such systems broadly impact every aspect of an economy. To quickly narrow down the focus of this project to one manageable by a single researcher with finite time, I chose to focus on a single industry that is a major producer of greenhouse gases: the production of energy for homes and businesses.

Next, going through the 6 pillars as laid out by Baregheh et al. (2009) I chose to focus primarily on measuring innovation by the number of successful new LLC firms founded that specifically deal some aspect of generating carbon-free power. **The specific method of innovation** will be the creation and registration of new green energy LLC businesses, and their successful operation. These businesses will have the following characteristics in order to be considered innovation for the purpose of testing the hypothesis, based on the remaining 5 pillars of the Baregheh definition: **the social entity** establishing these businesses will be entrepreneurs from California (to the exclusion of those from out of state looking to expand a business into the state), the **nature of the innovation** will be businesses that solve the issue of increased energy prices for traditional carbon-based energy, the **type of innovation** will be businesses that provide new products and

[21] which, in review are: a systematic methodology by which innovation is created and adopted, the social entity employing this process, the means by which they are able to create and adopt innovation, the nature of the innovation itself, the type of innovation, and the aim of the innovation.

services in the field of carbon-free energy generation[22], and the **aim of the innovation** will be businesses focused on reducing GHG emissions.

Another way to consider this conceptualization of a business itself being a form of innovation is this. The precise product or service a specific business brings to the market is not important so much as it increases the overall market feasibility of green energy. For instance, two competing solar panel installers are not promoting novel technology, after all rooftop solar panels have been available for over 40 years[23]. However, these two solar installation companies may differentiate themselves in innovative ways such as finding techniques to reduce labor costs and installation time, or having innovative advertising campaigns and branding to make their product more appealing to certain customers, or even offering a unique financing plan to make the technology more immediately accessible. Mazzucato and Semineuk establish this kind of innovation as the final stage of what they call the innovation chain – where a company brings a new technology or technique to market viability[24].

*Regulations for Businesses in California*

It is important to take a pause here to describe the two primary ways in which a new business can be registered in California: either as a corporation, or as an LLC. Both structures have advantages and disadvantages for a business with regards to regulations, raising revenue, and taxation, which I will lay out below. In this section I will also provide three reasons justifying why I chose to narrow my focus on just LLCs for this thesis.

A corporation is a special designation given by the IRS for a chartered company and are among the oldest legal entities recognized in California[25]. Legally, these businesses are distinct entities from their owners for the purposes of financial liabilities, and while a shareholder's stock could be worth $0, resulting in a total loss of investment should the corporation fail, legal actions

[22] be it building new power plants, installing solar panels or wind turbines on individual buildings, creating energy storage facilities, or researching new energy generation and storage technologies to bring to market.
[23] while they are increasing in efficiency, installers are rarely producers, they are buying from a separate supplier.
[24] See Figure 2.1.
[25] with the first corporations in the business data set I am using for this project having been registered in 1859.

against the corporation usually cannot impact the personal assets of ownership. Corporations have a more strictly defined, and largely inflexible, management and payout structure. Shareholders elect boards of directors that are required to have regular, documented meetings (Huser, S.). Ownership of a corporation is easily transferrable through means such as selling, gifting, or inheriting stock and a corporation does not disappear should ownership die. Corporations pay the corporate tax rate at both the federal and state level, which is typically lower than the present income tax for individuals, although this varies greatly with changes in the law. After the corporation itself pays tax, it distributes profits to shareholders through dividends, which are then taxed again, resulting in a "double taxation" (Huser, S.). Benefits, like health insurance or retirement accounts are tax-deductible by the corporation and are often used to incentivize talent into working for the business.

Limited liability companies (LLCs) are a more recent invention, which started to become widespread after a 1988 ruling by the IRS allowing them to be taxed differently than corporations. Like a corporation, an LLC offers financial protection to its ownership and is largely distinct from the personal holdings of the individual who owns it. LLCs differ in their ownership structure in that there are no requirements for boards of directors or regular shareholder meetings, and power sharing between and income distributions made to members of the LLC ownership team are not tied to capital contributions made or stock owned as they are in the more rigid corporation structure. In exchange for this freedom, owners of LLCs are more limited in transferring ownership, which requires changes to the operating agreement itself[26]. Since an LLC is not a corporation, it is not taxed directly by the corporate tax, and all its earnings are passed to its members, which is considered part of individual income for each owner and is taxed at their respective tax bracket as self-employed income (Huser, S.). LLCs are also able to pass losses to ownership as well, which can be written off on individual income taxes from other sources and thus is an attractive option for a small business or secondary source of income. However, benefits like health insurance are NOT deductible from individual taxes, and since an LLC itself does not pay business taxes, it makes it more expensive for an LLC to offer benefits packages.

[26] for instance, ownership in an LLC cannot be bequeathed to a surviving relative without approval from the other owners.

*Why Focus Only on LLCs and Not All Types of Business?*

There are three primary reasons why I have chosen to study LLCs, and why studying LLCs is important within the context of understanding policy impacts. Since being recognized as a legal entity, to proportion of new businesses registered as LLCs in California has grown from less than 20% in 1996, to roughly half by the summer of 2012. This proportion has stayed steady since then, showing that both traditional corporations and LLCs are, for now, here to stay (see Figure 3.1) and as such, there is merit in studying them individually.

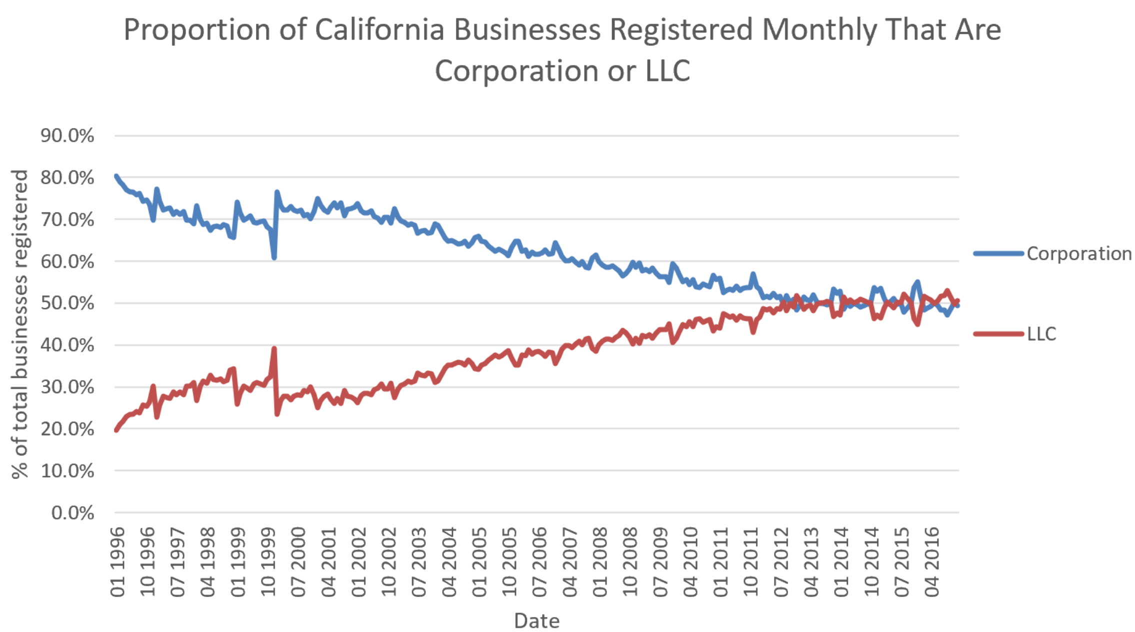


*Figure 3.1 – by 2012, half of all new businesses registered in California were LLCs.*

The change is proportionality also does not appear to have come entirely at the expense of the rate of registration of new corporations, as Figure 3.2 shows.

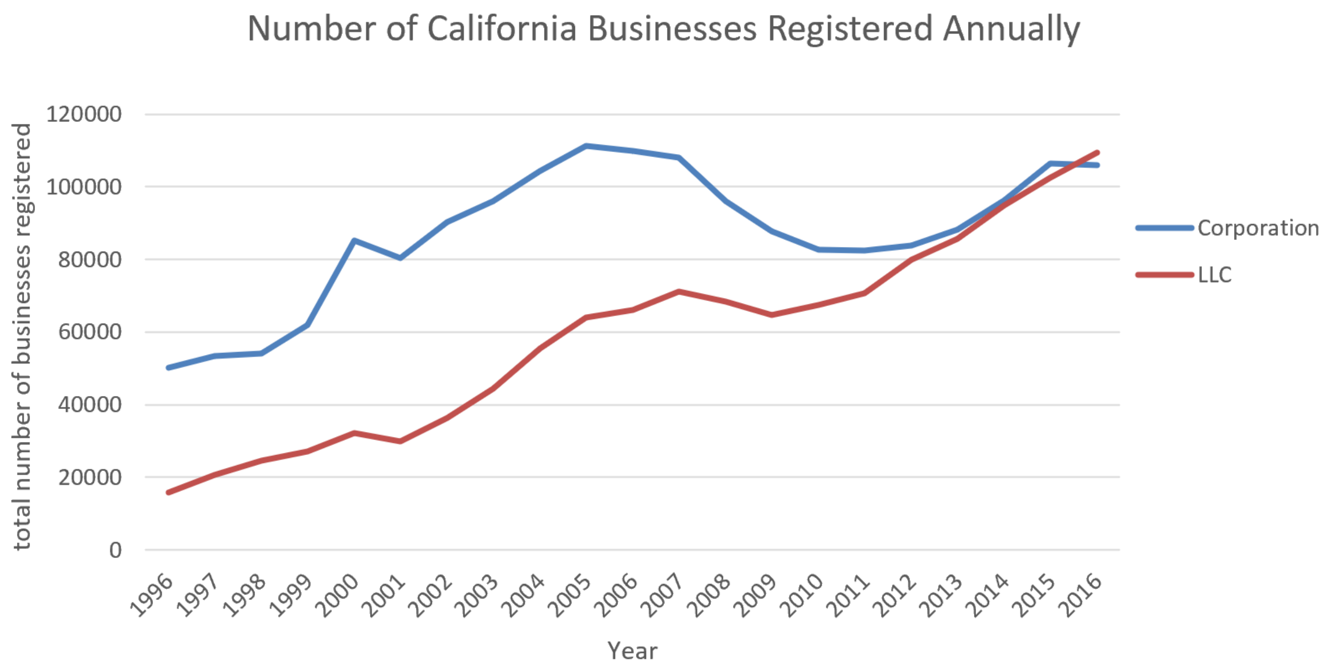


*Figure 3.2 – LLC registration has not entirely come at the expense of corporation registration.*

The number of corporations registered per year is roughly the same in 2015 as it was in 2005 while the number of LLCs has risen dramatically in that time. This evidence suggests that LLCs are not replacing corporations as the preferred legal structure for business, but rather supplementing them. This makes LLCs an important subfield of study when exploring the impacts of policy, especially one that is specifically designed to induce innovation within the economy.

Interestingly, Figure 3.2 also shows a potential advantage of the LLC structure over the traditional corporation and one that is important in understanding how society responds to political and economic shifts. The ease by which an LLC can be formed, and the advantages of a looser structure for revenue sharing, appears to have made LLCs a more appealing structure during rough economic times. As you can see in Figure 3.2, there was a prolonged and sharp decline in new corporate registrations from 2007 until 2012, a time period that coincides with the "Great Recession" and subsequent fallout. LLC registration suffered a less substantial dip in between 2007 and 2009, but the annual rate of registration began recovering much sooner and more robustly. Not tying monetary payout to capital contributions, as corporations are required to through the rigid regulations surrounding stocks, might make forming a new business more appealing to the risk-adverse during troubled economic times. From a practical standpoint within the context of my study, this also shows that I can make the case for not having to control too strongly for the Great Recession (2007-2009) in my data – LLC registration remained robust throughout the scope of this study. Since the policy I am studying was signed in 2006 and came into effect in 2009, the Great Recession could have created a false impression that the law hurt new enterprise, but the impact of that event on LLC registration appears to be minimal.

Finally, the barrier for entry is much lower for individuals who choose to start a business as an LLC. LLCs are a line item on individual tax returns in the United States, and, combined with the loose corporate structure and minimal required paperwork are also appealing from an organization standpoint for small enterprises. Because of these unique features, it can also be argued that studying how LLCs react to policy is a study of a certain subset of the middle and working classes are impacted by government action. From a political science standpoint, studying LLCs can more broadly provide a unique perspective on how a group of individuals (entrepreneurs) are impacted by, and responding to, policy, and in the era of shifting political allegiances and razor thin electoral margins, understanding these groups is an important aspect of understanding how coalitions are forming around certain issues.

*Limitations of the LLC Approach and Establishing Validity*

That last claim is not without potential criticism. Private citizens are not the only ones who can file a new LLC with the state of California, and I have found several examples of larger corporations filing individual power plant projects as separate LLCs[27]. Critics could rightly argue that new LLCs are not a good measure of grassroots innovation.

However, there are also examples in the dataset of corporations that would clearly qualify as small businesses for the scope of this study that also own small power plants[28]. Further,

[27] for example, Mariposa LLC, which owns and operates the Mariposa Energy Project, a 51MW gas-fired power plant is itself owned by Diamond Generating Corp, a multinational energy company (Collins Electrical)
[28] such as the Van Der Kooi Dairy Power LLC, a biomass generation facility owned and operated by the man who also runs the Van Der Kooi Dairy and Ranch (GovCB)

ownership and operation of power plants is only a small part of the energy generation industry. There is a wealth of support services, from installation to financing, to engineering consulting to parts manufacturing that are needed for the power generation industry to run smoothly, especially within the context of small-scale energy like solar. These kinds of businesses appear to make up the bulk of the LLCs within this study.

Another limitation of this approach to measuring economic innovation is the ease with which an individual with US$800 and a dream can register an LLC, which could give the false sense that more innovation is happening than is actually occurring. While combing through the dataset, I noticed many companies that came into business then were canceled a few months later. I found that several of these companies were tied to one small-time investor who would start a new company to submit bids for municipal construction projects, then dissolve the bidding company if they did not win the contract[29].

Without a doubt simply registering a new LLC in the state of California does not by itself constitute innovation. As per the definition for innovation laid out by Baregheg et al, an innovation must help a firm *successfully* win in its marketplace[30]. Not everyone who starts a business will be successful, let alone generate enough revenue off which to live, and the number of ways a business can fail is practically infinite. Success is also a subjective term, although perhaps less so in the case of business than in other topics of study. Possibly the best definition for a successful business is a company that generates enough revenue and profit to justify its continued existence for a given length of time. However, time operating cannot stand alone as a measure of success. Take, for instance, YouTube, which was established as an independent company in early 2005 only to be purchased by Google fewer than two years later for US$1.65 billion (La Monica, 2006). It would be simply unreasonable to assume that a company purchased for that sum of money, and whose brand is a household name worldwide, was unsuccessful, even if it technically did not "survive" as an independent firm for two full years. Thus, I will choose to look at LLCs that have *either* remained in existence *or* were purchased or converted to a

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[29] there is one renewable power project developer I uncovered during my research, Fred Nobel, who has established several LLCs for the purpose of such bids, some succeeded some failed. Those companies are denoted in the raw data linked in the Bibliography.
[30] see Section 2.2

traditional corporation. The California LLC database differentiates all three of these categories clearly, as I will discuss in more detail in subsequent chapters.

There is also the wider issue of some of the assumptions being made about people who register California LLCs. This study assumes entrepreneurs are rational actors, primarily focused on maximizing profit for themselves while working within their area of expertise. In reality, there are many reasons why a person would choose to go into business for themselves, and it cannot be stated with absolute certainty that a growth in small business innovation is entirely the result of market conditions, although market conditions are certainly a leading factor in determining the *success* of a business.

