Arizona's Solar Market Analysis and Research Tool

Regulation and Standards in the Energy Sector and their Effect on Solar Deployment

Version 1
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Arizona's Solar Market Analysis and Research Tool (Az SMART)

Arizona's Solar Market Analysis and Research Tool (Az SMART) is a breakthrough analysis environment that will enable stakeholders to examine the complex interaction of economic, security, environmental, and technological issues that impact Arizona's ability to become a global leader in solar power innovation, development and deployment. Multi-disciplinary research efforts and capabilities at Arizona State University and the University of Arizona are being utilized in close collaboration with partners from industry and government in the creation and use of Az SMART.

The goal of the three-year project is to develop a unique analysis tool, tailored to the examination of a successful roll-out of large-scale solar energy infrastructure in Arizona, and the required electric grid technologies to enable that infrastructure.

The principal outputs of the project are solar technical feasibility research, a Solar Scorecard for Arizona, and ultimately, the analytical tool that integrates them into a decision support framework. The end product will be accessible by remote web access (www.azsmart.org), as well as at Decision Theater, a dynamic, immersive visualization environment facility at Arizona State University

Arizona's Solar Scorecard

Researchers at the L. William Seidman Research Institute of the W. P. Carey School of Business at Arizona State University are developing Arizona's Solar Scorecard. The Solar Scorecard comprises metrics drawn from energy usage forecasts, environmental valuation analyses, economic development analyses, and energy security evaluations. It is assembled from a series of whitepapers which provide the research and analysis to translate commercial and public policy choices into measures of economic, environmental, social and energy security impact on Arizona. These papers will be completed over a three year span, with the first year largely concentrated on utility-scale power generation. The second and third years concentrate on distributed generation and transportation. The completed and currently planned14 whitepapers are as follows:

1. *Energy Sector Technology;*
2. *The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation;*
3. *Incentives and Taxation;*
4. *Regulations and Standards in the Energy Sector and their Effect on Solar Promotion;*
5. *AZ Energy Demand Analysis;*
6. *Present and Future Cost of New Utility-Scale Electricity Generation;*
7. *Energy Usage/ Supply Forecasts;*
8. *Emissions/Pollution Analysis;*
9. *Solar Export Potential;*
10. *Environmental Valuation Analysis;*
11. *Solar Inter-State Competition;*
12. *Economic Development Analysis;*
13. *Energy Security Issues;*
14. *The Determinants of the Financial Return from Residential Photovoltaic Systems.*

About This Paper

This white paper is the 4th paper of a series of 14 white papers that make up the Solar Scorecard. The goal of the paper is to inform the reader about mechanisms that encourage a reduction in carbon emissions through government intervention and, directly or indirectly, promote the use of renewable resources such as solar. The paper separates the mechanisms used by governments into two categories: direct (Cap-and-Trade and Carbon Tax) and indirect (Renewable Portfolio Standard, Energy Efficiency, and Loading Order). In addition, governments use subsidies to encourage a reduction in carbon emissions. An analysis on subsidies is available in the 3rd paper of this series: Taxes and Incentives.

This paper will develop over time and contribute to future papers in the Az SMART project. The first version focuses on the impact of government intervention on electricity generation in the state. In later versions, the paper will focus on the impact of regulations and standards on transportation.

Executive Summary

- The U.S. utility sector currently generates electricity at a price which does not reflect its social cost, which includes the negative externality of Greenhouse Gas (GHG) emissions.[1] To improve social welfare outcomes, the government could intervene in the market. Government intervention could influence utilities to invest in generation technologies which reduce GHG emissions and decrease consumption of electricity to the socially optimal level.[2] Reaching the socially optimal level requires individuals and firms to internalize the cost of GHG emissions. Governments have the ability to enforce, or move closer to, the socially optimal level of electricity production and consumption by intervening in the electricity market directly, through regulation, or indirectly, through carbon pricing and subsidies.

Government-Mandated Indirect Mechanisms

- Indirect government intervention in the electricity generation sector adjusts the cost of generating electricity to encourage utilities and other power producers to adopt alternative carbon-reduced technologies. The increased cost decreases GHG emissions by shifting generation technology *and* lowering electricity consumption. The two indirect government mechanisms used to reduce GHG emissions from the electricity sector are a Pigouvian tax and a cap-and-trade system. The impact of the carbon prices which result from these indirect mechanisms is shown in Table ES1.