### 3.7 Operationalizing "Green" Energy and Categorizing Energy Types

In short, this study will consider all energy production that emits greenhouse gases while generating to be "carbon-based" energy, and those that do not "green" energy. This is a distinction that will likely generate some discussion among readers, as there is no consensus among climate policymakers what should and should not be considered "Green" energy for the purpose of carbon taxation, subsidies, and other energy regulations. The United States Environmental Protection Agency (US-EPA) separates energy sources into three broad categories: Green, Renewable, and Traditional. As you can see in Figure 3.3, each of these categories contains energy sources that both do, and do not emit greenhouse gases.

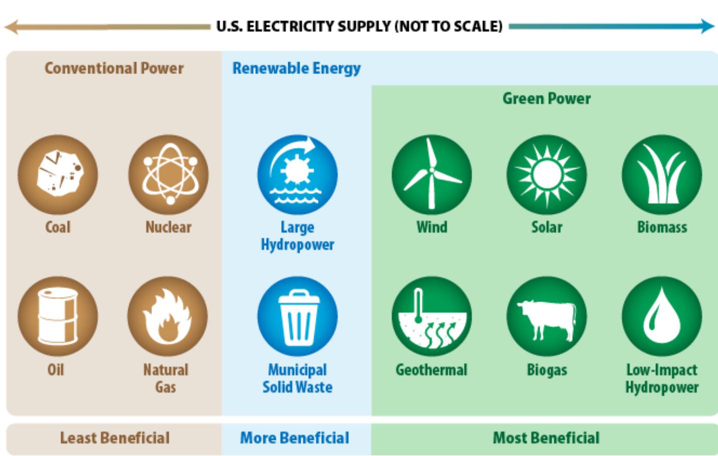


*Figure 3.3: Categorizing energy sources according to the EPA. (US EPA,OAR,OAP,CPPD)*

Of course the US-EPA also gives consideration to other factors impacting the environment, such as the problem with safely disposing of nuclear waste, or the fact that most biomass and municipal waste will end up emitting GHG anyway and burning them for energy doubles the benefit while also breaking down the worse emissions[31] into comparatively better ones making it a net benefit to the planet.

Reaching beyond the United States, the United Nations Environment Programme also considers Biomass energy to be “renewable” and “clean” (UNEP, 2021) despite emitting CO2 and identifies it as the leading source of renewable energy worldwide. Policy advocacy group Chatham House took UK and EU regulators to task stating that Biomass energy should not be considered for renewable energy subsidies because of their CO2 output (Timperley, 2017).

Unfortunately, for the purpose of testing California’s Cap-and-Trade, CARB has made life difficult for researchers: biomass and municipal waste sources of combustible fuels for energy may or may not be exempt from the cap depending on detailed specifics (CARB, 2019a), although biomass power plants are NOT exempt from reporting requirements for GHG emissions (CARB, 2020). Thus, as a researcher, I made a judgement call and decided to include ALL Biomass and Municipal Waste as a Carbon source of energy impacted by the GWSA, as it could be reasonably argued that the additional reporting to be classified as exempt from cap-and-trade counts in a broader sense as a price on that particular form of energy in the form of additional cost to monitor and report the data.

The next issue presented by the lack of alignment between policymakers and stakeholders is categorizing the energy types themselves. As shown above, the US EPA recognizes 12 distinct energy categories. I have found in practice that some of these categories can be combined based on the companies that work with each of these fuels. Based on the LLC descriptions provided by company representatives on their business registration forms[32], it is safe to combine the Oil and Natural Gas categories into one. Likewise, the EPA’s Large Hydropower and Low Impact

[31] such as methane, which is estimated to be between 28 and 36 times more potent of a global warming agent than CO2. (US EPA, 2019)
[32] 385 companies with some iteration of “Oil & Gas” in their descriptors were registered in California in the 20 years of this study.

Hydropower categories can be looped into one category, as both operate by having the kinetic force of water spin turbines and the differences in environmental impact of each type of plant is unrelated to GHG emissions. Finally, I chose to combine the EPA's Biomass, Biogas, and Municipal Solid Waste categories into one covering all non-fossilized organic material combustion, as the minor differences in how these fuels are harvested and processed do not impact the goal of this study.

Finally, through this research I uncovered another alternative fuel source not considered by the US EPA: the fuel cell. Fuel cells are still experimental technology, although there are several examples of California LLCs working to research and bring them to market viability. Fuel cells react hydrogen and oxygen to produce power without greenhouse gases. While most fuel cell companies are researching this technology for the purposes of using it in motor vehicles, which is outside the scope of this study, I identified several looking to use this technology for power generation and energy storage, and thus felt it necessary to include it as a separate category.

On the following page, Table 3.1 details how I divided the 9 categories of energy sources and 2 supplemental categories used in this project.

**Table 3.1 Classifying Energy Types**

| Fuel Type | Includes Companies That Do the Following | Energy Category | Notes |
|---|---|---|---|
| Biomass and Waste | Combusts non-fossilized organic materials (ex. Plant matter, food-based ethanol, agricultural waste) or gasses captured and derived from the decomposition of waste (ex. Landfill outgassing, compost outgassing) | Carbon | See section 3.4 on the controversy among policymakers and researchers regarding how this category of fuel should be treated for climate legislation. |
| Coal | Mining and burning of coal and coal derivatives | Carbon | |
| Fuel Cell | Researches, produces, generates power from or stores power in fuel cells that react elemental Hydrogen with Oxygen. | Green | There is one exception to the Fuel Cell category, Carbon fuel cells, which would be classified as Fuel Cell, but Carbon, not green |
| Geothermal | Energy generated from the natural heat of the Earth's crust and mantle | Green | |
| Hydroelectric | Use the kinetic energy of water, including dams, tidal and waves, to generate or store power. | Green | |
| Natural Gas | Lease land, drill, refine, or burn fossilized natural gas for energy | Carbon | |
| Nuclear | Use of controlled nuclear reactions to generate power. | Green | |
| Solar | Researches, produces or installs photovoltaic cells on houses, buildings, or as large power plants and municipal projects. | Green | |
| Wind | Designs, constructs, or manages turbines that convert the kinetic energy of wind to generate power. Includes both atmospheric wind and induced wind (such as from passing vehicles) | Green | |
| Multi | Specializes in more than one energy type. Also included in this category are companies that specialize in energy storage with chemical batteries. | Green/ Carbon | Under the strict definition of "Green" utilized in this study, a company that works with both Carbon-based and Green energy (such as a drilling company that specializes in both natural gas extraction and geothermal plant development) will be classified as Carbon. |
| Unknown | Companies identified as energy companies, but specific information on what type(s) of energy they work with couldn't be determined with confidence. | Unknown | Often times these companies appear to be registered to individuals doing general consulting work. |

### 3.8 Data Collection, Sampling, and Categorization

Business registration data for the state of California is available from 1859 through March of 2018 thanks to a public information request by the Los Angeles Times, and made available for free on GitHub[33]. This dataset is cumbersome, but it includes the registration data for every corporation and LLC licensed to operate in California, with each classification of business in its own .csv file, a text delimited database file that is usable in both Microsoft Excel and Access, which are the two programs I will primarily be using for this analysis.

The LLC database contains the date the company filed paperwork with the state, its current status[34], whether the filing is done by a company based in California or elsewhere[35], the name and address of the physical business, as well as contact information for agents authorized to make decisions for the company. The LLC file also includes a description of the company. These descriptions are filled in by the filing entity, and do not follow any particular standard. However, they do contain valuable information that will make it easier to identify the LLCs I would be interested in including in my study.

*Data Sampling*

On the LLC filing form, the state of California allows the filing entity to fill in their own description of the business. This is simply a blank line prompting the form-filer for a "Business Description", and there is no standard set of industries used to categorize businesses. This is a double-edged sword for a researcher, who benefits from highly detailed business descriptions allowing for nuanced categorizations for studies, but who is also harmed by the inconvenience of having to cast a wide net using query functions, then manually categorize the data to fit their purposes. While the LLC filing form states that including a business description is required, a large portion of businesses in the LLC database have blanks for descriptions. As such it is

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[33] more recent datasets are available in digital form through the California Secretary of State for a fee of $200, but for the purposes of this study and my limited budget, a three-year-old dataset will have to be sufficient.
[34] For a list of the statuses in this dataset, and their meanings, as well as how they were classified for use in this study (active vs. inactive) see Appendix B.
[35] the parlance used by the California Secretary of State's office is domestic and foreign respectively.

impossible for anyone studying this particular raw dataset to confidently state that they are studying *all* businesses within a given industry. Rather the researcher will have to rely on selecting an inherently selection-biased representative sample of businesses for the purpose of their study.

Since the data was already to be selection biased, I focused on trying to capture as many business descriptions as possible to catch as many companies relevant to this study as possible. I opted to do a *string* search using SQL in Access, focusing on small segments of letters that would be found in keywords associated with power generation and common fuels[36]. I continued to add strings and experiment with keywords until I hit a point where I was adding new terms to the query and not getting any more businesses in the results. Companies that had typos, certain abbreviations, or misspellings in their descriptions would be overlooked through this method of querying, although there is little indication that one industry would be more affected than any other, and it can be assumed the likelihood of typos or misspelling is randomly distributed across industries.

*Data Categorization*

Next, I scrolled through the list of business descriptions and classified them as one of four potential broad categories: Energy Sector – Green, Energy Sector – Carbon Based, Not in Scope, and Maybe in Scope for the descriptions that were not specific enough to make a judgement on without looking at the individual companies[37].

After discarding those identified as “Not in Scope”[38], I went through each company in the “Maybe in Scope” individually to try to identify whether they would be appropriate data for the scope of this project. This was done simply through Google searching the company for information on the nature of the business it was involved in. Companies that self-identified as

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[36] See Appendix A for the SQL code containing the search strings used.
[37] for example, “Energy Consulting”.
[38] which included unrelated businesses that coincidentally had key strings from my SQL query such as “Activated Carbon”, as well as businesses also substantially impacted by the GWSA but not within the energy sector specifically, such as “Gas Station”.

“energy companies” covered a variety of fields other than electric power generation including beverages and alternative medicine. Those were discarded. Also discarded during this pass was a subcategory of financial companies called holding companies which themselves do not engage in the energy business but rather hold financial interest in established companies. I treated these as distinct from companies specifically dealing with investment in energy companies which engage in riskier financial ventures meant to spur development and innovation, rather than skimming profits off a known successful entity.

I then went individually through the companies identified as either “Green” or “Carbon Based” to categorize them based on the fuel type they used (see Table 3.1). First, I categorized them based on the descriptions of the companies provided by the registrants on the registration forms[39]. For those I could not definitively categorize using the company descriptions, I attempted to categorize using the name of the company itself, which proved to be a useful alternate for the description in many cases[40]. For the companies that could not be categorized by either of these two methods, I resorted to Googling each individually to determine the nature of its business[41].

### 3.9 Data Analysis Strategy

Identifying renewable energy businesses, and having the date they were registered will, when combined, allow me to establish trends in the number of businesses registered quarterly both 40 quarters before, and 40 quarters after, the GWSA cap-and-trade system was signed into law. There are several ways I intend to present this data to give a complete picture of the broad trends in the energy LLC market.

First, I will present as raw numbers the trend in the number of successful new energy LLCs over Q4 1996 to Q4 of 2016 inclusive, distinguished by “green” and “carbon” energy. Next, I will show the proportion of successful new energy LLC registrations that were green and carbon in

[39] ex. “Solar Panel Installer” would be categorized as “Solar” and “Oil and Gas Drilling” would be categorized under “Natural Gas”.
[40] for example, a company called “California Solar Ranch LLC” that had listed its description as “Power Generation” was easy to categorize under “Solar”.
[41] The final dataset with relevant categorizations can be found at https://drive.google.com/file/d/1CsgEhM_MIBKEyMXAaohVF7wTh8YpdlO-/view?usp=sharing

each quarter and identify if and when there was a crossover[42]. Next, I will address the problem of recency bias that is caused by only looking at companies that were still in operation in 2018 through a comparison with overall trends in business survivorship from 1996-2016 as compiled by the BLS. Finally, I will control for other laws passed outside of the GWSA that might impact the rate of LLC registration in the energy sector.

Data in all instances will be presented as run-sequence plots, which makes it easy for researchers and casual readers alike to determine significant shifts in a dependent variable over time (NIST, 2012). California LLC data will be presented as a four-quarter[43] linear rolling average in all cases. The purpose of a rolling average is to smooth out random shocks that may occur, as well as adjust for seasonality in time data. According to the NIST, a rolling average "is conceptually a linear regression of the current value of the series against the white noise or random shocks of one or more prior values of the series" (NIST, 2012).

### 3.10 Limitations to the Data and This Approach

Establishing the validity of this data and the ability to generalize from my results will be a multi-stage process that I will briefly detail in this section. First, I will discuss how I will establish a plausible causality in this study. This will be done using Kellstedt and Whitten's four hurdles to causality framework. Following that, I will describe how I will establish context validity by controlling for two pieces of legislation unrelated to the GWSA, but whose impacts on California's energy market were profound.

*Establishing Correlation vs Causality*

Unlike in laboratory experiments, establishing causality in political science when looking at on-the-ground data for a particular polity is extraordinarily difficult, because there is no way to definitively control for all possible variables. Instead, Kellstedt and Whitten (2018) state that

[42] ie. which year(s) carbon energy companies represented a larger share of new energy LLCs and which year green energy companies did.
[43] 1 quarter is 3 months, clumped as [Jan, Feb, Mar] [Apr, May, Jun] [Jul, Aug, Sep] and [Oct, Nov, Dec] for every year in the study as is traditional for business reporting cycles.

notions of causality in political science study are probabilistic in nature, that is to say that a given condition increases the probability that effect Y will happen, but does not guarantee it will. They lay out four hurdles to establishing causal relationships in political science in the form of four questions (Kellstedt and Whitten, 2018: 59-60).

1. *Is there a credible causal mechanism that connects X to Y?*

   In the case of this study, we will be determining if the implementation of the Global Warming Solutions Act (X) resulted in the growth in the number of new green energy LLCs (Y) being registered every quarter after the passage of this act. As we will see in Chapter 5, growth in new green energy LLC registrations was mostly flat until a year or so after the passage of the GWSA, indicating that *something* happened around the time that the GWSA was passed that caused that shift.

2. *Can we rule out the possibility that Y could cause X?*

   Most likely. Because the effect is isolated to the time *after* the passage of the GWSA (condition Y), it is unlikely that hundreds of entrepreneurs banded together to lobby for complex cap-and-trade legislation for the purpose of starting new small businesses (X), and even if they had, it would have been more likely they by-passed the legislature through California's referendum system to do so.

3. *Is there covariation between X and Y?*

   Yes, growth in new green energy LLCs is flat until shortly after the passage of the GWSA, then increases rapidly. Further, as will be shown in Chapter 5, the trend in growth in the number of green energy LLCs is both stronger in post-GWSA years than in pre-GWSA years AND stronger than the growth in carbon-based energy LLCs across the twenty years of the study.

4. *Have we controlled for all confounding variables that might make the association between X and Y spurious?*

   There are several variables that I plan to control for when presenting results. The first is the growth across the state of California in new LLC registrations regardless of industry, as shown above, but also within the energy industry itself. The results in Chapter 5 will show a clear and ultimately permanent shift in the *proportion* of new energy LLCs, and new LLCs as a whole, registered in California that were focused on green energy in the years after the passage of the GWSA. Looking at the proportionality of new green energy companies makes the raw number of them irrelevant. Yes, the pace at which new LLCs being registered is increasing, but the pace at which green energy LLCs are being registered is increasing even more than that, eliminating that as a possible confounding variable.

The next potential confounding variable will be the business rate of failure. That is, the results could be giving us a false idea that the number of successful green energy LLCs has greatly increased when in reality green energy LLCs are failing at a much greater rate than other businesses and those registered in more recent years simply have not failed *yet*. Again, there are two ways in which I can show this. The first is by comparing the percentage of green energy LLCs registered per year that remained active when the database was compiled in 2018 to the percentage of all LLCs. In Chapter 4 you can see the results of this correlation, which actually shows green energy LLCs *underperforming* the average California LLC in many years, although that may be an artifact of a low sample size in those years.

The second way to eliminate the business rate of failure as a compounding variable is by using business life-length data compiled by the Bureau of Labor and Statistics for all American companies since 1993. Chapter 4 will show that California LLCs' rates of failure corresponds well to that of the rest of the US, and thus the BLS's average 1-year business failure rate of 66.3% can be applied to estimate the 10-year failure rate of green LLCs to show there is still robust and sustainable growth of profitable small businesses in that sector after the passage of the GWSA.

The third and final confounding variable I will have to control for is two pieces of legislation, one passed by California a few weeks before the GWSA, and the other a piece of federal legislation passed by the US Congress in 2009.

*Other Laws Outside of the GWSA That Will Impact Study*

**SB 1 – the 2006 "Million Solar Roofs" initiative.** A 2006 California law which dedicated US$3 billion in incentives towards installing 3 gigawatts worth of solar panels on Californian buildings[44]. This law was signed roughly one month before the GWSA, and for the purpose of this study will be considered as **separate** legislation that must be controlled for when drawing conclusions. This will be done because unlike the other laws discussed earlier in this chapter, the Million Solar Roofs program was signed into law *before* the GWSA had passed and was not specifically recommended for passage by CARB as part of the scoping document mandated by the GWSA. In order to test for the impact on green energy business innovation of the GWSA *specifically* I will conduct a test in Chapter 5 that will consider only the growth in innovation of *non-solar* green energy companies.

**The American Recovery and Reinvestment Act (ARRA)** According to US News and World Report, the ARRA dedicated a total of US$70 billion for energy related projects, comprised of US$50 billion in new spending and US$20 billion in tax provisions and credits. Among the new spending, US$6.3 billion was granted to state and local governments for energy projects (Ruggeri, 2009). US$453.7 million of that was sent to California and its county and city governments for a variety of energy projects, including roughly US$11 million specifically for solar development (US Department of Energy). LLCs in the scope of this study also received grants through the SBIR/STTR program funded by the ARRA.

Outside of direct funding, this law granted tax relief to businesses and individuals who shifted to cleaner energy sources. The EPA's Local Guide to the ARRA (2009) states that the $2000 caps for the residential solar and geothermal tax credits and the $4000 cap for small-scale wind power facilities tax credit were removed. The law also contained an extension of the Renewable Energy Production Tax Credit of US$0.021/kWh for wind, geothermal and closed-loop biomass energy and US$0.01/kWh for hydroelectric power, marine-kinetic, and open-loop biomass and waste outgassing energy. Critically, the law also allowed for companies to choose to take this as an

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[44] the program exceeded expectations, reaching 1 million roofs in 2015 and generating 9gW of power, three times the initial goal: (USC Schwarzenegger Institute, 2019).

investment credit, rather than a production credit, for fiscal years 2009 and 2010, when heavily indebted banks were not lending for risky ventures.

While the precise details of the ARRA's energy spending and credits are not important, what is important is that the law pushed a lot of new funding into clean energy projects, opening up more opportunity for new businesses. How to adjust the results and conclusions for this financing is far more complex that simply ignoring a specific category of LLCs, it would involve a complex and time-consuming tracing of funding contracts through individual municipal governments that would be too time consuming for an individual researcher's master's thesis. Instead, inferences about the impacts of the ARRA financing will be discussed further in Chapters 5 and 6.

## Chapter 4: Data Sources, Characteristics, and Use

Chapter 4 will start with a discussion of the characteristics of the data set as a whole, and how the dataset is categorized, including broad overviews of what 20 years of business data can show political scientists. Next it will discuss four specific quirks in the dataset and the impact those could have on the validity of the results of this study, and how these quirks were adjusted for. Chapter 4 will conclude by looking at the broad energy market trends in California over the 20 year test period of this study and establishing how those trends relate to business trends in general in California and the United States.

### 4.1 Characteristics of the Study Sample

The original LLC database contains 1,772,543 total records dating back to 1984. My first step was to isolate the data in the years and geography I was interested in studying, 1996 through 2016 with a "Domestic Entity" filing type. This was done using a simple query function in Access resulting in 1,231,989 records that could potentially be relevant to this study. The open-ended "business type" question in the database has gathered a sizeable portion of businesses, totaling 332,610 out of those 1,231,989 "domestic" records (or 27%) having either a blank description or amusing yet ultimately unhelpful descriptions such as "all legal business activity", leaving 889,389 records from which to query. After running the initial query, 19,173 records were left to be categorized.

After the extensive categorization process described in Chapter 3 was completed, a total of 2,930 California Energy LLCs registered between January 1, 1996 and December 31, 2016 were identified and categorized. Of these, 1,280 had statuses that indicated they were "successful"[45]. However, there are several quirks with this data set that still needed to be addressed before establishing it as the final sample for analysis.

*Active vs. Inactive Companies*

As discussed in Chapter 3, I used the "status" column of the LA Times LLC Dataset to determine whether a company should be considered successful for the purpose of this study. It is worth reiterating that the original database represents the status of these companies as of March 2018 when it was compiled. In the course of my research, I discovered several companies that had a status listed in the database indicating it was unsuccessful that were reactivated sometime before Winter of 2021. Likewise, companies that had statuses in March 2018 that would be considered successful by the standards established in Chapter 3 have since failed by those same standards. Because of the extenuating circumstances of the economic downturn caused by the COVID-19 pandemic, I decided to take the data as it is in the LA Times Database and not attempt to adjust it based on new information. This means that the final metric of "successful" company in this study would more accurately be stated as "company that was successful as of March 2018".

*Out of State Listed as Domestics*

Another quirk of this data appears to be an oversight on the part of the state of California. Of the 1,280 domestically-filed companies listed as successful, 153 had a business addresses that was out-of-state. Because this study is meant to look at the impact on LLCs registered by Californians specifically, I chose to pull these records out of the data for the final analysis, leaving the dataset with 1,127 companies listed as successful.

[45] Refer to Appendix B.

*Categorizing Multis and Unknowns*

88 of the remaining 1,127 successful energy LLCs in this dataset I was not able to categorize due to lack of information. The descriptions provided make it clear they belong in scope, but Google search results were fruitless in bringing up specifics on the company. It appears some of these companies were registered by individuals previously involved in the energy sector who have since left but maintain a consulting relationship with their former employers, however the exact nature of their work was uncertain, and I did not want to guess at the risk of harming the reliability of my data. It is important to note that I chose to keep these businesses in the data for internal validity purposes because they met all the other criteria to be included, and they could be considered to represent a margin of error for this study.

*ARRA Specific Companies*

As discussed in Section 3.10, the United States government provided direct financial investment to “Green” energy companies with the 2009 American Recovery and Reinvestment Act through various grant programs like SBIR/STTR. Only 3 California energy LLCs identified received ARRA funding. One, Jadoo Systems LLC, was founded in 2001 and had a record of success prior to the 2009 grant. The two others, Shakti Battery and Surprise Valley Geothermal, LLC, were both out of business by the time the LLC database was compiled and would not be considered active for the purpose of this study. Therefore, the ARRA’s direct funding program does not have a substantial effect on the results of this study[46].

## 4.2 Distribution of Power Sources in Active Companies Within Sample

In this subsection, I will present a broad overview of what California’s energy LLC market looked like at the time my dataset was compiled. I will show the breakdown of successful LLCs by their energy category: green and carbon-based energy, then present numbers and proportions of successful companies by specific fuel type. The purpose of this section is to give some

[46] other parts of the ARRA do have an impact on this study and will be discussed further in Chapter 6.

familiarity with the data and identify energy types that are likely driving trends with the hopes of establishing specific programs under the purvey of the GWSA that had the largest impact on energy market trends.

Tables 4.1 and 4.2 contain a breakdown of the total LLC dataset and the successful LLC dataset respectively, subdivided by fuel type. As you can see, the primary energy types driving the California market are Solar and Natural Gas. It stands to reason that most energy sector opportunity exists in these industries, as solar radiation and natural gas are two of California's most abundant natural resources[47].

**Table 4.1 All California Energy LLCs Registered Between 1996 and 2016 Inclusive by Energy Category and Fuel Type**

| Energy Category | Fuel Type[1] | Total Registered LLCs '96-'16 | % of the Energy Category | % of the Whole Energy Market |
|---|---|---|---|---|
| | *Natural Gas* | *649* | *79.9%* | *22.2%* |
| | *Biomass and Waste* | *152* | *13.8%* | *5.2%* |
| | *Multi* | *37* | *5.3%* | *1.3%* |
| | *Coal* | *7* | *0.9%* | *0.2%* |
| Carbon Energy Subtotal | | 845 | 100.0% | 28.8% |
| | *Solar* | *1,360* | *79.3%* | *46.4%* |
| | *Wind* | *164* | *9.6%* | *5.6%* |
| | *Hydroelectric* | *62* | *3.6%* | *2.1%* |
| | *Multi* | *56* | *3.3%* | *1.9%* |
| | *Geothermal* | *30* | *1.8%* | *1.0%* |
| | *Nuclear* | *19* | *1.1%* | *0.6%* |
| | *Unknown* | *13* | *0.8%* | *0.4%* |
| | *Fuel Cell* | *10* | *0.6%* | *0.3%* |
| Green Energy Subtotal | | 1,714 | 100.0% | 58.5% |
| Unknown | | 371 | 100.0% | 12.7% |
| **Total Market** | | **2,930** | **--** | **100.0%** |

[47] 3 of the 10 sunniest cities in the United States are in California (NOAA) and California withdraws over 12 billion cubic feet of natural gas every month (US-EIA)

**Table 4.2 Successful California Energy LLCs Registered Between 1996 and 2016 by Energy Category and Fuel Type**

| Energy Category | Fuel Type[1] | Total Successful LLCs | % of the Energy Category | % of the Whole Energy Market |
|---|---|---|---|---|
| | *Natural Gas* | *255* | *79.9%* | *22.6%* |
| | *Biomass and Waste* | *44* | *13.8%* | *3.9%* |
| | *Multi* | *17* | *5.3%* | *1.5%* |
| | *Coal* | *3* | *0.9%* | *0.3%* |
| Carbon Energy Subtotal | | 319 | 100.0% | 28.3% |
| | *Solar* | *621* | *86.3%* | *55.1%* |
| | *Wind* | *39* | *5.4%* | *3.5%* |
| | *Multi* | *26* | *3.6%* | *2.3%* |
| | *Hydroelectric* | *16* | *2.2%* | *1.4%* |
| | *Geothermal* | *9* | *1.3%* | *0.8%* |
| | *Unknown* | *6* | *0.8%* | *0.5%* |
| | *Fuel Cell* | *2* | *0.3%* | *0.2%* |
| | *Nuclear* | *1* | *0.1%* | *0.1%* |
| Green Energy Subtotal | | 720 | 100.0% | 63.9% |
| Unknown | | 88 | 100.0% | 7.8% |
| **Total Market** | | **1,127** | **--** | **100.0%** |

1 See Table 3.1 for descriptions of the Fuel Types

### 4.3 BLS and Data on How Many Companies Fail

By choosing only to look at businesses that were still in operation in 2018 or had been converted or merged out, I could be creating a bias towards newer companies which would skew my results data in favor of confirming my hypothesis. After all, the longer a business has been around, the more chances are for something to go wrong, or for its market to dry up. To combat this, I will be utilizing data from the US Bureau of Labor Statistics that tracks the annual number of business registrations across the country, as well as the age of all established businesses each year. Unfortunately, this data is not available broken down by state. Therefore, in the following section, I will establish that the survival rate of California LLCs correlates well enough to the survival rate of all US businesses that it can be used to approximate how many of the total number of California energy LLCs remained, or will remain, in operation for at least 10 years.

By setting a mark of "survived for 10 years", we can assume that a business was profitable, and therefore successful, for at least some of those years, to secure a livelihood for its owner. This will adjust for businesses that closed due to factors unrelated to the market, such as death or retirement of ownership for businesses formed in the early years of the study and adjust for businesses registered in the later years of the study that might still have runway from initial capital but aren't generating sufficient revenue to seriously be considered successful.

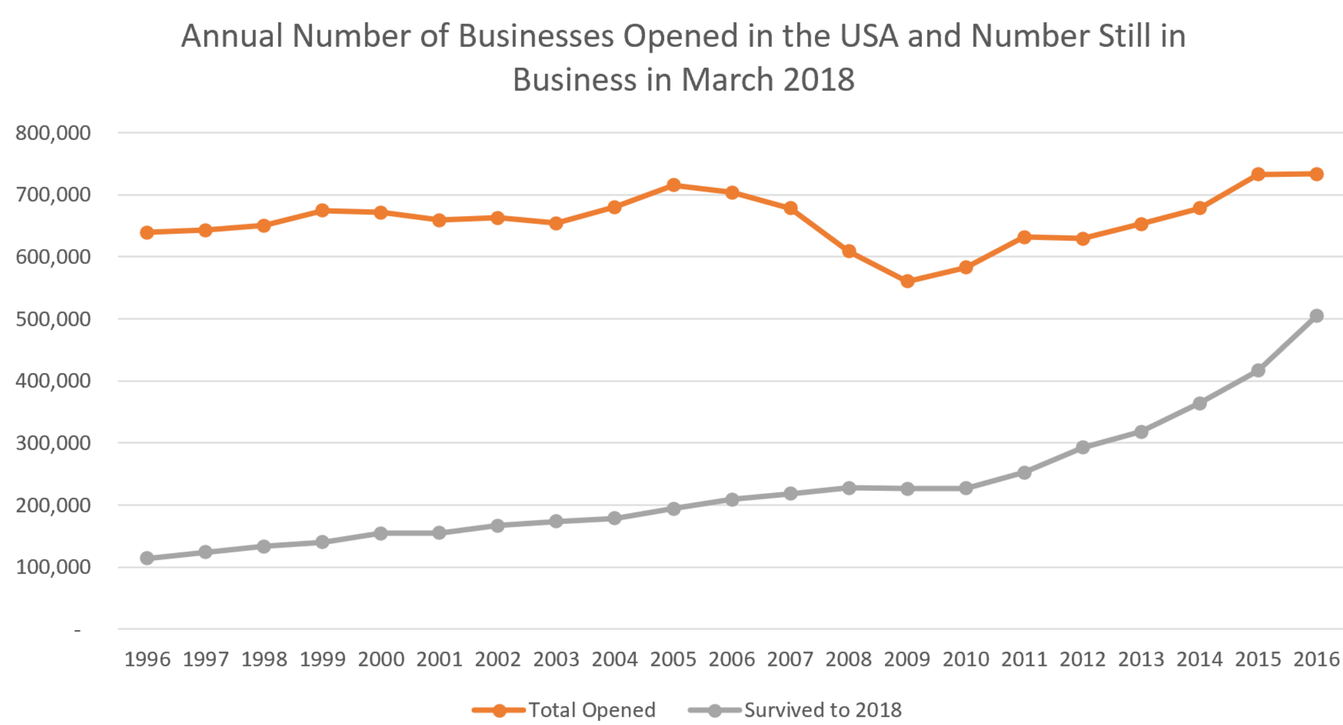


*Figure 4.1 Survival Rate of New Businesses Registered in the US, by Year. (Bureau of Labor Statistics, 2020) Notice how measuring only the number of businesses surviving in 2018 could bias results towards confirming that more successful businesses were opened in the later years of this study.*

In the following few paragraphs, I will first provide a comparison of the survivorship rates of California energy LLCs relative to all California LLCs to prove that there is no difference in survivorship rates between any California LLCs and that trends in the California LLC market can be used to broadly compare to national business survival statistics. Next, I will show a correlation between survivorship rates of California LLCs vs. those registered in the United States to show that California businesses follow the same broad trends as all new businesses within the United States regards to length of time in business. Using this, I will then show that we can use the estimate that 33.6% of all California energy LLCs will survive 10 years, for the purpose of testing in Chapter 5.

a) *Establish that California Energy LLCs have the same rate of success, year-to-year, as all California LLCs.*

As we can see below in Figure 4.3, the percentage of California Energy LLCs that failed based on registration year almost perfectly correlates to the percentage of all California LLCs that failed based on registration year, with an r2 of .968. Energy LLCs have seemingly done no worse or better than all other LLCs in the 20-year course of this study, thus the findings are sound within the context of the Californian economy.