[1] There is a significant debate within the literature in determining what the value of the externality is. This will be examined in future papers.

[2] The social optimum of generation is dependent upon the external costs associated with GHG emissions. Since there is some debate surrounding the valuation of the external cost, there is some debate about what the social optimum is (much of this will be discussed in a future paper). However, while the social optimum is debatable, there is a consensus about the impact that policies which take these external costs into account have on electricity generation.

Table ES1: Levelized Cost Impact of Carbon Pricing ($/MWh)

Generation Technology	*$20/ton*	*$40/ton*	*$60/ton*	*$80/ton*
Scrubbed Coal	$ 16.55	$ 33.11	$ 49.66	$ 66.21
IGCC	$ 14.11	$ 28.22	$ 42.33	$ 56.44
IGCC with CCS	$ 1.57	$ 3.15	$ 4.72	$ 6.29
Conv. Gas CC	$ 7.90	$ 15.80	$ 23.70	$ 31.60
Adv. Gas CC	$ 6.72	$ 13.44	$ 20.16	$ 26.88
Adv. Gas CC w/ CCS	$ 0.80	$ 1.59	$ 2.39	$ 3.18
Conv. Gas CT	$ 12.16	$ 24.32	$ 36.48	$ 48.64
Adv. Gas CT	$ 9.07	$ 18.15	$ 27.22	$ 36.29
Conv. Oil CT	$ 21.40	$ 42.81	$ 64.21	$ 85.61
Adv. Gas CT	$ 15.97	$ 31.94	$ 47.91	$ 63.88

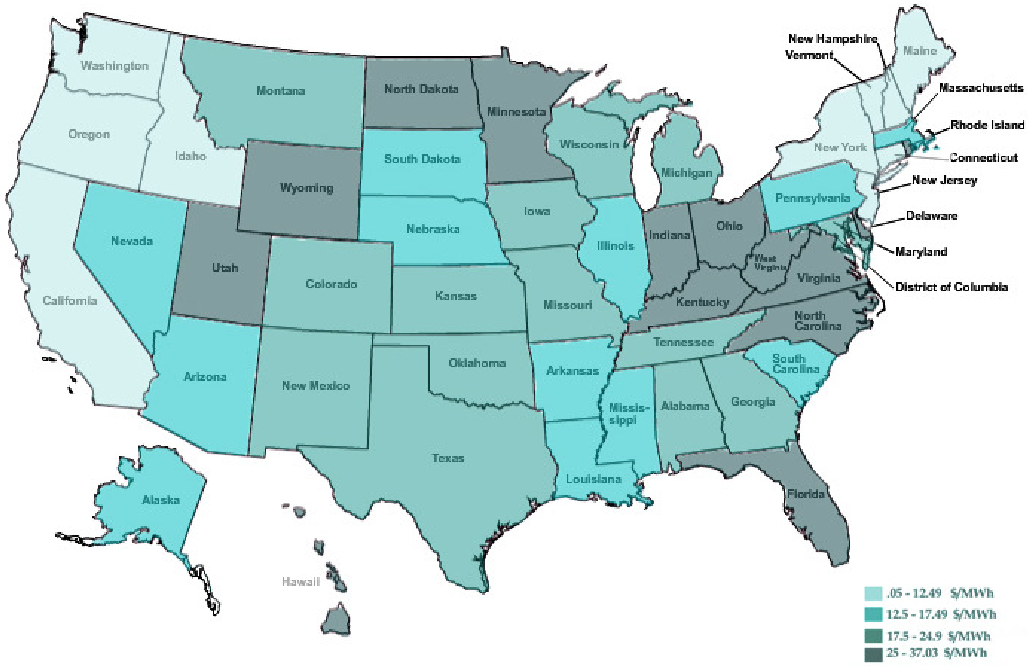
Source: EIA and Authors' Calculations

- Figure ES1 illustrates the impact a $30 per ton carbon price would have on each state if it were implemented in 2010. The light-colored states are those that are impacted the least. Each of these states relies on renewable energy sources, nuclear, and natural gas for electricity and less on coal. The dark-colored states are those that use significant amounts of coal and, as a result, are impacted the most by the carbon price.[3]

- As is evident in Figure ES1, Arizona is impacted less than the national average due largely to its generation fueled by natural gas and uranium. Each of these sources emits less carbon than coal, which states like Wyoming and Utah rely heavily upon for electricity generation.

[3]Coal has the highest carbon content per MWh and, therefore, for a given carbon price, will face the highest increase in cost.

Figure ES1: Impact of a $30 per Ton Carbon Price on All 50 States and D.C.[4]



Source: EIA and Authors' Calculations

- A Pigouvian tax on carbon is one of two methods of government intervention currently used to place a cost on carbon emissions in the electricity generation sector. The most important step in implementing the tax is for lawmakers to set the correct tax level. If the tax is too low, it will not change the behavior of utilities sufficiently to induce a significant decrease in carbon emissions. If the tax is set too high, it will discourage potential technology solutions from being adopted and increase electricity prices higher than necessary. After the level is set, the tax is applied to any generation technology which emits carbon. At this point, the tax functions as a price on carbon, increasing the cost of carbon-emitting generation technologies.

- Cap-and-trade systems place a price on carbon by setting a limit on the quantity of emissions allowed by electricity generating firms. Once the limit has been determined, allowances to emit carbon are distributed via some mechanism. The two biggest

[4] The carbon price impact is based on electricity generation mix, not consumption.

decisions regarding the structure of a cap-and-trade system are distributing allowances by quota or auction and whether to regulate upstream, midstream, or downstream.

- The implementation of a carbon pricing mechanism raises the cost of coal and natural gas, lowering the relative cost of all resources that emit less or zero carbon. The resources that emit little to no carbon are coal and natural gas with CCS equipment, nuclear and all renewable sources. Assuming that there is no regulation in place requiring electricity generating firms to generate a portion of their energy from solar, the cost of solar power, relative to nuclear and technologies with CCS equipment, will change very little as a result. Due to the lack of change in the cost of solar, relative to technologies that do not emit large amounts of carbon, regulation may be required to encourage solar adoption.

Government-Mandated Direct Mechanisms

- Government-mandated direct mechanisms enforce a particular solution or set of solutions on the electricity generation sector. Renewable energy requirements, energy efficiency programs, and loading order all promote particular technologies over other solutions that the market may choose without direct intervention. As a result, they may be more capable of promoting solar power in a more significant manner than a carbon pricing mechanism because they prevent carbon-limited alternatives, such as nuclear, natural gas, and clean coal, from competing with solar.

- Renewable portfolio standards (RPS) require regulated utilities to generate a certain amount of their total electricity generation from renewable resources. The standard method of measurement is a percentage of electricity retail sales (ERS) generated by renewable resources by a target year. The state of Arizona provides rates of generation required each year to prevent utilities from ramping up renewable generation in the final year and creating regulatory and production complications. An alternative method of measurement in use is a required amount of renewable capacity available by a certain date.

- Energy efficiency programs are government-mandated methods of reducing electricity demand. 16 states[5] have current or pending programs that either require a certain percentage of electricity that must be reduced through energy efficiency measures or allow it to qualify as an eligible resource for its RPS. The ability of energy efficiency gains to offset state RPS requirements is important for states with limited low-cost renewable resources. Although market intervention often leads to inefficiency, energy efficiency programs are the exception because there are cost-effective improvements available. One of the reasons significant energy efficiency gains are available is because electricity consumers, who have the greatest incentive to buy energy efficient devices, do not make the efficient choice, largely due to information deficiency (U.S. DOE Energy Efficiency and Renewable Energy, 2010).

- Loading order is a method of regulation which seeks to meet increasing electricity demand with a pre-determined set of preferred. In the California loading order system, energy efficiency, demand response, renewable resources, and distributed generation are given preference over other resources for meeting increases in future electricity demand. The other resources would include nuclear as well as coal, natural gas, and petroleum with or without carbon emission reducing technology. By making this distinction, California regulators are signaling their preference for renewable resources and reducing electricity demand as tools for mitigating carbon emissions over nuclear and clean coal and natural gas.

[5] Texas (1999), Vermont (2000), California, Hawaii, Pennsylvania (2004), Connecticut, Nevada (2005), Colorado, Washington (2006), Minnesota, Virginia, Illinois, North Carolina (2007), Arizona (2009), New Jersey and New York (pending).