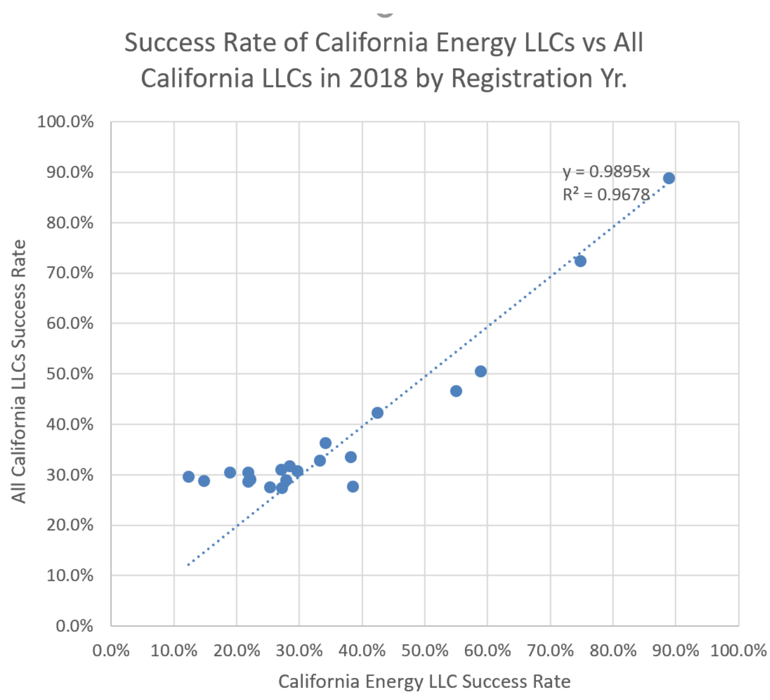


*Figure 4.2: Correlation of the success rate of California Energy LLCs and California LLCs for all industries based on year registered. Each dot represents 1 year.*

This trend also holds when energy LLCs are divided by the green and carbon categories, although the correlations are not as statistically significant, especially with green energy[48]. This may be the result of a low sample size. These correlations prove something important for establishing validity in the results: that energy LLCs are no more, or less, likely to succeed than an LLC in any other industry when registered in California and thus statistics comparing California's LLC success rate with other states or the national rate can be reasonably used to make generalizations about the California energy industry.

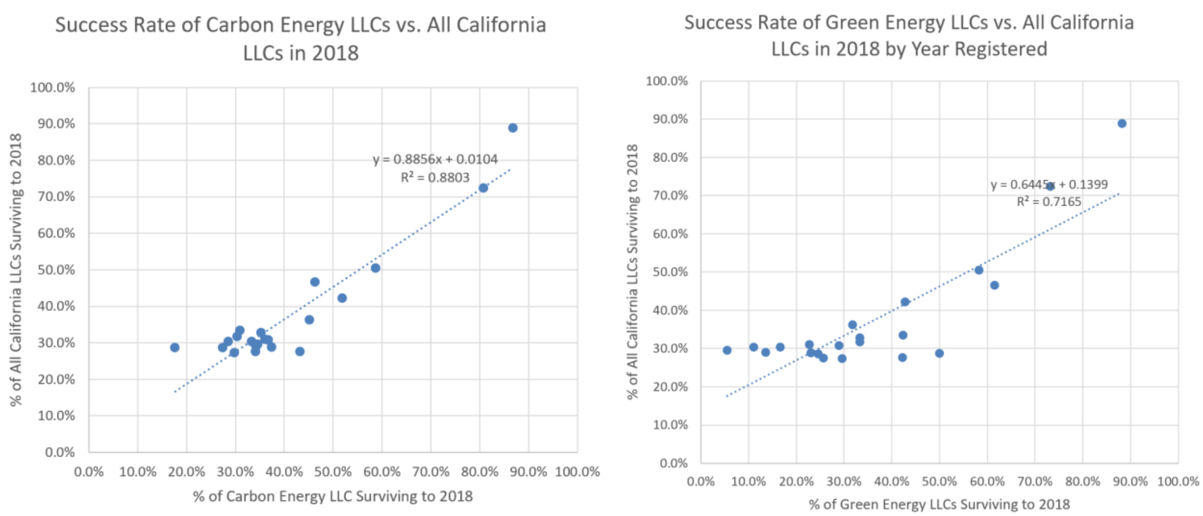


*Figure 4.3 Correlation of Success Rate of Carbon Energy LLCs and Green Energy LLCs respectively to All California LLCs. Each dot represents 1 year. Much of the correlation between California Energy LLCs and California LLCs appears to be driven by Carbon-based businesses, although Green Energy businesses have a much lower sample size prior to 2006.*

b) *Establish that California LLCs are Succeeding at Roughly the Same Rate as All American Businesses*

According to the Bureau of Labor and Statistics (BLS), across the whole American economy, of the 609,638 new businesses operating in March of 1996, only 436,505 (71.6%) were still operating three years later, and only 203,390 (33.3%) were still in operation after ten years (Bureau of Labor Statistics, 2020). In fact, since the BLS began tracking business age at the national scale, there has been remarkable consistency in the failure rate of private firms. Around

[48] nor is it nearly a one-to-one correlation, with green energy LLCs underperforming other types of businesses.

two-thirds of all registered firms will fail within 10 years in the United States and there is little significant fluctuation in this rate during recessions or boom years. Figure 4.5 shows a correlation between the failure rate of California LLCs and the failure rate of all American businesses per the BLS, based on year registered.

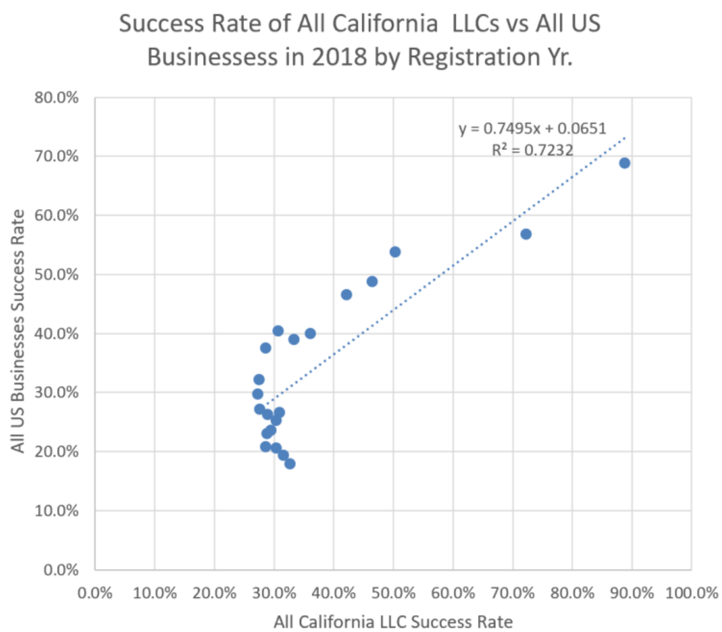


*Figure 4.4 Correlation between the success rates of California LLCs and All US Businesses in 2018, based on year registered.*

The correlation between US and California business failure rates is strong, with an r2 of .7532. It should be sufficient to use BLS annual business failure rates data for adjustments to the California LLC database results to remove potential recency bias. In Figure 4.5 I have used the BLS data to determine the rate of businesses that survive to 10 years. This will be used to estimate how many of the 2,930 total energy LLCs registered in California during the study period had survived, or will survive, at least 10 years in the results below, as a validity check.

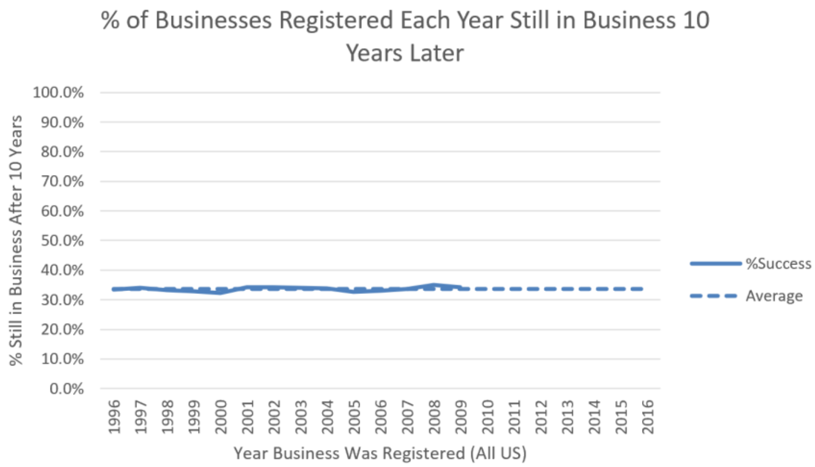


*Figure 4.5 10-Year Success Rate of American Businesses, Registered per Year. Shows remarkable consistency, and a 33.6% average success rate is a viable estimate to adjust data.*

## **Chapter 5: Data Analysis and Results**

This section will detail the results from analyzing the data and tying those results back to the hypothesis. Section 5.1 will look at the twenty-year trends in successful new energy LLC registrations for companies working in both the green and carbon energy industries, first as raw numbers of companies, then as proportions of both the energy sector and all LLC registrations and finally the year-to-year growth rate across all sectors to identify if specific sectors have grown relative to the whole energy market and whole small business market.

The final two sections of this chapter will address two validity tests performed to ensure that a causal mechanism can be reasonably implied. First, the problem of potential recency bias in the data will be addressed by comparing California energy LLC success rates with data collected on business success rates by the BLS to show that even adjusting registrations data to mirror the historic ten-year success rate of companies keeps the results of these data, and conclusions drawn from it, robust. Finally, there will be a test controlling for the impact of the Million Solar Roofs initiative on the trends in successful green energy LLCs.

## 5.1 Green and Carbon Energy LLC Trends

Figure 5.1 shows a trend of the number of successful new energy LLCs registered between 1996 and 2016 in California per economic quarter.

From this graph, it would appear as though the GWSA indeed was a catalyst for an increase in new business registrations in the green energy industry. Starting in Q1 of 2007, the number of successful green energy businesses registered annually has skyrocketed, and by 2016, there was a ten-fold increase in the average number of successful new green businesses registered quarterly.

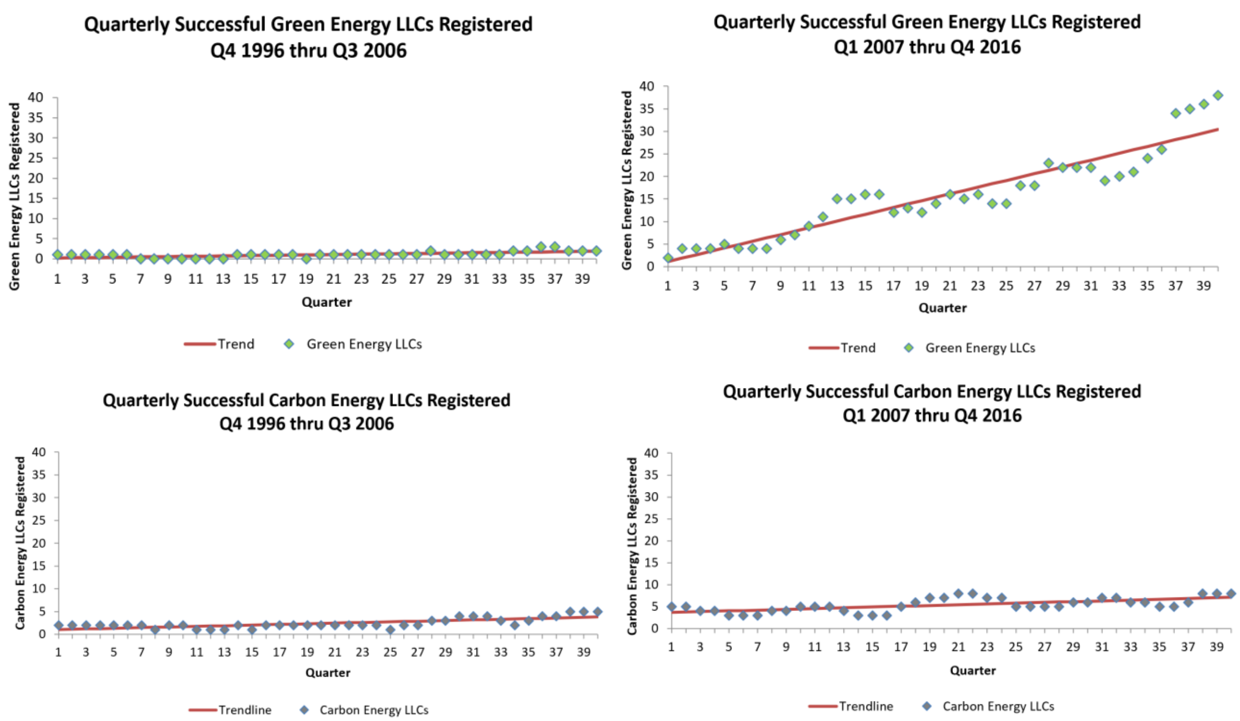


*Figure 5.1 Trend in the quarterly registration of successful energy LLCs. GWSA passed Q4 of 2006, pre-GWSA data is on the left, post-GWSA data on the right.*

Statistical analysis shows this growth is highly statistically significant, with the slope of the trend line, in this case representing growth in average number of quarterly green energy LLC registrations, exceeding both the growth in registration numbers of carbon businesses over the same period (Q1 2007 to Q4 2016), AND the growth rate of green businesses from Q4 1996 to Q3 2006, as demonstrated in Table 5.1.

**Table 5.1 Statistical Data for quarterly growth in new energy LLC registrations, divided by Energy Category.**

| Energy Category | Time Period | Trendline Equation | $r^2$ | Conclusion |
|---|---|---|---|---|
| Green | Q4 1996 - Q3 2006 | Y = 0.04x + 0.18 | 0.45 | Slight growth, moderate statistical significance |
| Green | Q1 2007 - Q4 2016 | Y = 0.75x + 0.36 | 0.87 | Strong growth, strong statistical significance |
| Carbon | Q4 1996 - Q3 2006 | Y = 0.07x + 0.98 | 0.53 | Slight growth, moderate statistical significance |
| Carbon | Q1 2007 - Q4 2016 | Y = 0.09x + 3.6 | 0.42 | Slight growth, moderate statistical significance |

*The GWSA (independent variable) was introduced in Q4 of 2006. $p<0.05$ in all cases. Full statistical readouts from the Excel analysis available in Appendix C.*

These data would seem to indicate that the passage of the GWSA induced a profound and statistically significant growth in new green energy LLC registrations. This result also is indicated when looking at the *proportion* of new energy LLCs that were classified as green and carbon over time, shown below in Figure 5.2.

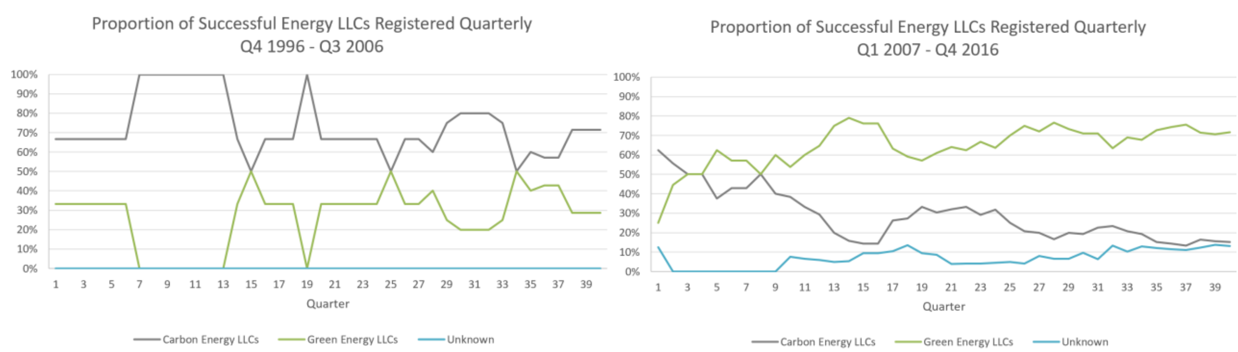


*Figure 5.2 Trend in the proportion of successful energy LLCs registered quarterly. GWSA passed Q4 of 2006, pre-GWSA data is on the left, post-GWSA data on the right.*

Looking at the proportion of new successful energy businesses, we can see a marked shift in registrations in the year following the passage of the GWSA, where green and carbon-based energy business registrations effectively swap proportionalities and level out to a “new normal”. Even if the energy businesses for which I could not determine a specific energy source were all carbon-based energy, it would not alter the message from the data: there was a fundamental shift in California's energy LLC market that coincides with the passage of the GWSA.

A further look comparing the proportion of successful green and carbon energy LLCs relative to all successful LLCs registered in California over the same timespan, Figure 5.3, shows a sustained increase in the share of new companies that were involved in green energy after the passage of the GWSA, with a peak in 2010 of 0.30% of all successful California LLCs registered that year being green energy companies, before leveling off to a proportion roughly five-times greater than it was in the decade prior to the passage of the GWSA.

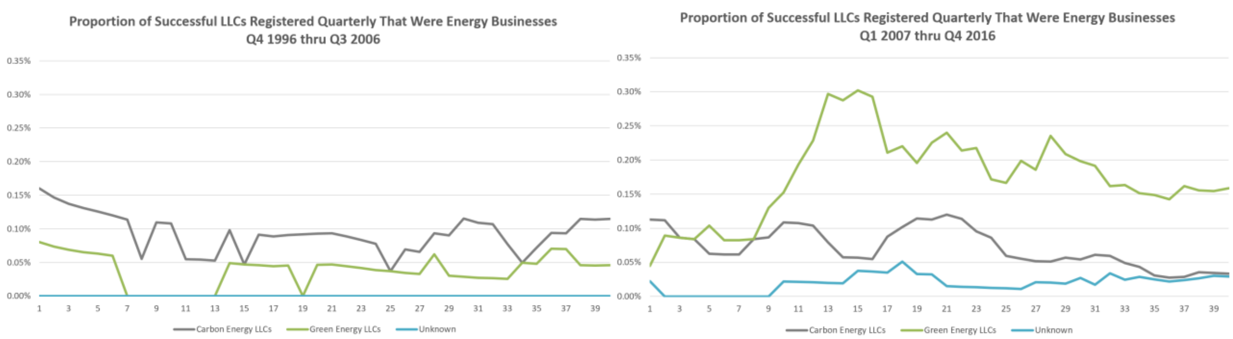


*Figure 5.3 Trend in the proportion of all successful LLCs by quarter that were energy businesses. Pre-GWSA data on the left, post-GWSA data on the right.*

These data show a decrease in the proportion of new LLCs that were involved in carbon-based energy, but one that is markedly less stark than the increase in the proportion of new green energy LLCs. Thus, it would appear that the overall proportion of new energy LLCs registered annually has increased coinciding with the passage of the GWSA in 2006. The implication of this will be discussed in Chapter 6.

**5.2 Establishing Validity – Results Remain Robust When Corrected for Recency Bias**

The biggest criticisms of looking at registration trends of successful small businesses over a period of time are recency and survivorship bias. Defining success as either still in operation in 2018 or merged out or sold inherently biases the data towards younger companies. Given the unique business structure of LLCs detailed in Chapter 3, a company can cease to exist for a number of reasons completely unrelated to market forces, such as the death of the owner or simply the completion of the project for which the company was founded in the first place.

To prove the data is robust, I will adjust the California energy LLC data to reflect the average 10-year survivorship rate of all companies registered in a given year. That is, functionally defining success as “a company that generated enough revenue to stay in business for 10 years.”

Using the actual success rate data from BLS from the years 1996-2009, and using the average 10-year success rate across that timespan of 33.6% to estimate the 10-year success rate of new energy LLCs registered between 2010-2016, we can confidently estimate how many California LLCs remained in business (or will remain in business) for at least 10 years. In Figure 5.4, I used these figures to estimate the number of carbon and green energy LLCs that survived at least 10 years after registration, again divided by which quarter they were registered in.

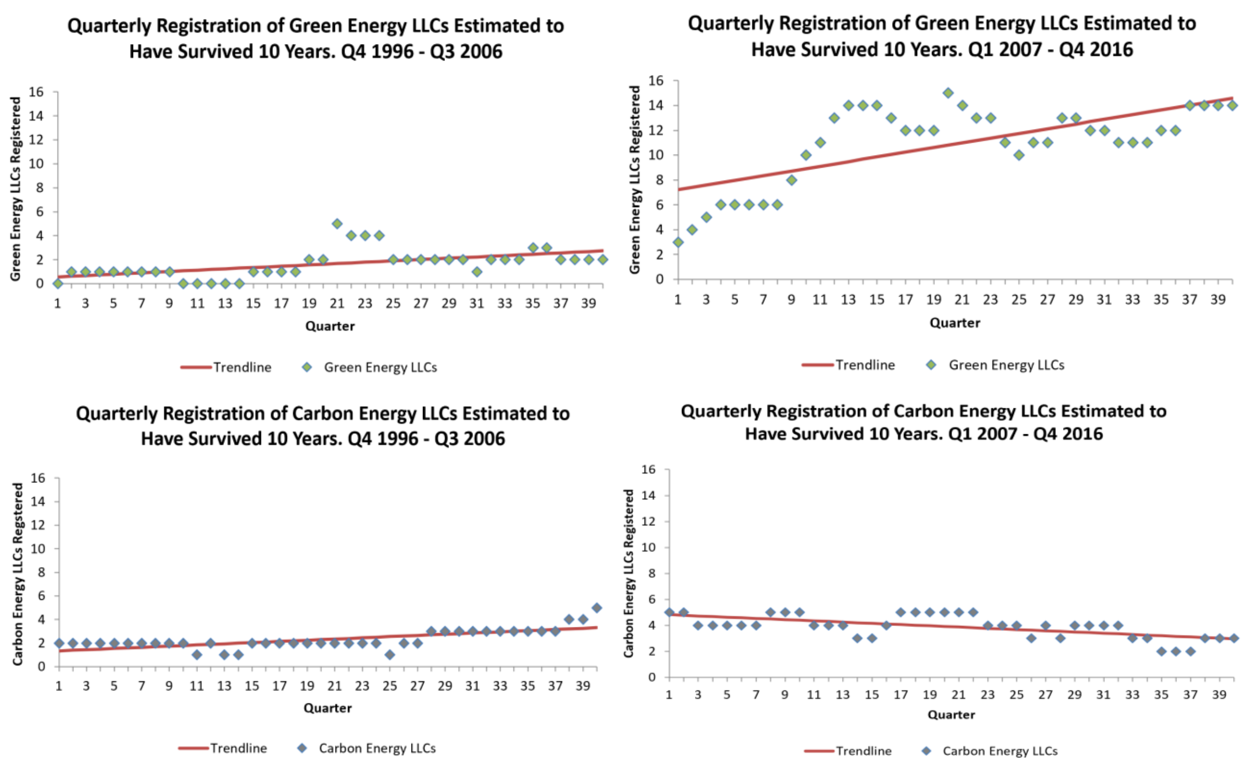


*Figure 5.4 Trend in estimated registration of California energy LLCs that survived 10-years based on all registered LLCs regardless of status in 2018. The transition to a majority of*

*successful companies being green energy based occurring after the passage of the GWSA remains.*

**Table 5.2 – Statistical Data for quarterly growth in new energy LLC registrations for companies estimated to have survived at least 10-years, divided by Energy Category.**

| Energy Category | Time Period | Trendline Equation | $r^2$ | Conclusion |
|---|---|---|---|---|
| Green | Q4 1996 - Q3 2006 | Y = 0.05x + 0.51 | 0.30 | Slight growth, moderate statistical significance |
| Green | Q1 2007 - Q4 2016 | Y = 0.19x + 7.02 | 0.47 | Clear growth, moderate statistical significance |
| Carbon | Q4 1996 - Q3 2006 | Y = 0.05x + 1.29 | 0.51 | Slight growth, moderate statistical significance |
| Carbon | Q1 2007 - Q4 2016 | Y = -0.05x + 4.58 | 0.38 | Slight **negative** growth, moderate statistical significance |

As we can see, even when forecasting the success rates, the change in green energy LLCs is still profound after 2006. It is impossible to objectively state energy businesses registered in the 2010s will always fail at the same rate as LLCs in those industries have in the past. However, the strength of the correlations tying their previous success rates to those of other businesses in both California, and the United States as a whole, over a 20-year timespan show that in the *most likely scenario* the transition from a majority of successful California energy LLCs registered every quarter being carbon based to being green energy based will remain significant. Carbon energy might even trend slightly downward.

In these data, we see a stark leap in the number of green energy LLCs first 8 quarters of the post-GWSA test before it levels off to a new normal, as indicated in Table 5.2 which shows flatter growth for green energy LLCs after the passage of the GWSA than in Table 5.1, but with a high intercept.

**5.3 Establishing Validity – Results Are Altered When Correcting for Other Legislation**

Finally, in order to have an idea of the impact of the GWSA itself, we must correct for one piece of legislation passed outside the purvey of AB32: the California-specific Million Solar Roofs initiative. Since it is impossible looking only at business registration data to determine which solar energy LLCs were registered in response to the GWSA vs Million Solar Roofs[49], I have chosen to instead remove ALL solar LLCs from the "green" category and showing the carbon and green trends without solar LLCs considered. If the induced innovation hypothesis holds, the GWSA should have induced innovation in these non-solar green energy industries as well, even without the benefit of a massive tax benefit program for adopting the new tech.

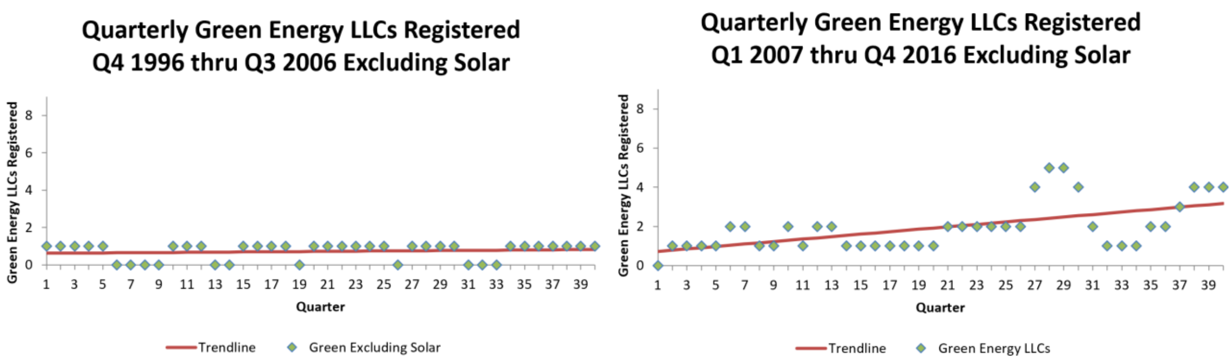


*Figure 5.5 Trends in sucessful green energy LLCs that are NOT solar companies. Refer to Figure 5.1 for the Carbon LLC data, which is identical.*

**Table 5.3 -- Statistical Data for trend in quarterly new non-solar energy LLC registrations**

| Energy Category | Time Period | Trendline Equation | $r^2$ | Conclusion |
|---|---|---|---|---|
| Green | Q4 1996 - Q3 2006 | Y = 0.01x + 0.62 | 0.02 | No statistically significant trend. P > 0.05 as well |
| Green | Q1 2007 - Q4 2016 | Y = 0.06x + 0.66 | 0.35 | Slight growth, moderate statistical significance |
| Carbon[1] | Q4 1996 - Q3 2006 | Y = 0.07x + 0.98 | 0.51 | Slight growth, moderate statistical significance |
| Carbon[1] | Q1 2007 - Q4 2016 | Y = 0.09x + 3.6 | 0.38 | Slight growth, moderate statistical significance |

1 Data is identical to Table 5.1.

As you can see, solar is the primary driver for growth in small business registrations in California's green energy sector. There is still an increase in the raw number as well as the proportion of new LLC registrations in green energy after the passage of the GWSA, indicating the carbon price and non-solar green energy projects and subsidies have helped some, although

49 in fact, as I will discuss in Chapter 6 it is likely the two worked in conjunction to create a vibrant market where new businesses could thrive.

the effect is clearly muted. At no point does the growth trend outpace carbon energy, although the difference is functionally negligible.

Also of note, at no point in the data set controlling for solar energy does the proportion of new, successful, green energy LLCs exceed that of carbon-based energy LLCs, although there are several quarters where registrations for each category are identical.

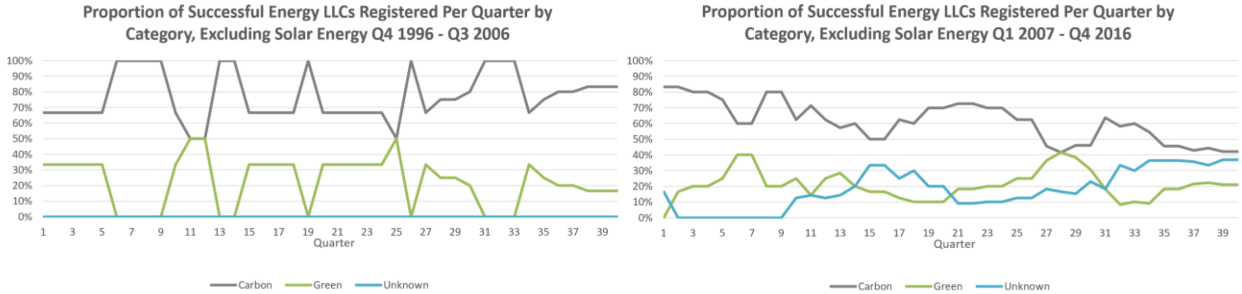


*Figure 5.6 Trend in the proportion of successful energy LLCs registered quarterly, with solar energy companies removed. 4-quarter rolling average.*

## **Chapter 6: Conclusions**

This chapter will attempt to draw some conclusions from the results of the data testing in the previous chapter. First will be an assessment of the impact of the Global Warming Solutions Act on small business innovation in California's energy sector, followed by an assessment of the impacts other programs had on the results of this data. The third section will be a final assessment of the results of this study, drawing a final conclusion on the veracity of the induced innovation hypothesis as proposed by economists in support of carbon pricing. Finally, there will be a section discussing potentially interesting follow-up studies.

### **6.1 Impact of the GWSA and Related Programs**

From the data, it seems clear that 2006 was a turning point for small business innovation in green energy in California. The year after the GWSA was signed into law, establishing a firm cap on carbon emissions across the economy, green energy LLCs became the majority of all new energy companies registered annually, a shift that, with 10 years of data, appears to be permanent.

Likewise, growth in green energy LLC registrations as a proportion of all LLC registrations began to increase in the mid ‘00s, before spiking to an all-time high in 2010 then leveling off to a new “normal” that was a rate of roughly 5x what it was once the GWSA cap and trade program was in full effect.

Other programs recommended by the scoping document for the GWSA that were signed into law in the years following the GWSA don’t appear to have individually dramatically impacted the growth trends in green energy LLC registrations that started in 2006, but nonetheless play an important role in the GWSA itself – it showed that the government of California is committed to a stable, planned, and transparent phasing in of increasing standards, which removes some of the inherent risk of the unknown associated with entrepreneurship. A clear standard for carbon emissions on a 15-year horizon, with requirements for adjustments to a 25-year and 45-year horizons forthcoming as established by the GWSA and associated executive orders, combined with regulatory alignment between public and private utilities as detailed in SB1368, commitments to green energy investment in SB 535 and SB X1-2, and deregulation of building and financing small-scale power projects on private property in AB 811 can be said to be correlated with the boom in green energy companies in the years from 2007 through 2016.

**6.2 Impacts of Other Programs**

However, establishing correlation and causation are different beasts. There are two main factors why I think saying the GWSA **can not** be labeled as the specific, or even the predominant *cause* of this dramatic change: the Million Solar Roofs program and the American Recovery and Reinvestment Act.

*Impact of Million Solar Roofs*

The Million Solar Roofs program was signed into law one month prior to, and thus separately from, the GWSA. This program, which was declared an overwhelming success in 2019 installing *triple* the amount of gigawatts worth of solar energy as originally planned (USC Schwarzenegger Institute, 2019), offered US$3 billion in direct investment into solar panel installation in the form of tax incentives for Californian property owners. The timing and impact of this program specifically does make it difficult to draw a conclusion that the emissions cap-and-trade system was the primary driving force behind the rapid growth in new green energy LLCs after 2006. This is especially true given how many new green energy companies are involved in solar panel development, design, and installation[50]. It is unreasonable to assume the program had no impact, but so too is it unreasonable to assume the Million Solar Roofs program was the sole driver behind these changes either. The simple math of an increased price of carbon-based energy caused by the GWSA and the financial incentives decreasing the price of installing solar energy made the programs more lucrative working in conjunction than separately.

It is also erroneous to think that policy is the *only* factor in why solar energy companies make up the lion's share of new green energy LLCs, and new energy LLCs in general. The nature of photovoltaic technology itself makes it much easier to have small-scale operations[51] than would, say, a biomass facility. This makes the barrier of entry into the industry much lower for small businesses. Solar energy is also an abundant resource in California, and a reliable one, with Los Angeles having 283 sunny days per year (BestPlaces, 2016). Changing consumer attitudes is also a common effect in the growth or shrinkage of certain industries, and any one of a number of factors, including a desire to be less reliant on a public grid prone to natural and man-made disasters and wanting to transition to a "greener" lifestyle. Further study would be required to determine all the factors that have driven California's solar energy LLC revolution, and to what degree.

*Impact of the ARRA*

The American Recovery and Reinvestment Act was passed two and a half years after the GWSA, and a scant two months after CARB released its scoping document. As we saw in the data, the year following those two events, 2010, represents the peak and new plateau in the number of successful new energy LLCs being registered quarterly that were green when corrected for a 10-

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[50] accounting for upwards of 95% of new green energy LLCs registered in some years, and as we saw in the previous chapter, without solar energy companies, the rolling-average number of new green energy LLCs registered quarterly in California never once exceeded the number of carbon-based energy ones.

[51] such as a rooftop array on a family home.

year survival estimate. Refer back to figure 5.4 where point 11, which in the 4-quarter rolling average represents the average number of new businesses registered each quarter in 2009, is the new high that maintains itself through the remaining 29 quarters of the study. As with the Million Solar Roofs program, it is impossible to accurately portray the specific impact of the ARRA on LLC registration in California, as it worked in conjunction with the goals and policies set out in the GWSA and supporting laws. While direct funding provided to California energy LLCs through the SBIR/STTR program probably did not have a profound impact[52], direct funding provided to county and city governments for green energy projects absolutely did. This poses a problem for researchers trying to get a clear view on where LLC growth is coming from with regards to the GWSA. The GWSA specifically sets requirements for public power projects to produce 33% of their energy from non-carbon sources and provides a small bit of funding to do so, but with the addition of the ARRA money, it is not entirely self-funded by the state of California.

The ARRA also offers federal tax breaks for companies or consumers that invest in green power, which could be taken in addition to state tax breaks, increasing the immediate financial benefit of investing in new technologies, which further compounds with the additional cost of the carbon-taxed traditional fuel. From the perspective of determining whether a societal trend is the result of a single policy, however, this muddies the water. As with the Million Solar Roofs program, it is likely the additional funds from the ARRA worked in conjunction with the provisions of the GWSA to spur opportunities for new small businesses. Further study would be needed to determine the direct impacts of the ARRA and GWSA each had.

### 6.3 Final Conclusions on the Hypothesis – Is Carbon Pricing a Useful Mechanism for Inducing Innovation?

In a word, yes, but carbon pricing alone cannot be said to be the cure all and is best supplemented by opening new streams of revenue into inducing the development and deployment of novel technologies, in line more with what Mazzucato proposes in her theory on

[52] as discussed in Chapter 3, only 1 successful energy LLC received such funding, most money for R&D and direct investment went to universities and established corporations.

government as an entrepreneur, and less with the classical neoliberal model that the carbon price alone is sufficient to induce significant innovation.

The GWSA uses the carbon price to establish a firm carbon reduction goal on a timeline that allows the market to adjust and plan accordingly, which sets the motivation for change. However, the GWSA *also* commits funding and regulatory changes that reduces the financial risk of investing in new technology and creates a new customer base in the form of both municipal energy projects AND individual citizens looking to take advantage of tax relief programs. Further, just as the GWSA cap-and-trade was coming online, California received a net of roughly US$2.5 billion from the US Department of Energy towards energy-related projects, including many municipal power plants, which most assuredly created conditions that helped push some companies to viability that otherwise would have failed or never been created at all. The GWSA itself allows for the creation of an additional energy fund financed through the sale of emissions allowances, meaning that the money raised from pricing carbon does, in part, get cycled back into green energy projects.

Thus, the conclusion would be that a *combination* of a carbon price and government spending on energy infrastructure effectively spurs small business innovation and expands opportunity for entrepreneurs, and policymakers looking to design such a program should be especially cognizant of directing funds raised off the carbon price towards business and innovation if they wish to open up such channels of opportunity for their constituents. This finding is also in line with the conclusions of the quantitative studies by Weigt et al (2013) and Enevoldsen et al (2007) on energy production and emissions reduction under European carbon pricing schemes, as well as the qualitative study by Gianoli and Bravo (2020) on industry in Rotterdam.

**6.4 Recommendations for Further Study**

There is a wealth of potential follow up studies on business innovation that this study only scratched the surface of. Political scientists interested in the impacts of carbon pricing policies on different business structures might wish to do a comparison study of California corporations and California LLCs and changes in registration rates between green and carbon energy companies.

Still others may wish to compare the different impacts on new business innovation between California's "tax and invest" approach to carbon, to a program like British Columbia's "tax and redistribute" approach where the money raised from the carbon tax is returned as a dividend to all residents to spend as they see fit. The GWSA's commitment to clean energy projects in disadvantaged communities would be an interesting field of study for researchers interested in climate justice, especially to see if these municipal projects are expanding entrepreneurial opportunities for disadvantaged peoples. The size and strength of California's economy also means policy passed there has a ripple effect throughout the US economy. Studies of energy standards and small businesses in the other states in the Western US, especially those which actively align their own GHG emissions standards to CARB's could offer a wealth of knowledge not just on the economic impacts of climate policy, but increase and modernize our understanding of federalized countries in general.

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## Appendix A: MS Access SQL Code to pull the data sample

#### Pull Business descriptions with relevant keyphrases for easier identification

```
SELECT LPMasterBusinessTypesandCounts.llc_type_of_business,
    Sum(LPMasterBusinessTypesandCounts.CountOfname) AS SumOfCountOfname
FROM LPMasterBusinessTypesandCounts
GROUP BY LPMasterBusinessTypesandCounts.llc_type_of_business
HAVING (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*SOL*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*WIND*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*GREEN*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*ENERG*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*ENV*")) or
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*ELECTRIC*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*POWER*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*BATTER*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*PWR*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*FUEL*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*CARBON*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*NRG*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*SUN*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*TURBINE*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*HYDRO*"))  OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*GEOT*"))  OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*NUCL*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*NUKE*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*GAS*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*COAL*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*GENERAT*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*PLANT*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*PWR*"))  OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*TANK*")) OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*PROPANE*"))  OR
    (((LPMasterBusinessTypesandCounts.llc_type_of_business) Like "*HEAT*"));
#### After categorizing business descriptions into YES/NO/MAYBE tie remainder to pull the individual companies
    for the final data sample, ready to classify energy category and fuel types

SELECT LPMASTER.file_number, LPMASTER.file_date, LPMASTER.status, LPMASTER.filing_type,
    LPMASTER.name, LPMASTER.mailing_address, LPMASTER.mailing_city, LPMASTER.mailing_state,
    LPMASTER.mailing_zip, LPMASTER.llc_type_of_business, Descriptions_Tagged.llc_type_of_business,
    Descriptions_Tagged.Scope, Descriptions_Tagged.[Energy Type], Descriptions_Tagged.[Green?],
    Descriptions_Tagged.Field6
FROM Descriptions_Tagged INNER JOIN LPMASTER ON Descriptions_Tagged.llc_type_of_business =
    LPMASTER.llc_type_of_business
GROUP BY LPMASTER.file_number, LPMASTER.file_date, LPMASTER.status, LPMASTER.filing_type,
    LPMASTER.name, LPMASTER.mailing_address, LPMASTER.mailing_city, LPMASTER.mailing_state,
    LPMASTER.mailing_zip, LPMASTER.llc_type_of_business, Descriptions_Tagged.llc_type_of_business,
    Descriptions_Tagged.Scope, Descriptions_Tagged.[Energy Type], Descriptions_Tagged.[Green?],
    Descriptions_Tagged.Field6;
```

**Appendix B: California LLC Database "Activity" Descriptions**

| Activity Classification Code | Meaning | Detailed Description | Successful? |
|---|---|---|---|
| A | Active | Company is Active with up-to-date information | Yes |
| M | Merged out | Company has been merged into another entity | Yes |
| O | Converted out | Company has converted into a corporation | Yes |
| B | Dishonored Check | Company's filing payment was not acceptable | No |
| C | Canceled | Company license was canceled by owner(s) | No |
| D | Dissolved | Company was dissolved by the owner(s) | No |
| P | Pending Cancellation | Company has filed paperwork to cancel | No |
| F | Franchise Tax Board (FTB) Suspended/Forfeited | Franchise Tax Board has suspended or revoked the company's license to do business (usually due to tax issues) | No |
| S | Secretary of State (SOS) Suspended/Forfeited | Secretary of State has suspended or revoked the company's license | No |
| 2 | SOS/FTB Suspended/Foreited | Both the Franchise Tax Board AND Secretary of State have taken actions to suspend or remove the LLC's license | No |

Sourced from the PDF file entitled "LP-LLC-PRODUCT.INFO" in the LA Times Github database

## Appendix C: Original Data Tables and Full Statistical Outputs for Results

Table for Figure 5.1

| Quarter | Green LLC pre-GWSA | Green LLC post-GWSA | Carbon LLC pre-GWSA | Carbon LLC post-GWSA |
|---|---|---|---|---|
| 1 | 1 | 2 | 2 | 5 |
| 2 | 1 | 4 | 2 | 5 |
| 3 | 1 | 4 | 2 | 4 |
| 4 | 1 | 4 | 2 | 4 |
| 5 | 1 | 5 | 2 | 3 |
| 6 | 1 | 4 | 2 | 3 |
| 7 | 0 | 4 | 2 | 3 |
| 8 | 0 | 4 | 1 | 4 |
| 9 | 0 | 6 | 2 | 4 |
| 10 | 0 | 7 | 2 | 5 |
| 11 | 0 | 9 | 1 | 5 |
| 12 | 0 | 11 | 1 | 5 |
| 13 | 0 | 15 | 1 | 4 |
| 14 | 1 | 15 | 2 | 3 |
| 15 | 1 | 16 | 1 | 3 |
| 16 | 1 | 16 | 2 | 3 |
| 17 | 1 | 12 | 2 | 5 |
| 18 | 1 | 13 | 2 | 6 |
| 19 | 0 | 12 | 2 | 7 |
| 20 | 1 | 14 | 2 | 7 |
| 21 | 1 | 16 | 2 | 8 |
| 22 | 1 | 15 | 2 | 8 |
| 23 | 1 | 16 | 2 | 7 |
| 24 | 1 | 14 | 2 | 7 |
| 25 | 1 | 14 | 1 | 5 |
| 26 | 1 | 18 | 2 | 5 |
| 27 | 1 | 18 | 2 | 5 |
| 28 | 2 | 23 | 3 | 5 |
| 29 | 1 | 22 | 3 | 6 |
| 30 | 1 | 22 | 4 | 6 |
| 31 | 1 | 22 | 4 | 7 |
| 32 | 1 | 19 | 4 | 7 |
| 33 | 1 | 20 | 3 | 6 |
| 34 | 2 | 21 | 2 | 6 |
| 35 | 2 | 24 | 3 | 5 |
| 36 | 3 | 26 | 4 | 5 |
| 37 | 3 | 34 | 4 | 6 |
| 38 | 2 | 35 | 5 | 8 |
| 39 | 2 | 36 | 5 | 8 |
| 40 | 2 | 38 | 5 | 8 |

Statistics for Successful Green Energy LLCs Q4 1996 – Q3 2006

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.67 |
| R Square | 0.45 |
| Adjusted R Square | 0.44 |
| Standard Error | 0.56 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 0.17 | 0.18 | 0.91 | 0.37 | -0.20 | 0.53 |
| Quarter | 0.04 | 0.01 | 5.61 | 0.00 | 0.03 | 0.06 |

Statistics for Successful Green Energy LLCs Q1 2007 – Q4 2016

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.93 |
| R Square | 0.87 |
| Adjusted R Square | 0.87 |
| Standard Error | 3.37 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 0.36 | 1.09 | 0.33 | 0.74 | -1.84 | 2.56 |
| Quarter | 0.75 | 0.05 | 16.25 | 0.00 | 0.66 | 0.84 |

Statistics for Successful Carbon Energy LLCs Q4 1996 – Q3 2006

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.73 |
| R Square | 0.53 |
| Adjusted R Square | 0.52 |
| Standard Error | 0.78 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 0.98 | 0.25 | 3.88 | 0.00 | 0.47 | 1.49 |
| Quarter | 0.07 | 0.01 | 6.57 | 0.00 | 0.05 | 0.09 |

Statistics for Successful Carobn Energy LLCs Q1 2007 – Q4 2016

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.65 |
| R Square | 0.42 |
| Adjusted R Square | 0.41 |
| Standard Error | 1.22 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 3.60 | 0.39 | 9.16 | 0.00 | 2.80 | 4.40 |
| Quarter | 0.09 | 0.02 | 5.26 | 0.00 | 0.05 | 0.12 |

Table for Figure 5.2

| Quarter | Green % Energy Pre | Green % Energy Post | C % Energy Pre | C % Energy Post | Unk % Energy Pre | Unk % Energy Post |
|---|---|---|---|---|---|---|
| 1 | 33% | 25% | 67% | 63% | 0% | 13% |
| 2 | 33% | 44% | 67% | 56% | 0% | 0% |
| 3 | 33% | 50% | 67% | 50% | 0% | 0% |
| 4 | 33% | 50% | 67% | 50% | 0% | 0% |
| 5 | 33% | 63% | 67% | 38% | 0% | 0% |
| 6 | 33% | 57% | 67% | 43% | 0% | 0% |
| 7 | 0% | 57% | 100% | 43% | 0% | 0% |
| 8 | 0% | 50% | 100% | 50% | 0% | 0% |
| 9 | 0% | 60% | 100% | 40% | 0% | 0% |
| 10 | 0% | 54% | 100% | 38% | 0% | 8% |
| 11 | 0% | 60% | 100% | 33% | 0% | 7% |
| 12 | 0% | 65% | 100% | 29% | 0% | 6% |
| 13 | 0% | 75% | 100% | 20% | 0% | 5% |
| 14 | 33% | 79% | 67% | 16% | 0% | 5% |
| 15 | 50% | 76% | 50% | 14% | 0% | 10% |
| 16 | 33% | 76% | 67% | 14% | 0% | 10% |
| 17 | 33% | 63% | 67% | 26% | 0% | 11% |
| 18 | 33% | 59% | 67% | 27% | 0% | 14% |
| 19 | 0% | 57% | 100% | 33% | 0% | 10% |
| 20 | 33% | 61% | 67% | 30% | 0% | 9% |
| 21 | 33% | 64% | 67% | 32% | 0% | 4% |
| 22 | 33% | 63% | 67% | 33% | 0% | 4% |
| 23 | 33% | 67% | 67% | 29% | 0% | 4% |
| 24 | 33% | 64% | 67% | 32% | 0% | 5% |
| 25 | 50% | 70% | 50% | 25% | 0% | 5% |
| 26 | 33% | 75% | 67% | 21% | 0% | 4% |
| 27 | 33% | 72% | 67% | 20% | 0% | 8% |
| 28 | 40% | 77% | 60% | 17% | 0% | 7% |
| 29 | 25% | 73% | 75% | 20% | 0% | 7% |
| 30 | 20% | 71% | 80% | 19% | 0% | 10% |
| 31 | 20% | 71% | 80% | 23% | 0% | 6% |
| 32 | 20% | 63% | 80% | 23% | 0% | 13% |
| 33 | 25% | 69% | 75% | 21% | 0% | 10% |
| 34 | 50% | 68% | 50% | 19% | 0% | 13% |
| 35 | 40% | 73% | 60% | 15% | 0% | 12% |
| 36 | 43% | 74% | 57% | 14% | 0% | 11% |
| 37 | 43% | 76% | 57% | 13% | 0% | 11% |
| 38 | 29% | 71% | 71% | 16% | 0% | 12% |
| 39 | 29% | 71% | 71% | 16% | 0% | 14% |
| 40 | 29% | 72% | 71% | 15% | 0% | 13% |

Table for Figure 5.3

| Quarter | Green % All Pre | Green % All Post | C % All Pre | C % All Post | Unk % All Pre | Unk % All Post |
|---|---|---|---|---|---|---|
| 1 | 0.08% | 0.04% | 0.16% | 0.11% | 0.00% | 0.02% |
| 2 | 0.07% | 0.09% | 0.15% | 0.11% | 0.00% | 0.00% |
| 3 | 0.07% | 0.09% | 0.14% | 0.09% | 0.00% | 0.00% |
| 4 | 0.07% | 0.08% | 0.13% | 0.08% | 0.00% | 0.00% |
| 5 | 0.06% | 0.10% | 0.13% | 0.06% | 0.00% | 0.00% |
| 6 | 0.06% | 0.08% | 0.12% | 0.06% | 0.00% | 0.00% |
| 7 | 0.00% | 0.08% | 0.11% | 0.06% | 0.00% | 0.00% |
| 8 | 0.00% | 0.08% | 0.06% | 0.08% | 0.00% | 0.00% |
| 9 | 0.00% | 0.13% | 0.11% | 0.09% | 0.00% | 0.00% |
| 10 | 0.00% | 0.15% | 0.11% | 0.11% | 0.00% | 0.02% |
| 11 | 0.00% | 0.19% | 0.05% | 0.11% | 0.00% | 0.02% |
| 12 | 0.00% | 0.23% | 0.05% | 0.10% | 0.00% | 0.02% |
| 13 | 0.00% | 0.30% | 0.05% | 0.08% | 0.00% | 0.02% |
| 14 | 0.05% | 0.29% | 0.10% | 0.06% | 0.00% | 0.02% |
| 15 | 0.05% | 0.30% | 0.05% | 0.06% | 0.00% | 0.04% |
| 16 | 0.05% | 0.29% | 0.09% | 0.05% | 0.00% | 0.04% |
| 17 | 0.04% | 0.21% | 0.09% | 0.09% | 0.00% | 0.04% |
| 18 | 0.05% | 0.22% | 0.09% | 0.10% | 0.00% | 0.05% |
| 19 | 0.00% | 0.20% | 0.09% | 0.11% | 0.00% | 0.03% |
| 20 | 0.05% | 0.23% | 0.09% | 0.11% | 0.00% | 0.03% |
| 21 | 0.05% | 0.24% | 0.09% | 0.12% | 0.00% | 0.02% |
| 22 | 0.04% | 0.21% | 0.09% | 0.11% | 0.00% | 0.01% |
| 23 | 0.04% | 0.22% | 0.08% | 0.10% | 0.00% | 0.01% |
| 24 | 0.04% | 0.17% | 0.08% | 0.09% | 0.00% | 0.01% |
| 25 | 0.04% | 0.17% | 0.04% | 0.06% | 0.00% | 0.01% |
| 26 | 0.03% | 0.20% | 0.07% | 0.06% | 0.00% | 0.01% |
| 27 | 0.03% | 0.19% | 0.07% | 0.05% | 0.00% | 0.02% |
| 28 | 0.06% | 0.24% | 0.09% | 0.05% | 0.00% | 0.02% |
| 29 | 0.03% | 0.21% | 0.09% | 0.06% | 0.00% | 0.02% |
| 30 | 0.03% | 0.20% | 0.12% | 0.05% | 0.00% | 0.03% |
| 31 | 0.03% | 0.19% | 0.11% | 0.06% | 0.00% | 0.02% |
| 32 | 0.03% | 0.16% | 0.11% | 0.06% | 0.00% | 0.03% |
| 33 | 0.03% | 0.16% | 0.08% | 0.05% | 0.00% | 0.02% |
| 34 | 0.05% | 0.15% | 0.05% | 0.04% | 0.00% | 0.03% |
| 35 | 0.05% | 0.15% | 0.07% | 0.03% | 0.00% | 0.02% |
| 36 | 0.07% | 0.14% | 0.09% | 0.03% | 0.00% | 0.02% |
| 37 | 0.07% | 0.16% | 0.09% | 0.03% | 0.00% | 0.02% |
| 38 | 0.05% | 0.16% | 0.11% | 0.04% | 0.00% | 0.03% |
| 39 | 0.05% | 0.15% | 0.11% | 0.03% | 0.00% | 0.03% |
| 40 | 0.05% | 0.16% | 0.12% | 0.03% | 0.00% | 0.03% |

Table for Figure 5.4

| Quarter | Est 10 yr Green Pre | Est 10 yr Green Post | Est 10 yr Carbon Pre | Est 10 yr Carbon Post |
|---|---|---|---|---|
| 1 | 0 | 3 | 2 | 5 |
| 2 | 1 | 4 | 2 | 5 |
| 3 | 1 | 5 | 2 | 4 |
| 4 | 1 | 6 | 2 | 4 |
| 5 | 1 | 6 | 2 | 4 |
| 6 | 1 | 6 | 2 | 4 |
| 7 | 1 | 6 | 2 | 4 |
| 8 | 1 | 6 | 2 | 5 |
| 9 | 1 | 8 | 2 | 5 |
| 10 | 0 | 10 | 2 | 5 |
| 11 | 0 | 11 | 1 | 4 |
| 12 | 0 | 13 | 2 | 4 |
| 13 | 0 | 14 | 1 | 4 |
| 14 | 0 | 14 | 1 | 3 |
| 15 | 1 | 14 | 2 | 3 |
| 16 | 1 | 13 | 2 | 4 |
| 17 | 1 | 12 | 2 | 5 |
| 18 | 1 | 12 | 2 | 5 |
| 19 | 2 | 12 | 2 | 5 |
| 20 | 2 | 15 | 2 | 5 |
| 21 | 5 | 14 | 2 | 5 |
| 22 | 4 | 13 | 2 | 5 |
| 23 | 4 | 13 | 2 | 4 |
| 24 | 4 | 11 | 2 | 4 |
| 25 | 2 | 10 | 1 | 4 |
| 26 | 2 | 11 | 2 | 3 |
| 27 | 2 | 11 | 2 | 4 |
| 28 | 2 | 13 | 3 | 3 |
| 29 | 2 | 13 | 3 | 4 |
| 30 | 2 | 12 | 3 | 4 |
| 31 | 1 | 12 | 3 | 4 |
| 32 | 2 | 11 | 3 | 4 |
| 33 | 2 | 11 | 3 | 3 |
| 34 | 2 | 11 | 3 | 3 |
| 35 | 3 | 12 | 3 | 2 |
| 36 | 3 | 12 | 3 | 2 |
| 37 | 2 | 14 | 3 | 2 |
| 38 | 2 | 14 | 4 | 3 |
| 39 | 2 | 14 | 4 | 3 |
| 40 | 2 | 14 | 5 | 3 |

Statistics for 10-Year Survival Green LLC Q4 1996 – Q3 2006

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.55 |
| R Square | 0.30 |
| Adjusted R Square | 0.28 |
| Standard Error | 1.01 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 0.51 | 0.33 | 1.57 | 0.12 | -0.15 | 1.17 |
| t | 0.06 | 0.01 | 4.02 | 0.00 | 0.03 | 0.08 |

Statistics for 10-Year Survival Green LLC Q1 2007 – Q4 2016

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.69 |
| R Square | 0.47 |
| Adjusted R Square | 0.46 |
| Standard Error | 2.37 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 7.03 | 0.76 | 9.20 | 0.00 | 5.48 | 8.57 |
| Quarter | 0.19 | 0.03 | 5.82 | 0.00 | 0.12 | 0.25 |

Statistics for 10-Year Survival Carbon LLC Q4 1996 – Q3 2006

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.71 |
| R Square | 0.51 |
| Adjusted R Square | 0.50 |
| Standard Error | 0.59 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 1.29 | 0.19 | 6.80 | 0.00 | 0.90 | 1.67 |
| Quarter | 0.05 | 0.01 | 6.28 | 0.00 | 0.03 | 0.07 |

Statistics for 10-Year Survival Carbon LLC Q1 2007 – Q4 2016

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.62 |
| R Square | 0.38 |
| Adjusted R Square | 0.37 |
| Standard Error | 0.72 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 4.88 | 0.23 | 21.13 | 0.00 | 4.41 | 5.34 |
| Quarter | -0.05 | 0.01 | -4.86 | 0.00 | -0.07 | -0.03 |

Table for Figure 5.5

| Quarter | Pre GWSA Green Minus Solar | Post GWSA Green Minus Solar |
|---|---|---|
| 1 | 1 | 0 |
| 2 | 1 | 1 |
| 3 | 1 | 1 |
| 4 | 1 | 1 |
| 5 | 1 | 1 |
| 6 | 0 | 2 |
| 7 | 0 | 2 |
| 8 | 0 | 1 |
| 9 | 0 | 1 |
| 10 | 1 | 2 |
| 11 | 1 | 1 |
| 12 | 1 | 2 |
| 13 | 0 | 2 |
| 14 | 0 | 1 |
| 15 | 1 | 1 |
| 16 | 1 | 1 |
| 17 | 1 | 1 |
| 18 | 1 | 1 |
| 19 | 0 | 1 |
| 20 | 1 | 1 |
| 21 | 1 | 2 |
| 22 | 1 | 2 |
| 23 | 1 | 2 |
| 24 | 1 | 2 |
| 25 | 1 | 2 |
| 26 | 0 | 2 |
| 27 | 1 | 4 |
| 28 | 1 | 5 |
| 29 | 1 | 5 |
| 30 | 1 | 4 |
| 31 | 0 | 2 |
| 32 | 0 | 1 |
| 33 | 0 | 1 |
| 34 | 1 | 1 |
| 35 | 1 | 2 |
| 36 | 1 | 2 |
| 37 | 1 | 3 |
| 38 | 1 | 4 |
| 39 | 1 | 4 |
| 40 | 1 | 4 |

Statistics for Green Minus Solar Q4 1996 – Q3 2006

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.13 |
| R Square | 0.02 |
| Adjusted R Square | -0.01 |
| Standard Error | 0.45 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 0.62 | 0.15 | 4.23 | 0.00 | 0.32 | 0.92 |
| Quarter | 0.01 | 0.01 | 0.83 | 0.41 | -0.01 | 0.02 |

Statistics for Green Minus Solar Q1 2007 – Q4 2016

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.59 |
| R Square | 0.35 |
| Adjusted R Square | 0.33 |
| Standard Error | 1.01 |
| Observations | 40.00 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 0.66 | 0.33 | 2.03 | 0.05 | 0.00 | 1.32 |
| Quarter | 0.06 | 0.01 | 4.54 | 0.00 | 0.03 | 0.09 |

Table for Figure 5.6

| Quarter | Green Minus Solar Pre GWSA | Green Minus Solar Post GWSA | Carbon Pre GWSA | Carbon Post GWSA | Unk Pre GWSA | Unk Post GWSA |
|---|---|---|---|---|---|---|
| 1 | 33% | 0% | 67% | 83% | 0% | 17% |
| 2 | 33% | 17% | 67% | 83% | 0% | 0% |
| 3 | 33% | 20% | 67% | 80% | 0% | 0% |
| 4 | 33% | 20% | 67% | 80% | 0% | 0% |
| 5 | 33% | 25% | 67% | 75% | 0% | 0% |
| 6 | 0% | 40% | 100% | 60% | 0% | 0% |
| 7 | 0% | 40% | 100% | 60% | 0% | 0% |
| 8 | 0% | 20% | 100% | 80% | 0% | 0% |
| 9 | 0% | 20% | 100% | 80% | 0% | 0% |
| 10 | 33% | 25% | 67% | 63% | 0% | 13% |
| 11 | 50% | 14% | 50% | 71% | 0% | 14% |
| 12 | 50% | 25% | 50% | 63% | 0% | 13% |
| 13 | 0% | 29% | 100% | 57% | 0% | 14% |
| 14 | 0% | 20% | 100% | 60% | 0% | 20% |
| 15 | 33% | 17% | 67% | 50% | 0% | 33% |
| 16 | 33% | 17% | 67% | 50% | 0% | 33% |
| 17 | 33% | 13% | 67% | 63% | 0% | 25% |
| 18 | 33% | 10% | 67% | 60% | 0% | 30% |
| 19 | 0% | 10% | 100% | 70% | 0% | 20% |
| 20 | 33% | 10% | 67% | 70% | 0% | 20% |
| 21 | 33% | 18% | 67% | 73% | 0% | 9% |
| 22 | 33% | 18% | 67% | 73% | 0% | 9% |
| 23 | 33% | 20% | 67% | 70% | 0% | 10% |
| 24 | 33% | 20% | 67% | 70% | 0% | 10% |
| 25 | 50% | 25% | 50% | 63% | 0% | 13% |
| 26 | 0% | 25% | 100% | 63% | 0% | 13% |
| 27 | 33% | 36% | 67% | 45% | 0% | 18% |
| 28 | 25% | 42% | 75% | 42% | 0% | 17% |
| 29 | 25% | 38% | 75% | 46% | 0% | 15% |
| 30 | 20% | 31% | 80% | 46% | 0% | 23% |
| 31 | 0% | 18% | 100% | 64% | 0% | 18% |
| 32 | 0% | 8% | 100% | 58% | 0% | 33% |
| 33 | 0% | 10% | 100% | 60% | 0% | 30% |
| 34 | 33% | 9% | 67% | 55% | 0% | 36% |
| 35 | 25% | 18% | 75% | 45% | 0% | 36% |
| 36 | 20% | 18% | 80% | 45% | 0% | 36% |
| 37 | 20% | 21% | 80% | 43% | 0% | 36% |
| 38 | 17% | 22% | 83% | 44% | 0% | 33% |
| 39 | 17% | 21% | 83% | 42% | 0% | 37% |
| 40 | 17% | 21% | 83% | 42% | 0% | 37% |

## Appendix D: Trends in individual fuel type sectors

### Trends Within Green Energy

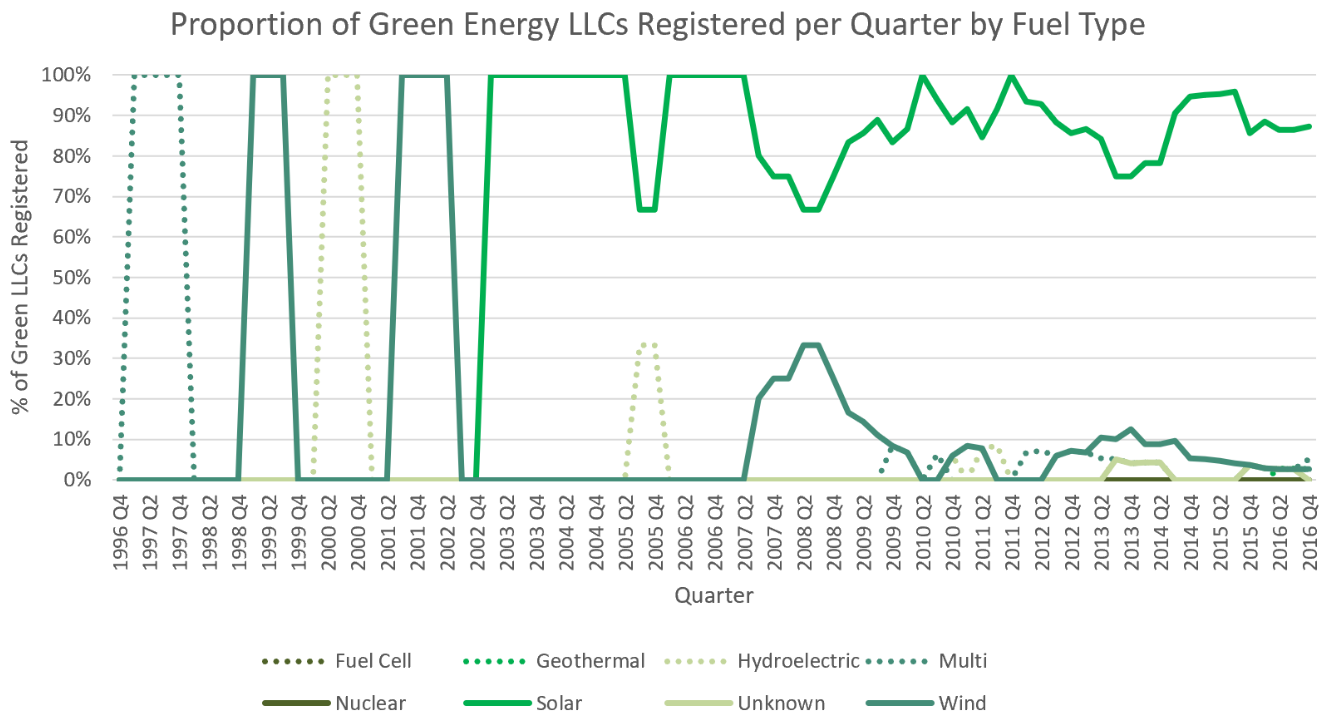



*Figure D1 Proportion of Successful Green Energy Businesses for Each Fuel Type*

Possibly the most interesting thing about looking at trends in green energy fuel types is the shift in focus from wind energy to solar that occurred around the turn of the XXI Century. Of course the sample size of companies per quarter was quite small until 2006 which has made the pre-2006 data extremely noisy, and not much should be read into it. A look at the graphs of raw numbers of LLCs show the number of successful wind energy companies registered per quarter remained mostly flat across the course of this study. While solar energy LLCs were already increasing in proportion of all green energy companies as early as 2002, the raw number of them did not start a dramatic increase until 2008, after the GWSA was passed.

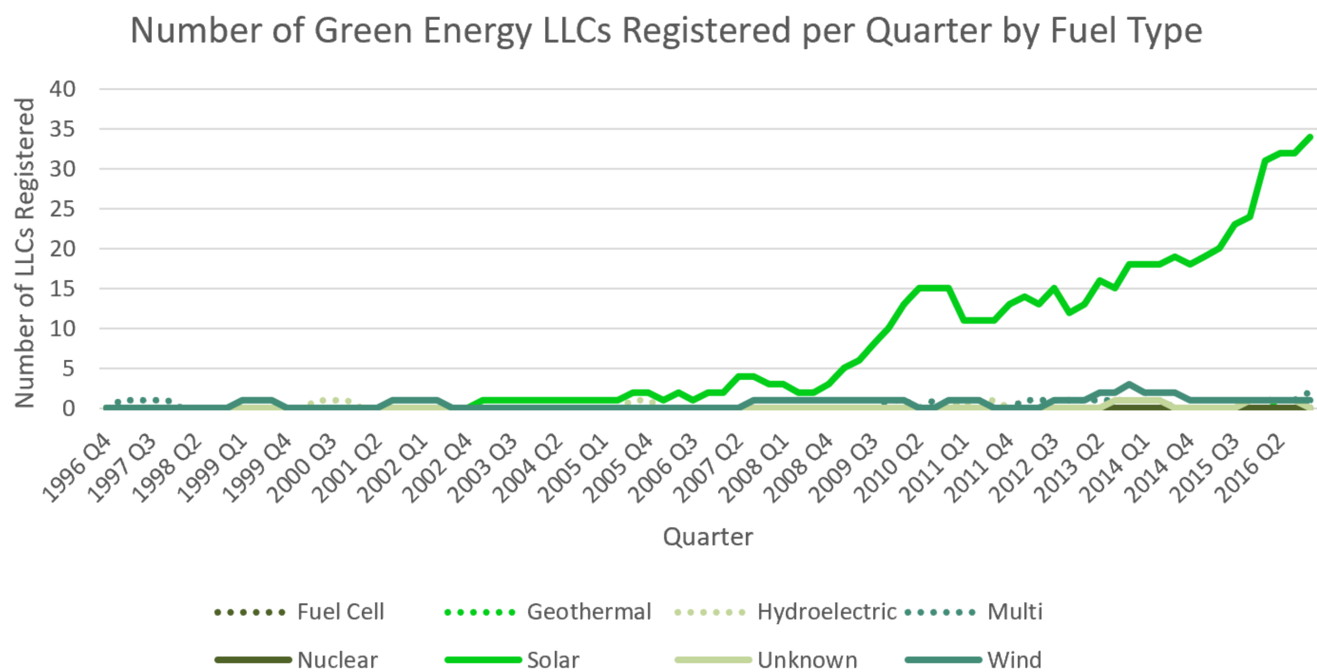
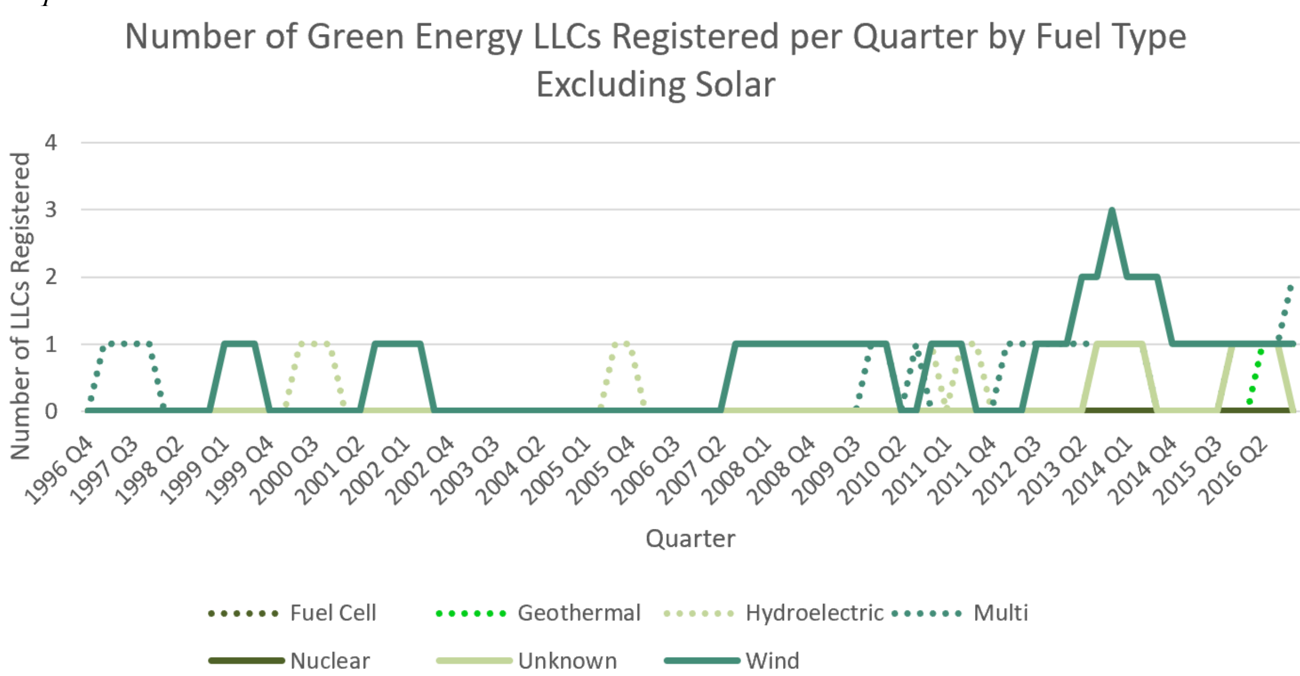



*Figure D2a (top) and D2b(bottom) showing trends in number of green energy LLCs registered per quarter.*



**Trends Within Carbon Energy**

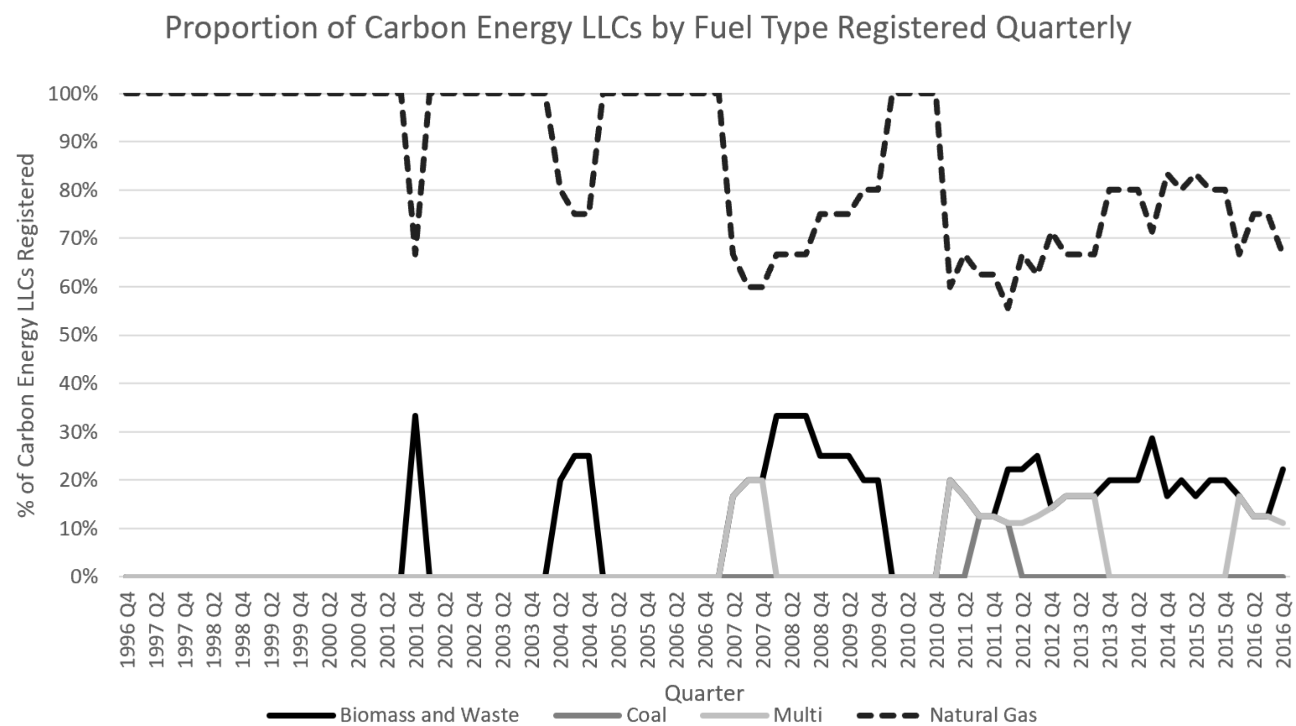



*Figure D3 Proportion of Carbon Energy LLCs Registered per Year by Fuel Type*

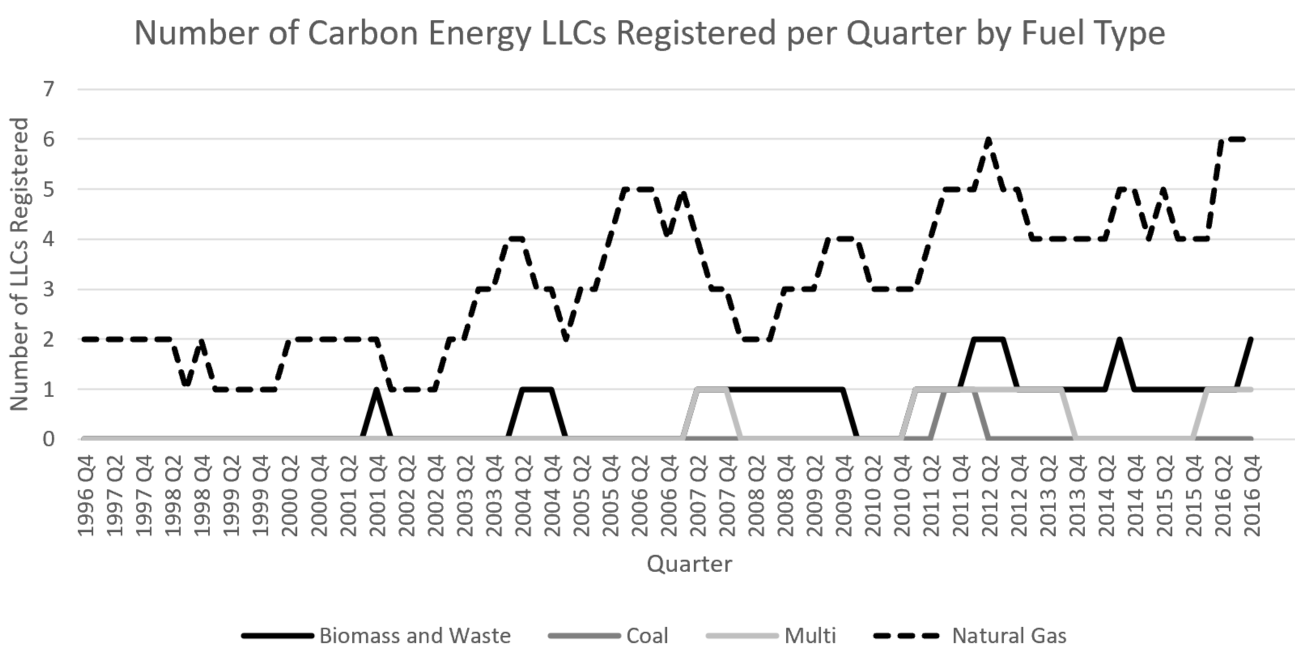



*Figure D4 Number of carbon energy LLCs registered per quarter by fuel type.*

As with solar in the green energy industry, natural gas LLCs dominate the carbon energy sector, accounting for 100% of successful carbon energy LLCs registered in 42 of the 80 quarters covered by this study. However, the data clearly show a decrease in the proportion of natural gas LLCs in the carbon energy sector after 2006 and the passage of the GWSA, and a marked and sustained increase in the proportion of biomass and waste gas occurring at the same time. This increase can be seen in the raw numbers as well, with a modest increase in the number of successful LLCs dealing in biomass and waste energy registered from 1 new company every 12 quarters to 24 straight quarters with at least 1 new successful company. However, most noteworthily is that the number of new successful natural gas companies has also increased, just at a slower rate than biomass and waste.