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List of Acronyms

Abbreviation	*Definition*
Entities	
ACC	Arizona Corporation Commission
APS	Arizona Public Service Company
Az SMART	Arizona's Solar Market Analysis and Research Tool
CDM	Clean Development Mechanism
CEC	California Energy Commission
DOE	Department of Energy (United States)
EERE	Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
ICP	Institutional Conservation Program
IEA	International Energy Agency
MGGRA	Midwest Greenhouse Gas Reduction Accord
NETL	National Energy Technology Laboratory
NREL	National Renewable Energy Laboratory
RGGI	Regional Greenhouse Gas Initiative
SRP	Salt River Project
SECP	State Energy Conservation Program
UNFCCC	United Nations Framework Convention on Climate Change
WCI	Western Climate Initiative
Other Terms	
Btu	British thermal unit
CC	Combined Cycle
CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
CT	Combustion Turbine
ERS	Electricity Retail Sales

Abbreviation	*Definition*
GWh	Gigawatt Hour
GHG	Greenhouse Gas
IGCC	Integrated Gasification and Combined Cycle
MWh	Megawatt hour
PV	Photovoltaic
RES	Renewable energy standard
RET	Renewable Energy Target
RPS	Renewable Portfolio Standard
SO_2	Sulfur Dioxide

1. Introduction

Since the construction of the first power plant in 1882, the U.S. utility sector has lacked regulation limiting greenhouse gas (GHG) emissions. As a result the price of electricity does not reflect the social cost of electricity,[6] which includes the negative externality of GHG emissions. Improving social welfare[7] may require government intervention in the market. Appropriate policy will influence utilities to invest in generation technologies which reduce GHG emissions and decrease consumption of electricity to the socially optimal level.

Governments intervene in the electricity market *directly*, through regulation, or *indirectly*, through carbon pricing and subsidies. Direct intervention mandates specific technologies or methods of generation through the use of renewable portfolio requirements, energy efficiency programs, and loading orders. Indirect intervention encourages electricity generating firms to adopt technologies by altering the price of generation through the use of Pigouvian taxes,[8] cap-and-trade schemes, and subsidies. Due to their complex nature, subsidies were addressed separately from this paper in Incentives and Taxation, which is another paper in the Az SMART project.

Due to the focus of the Az SMART project on solar power, this paper concentrates on the impact on solar electricity generation of government intervention in the electricity market. We analyze the effect of direct and indirect government intervention on the adoption of solar and calculate the potential impact of a GHG price on the major forms of electricity generation.

Section 2 of this paper describes the indirect government mandated mechanisms, their impact on solar power, and global adoption of each mechanism. The section also includes an analysis of the effect of a GHG price on the levelized cost of the major forms of electricity generation.

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[6] Social cost accounts for the costs to society which may not be reflected in the price of a good. In this context, the cost to humanity of GHG emissions includes pollution of the air and water and climate change.

[7] Social welfare would be improved in this case by reducing the potentially harmful effects of GHG emissions.

[8] A Pigouvian tax is placed on negative externalities to correct for market failure. In the context of this paper, we investigate a Pigouvian tax on carbon, which is designed to correct for the negative externality of GHG emissions.

Section 3 is a similar analysis on direct government mandated mechanisms. Section 4 summarizes the difference between direct and indirect mechanisms and identifies which is most likely to encourage the adoption of solar.

2. Government-Mandated Indirect Mechanisms

Indirect government intervention in the electricity generation sector involves altering the cost of generating electricity to encourage utilities and other power producers to adopt alternative carbon-reduced generation technologies. These technologies are generally more expensive than the previous generation technologies because, without intervention, electricity generating firms choose the lowest cost form of generation. The majority of the cost increase is passed on to electricity consumers in the form of higher electricity prices,[9] which reduces electricity consumption. The combination of lowering electricity consumption towards the socially optimal level and increasing the importance of non-carbon emitting technologies in utilities generation portfolio is the goal of indirect government intervention.

There are currently two indirect government mechanisms used globally to reduce GHG emissions from the electricity sector. A Pigouvian tax increases the cost of GHG-emitting technologies through a tax based on the level of GHGs each technology emits. A cap-and-trade system places a cap on allowed GHG emissions, which increases the cost of GHG-emitting technologies due to emitting entities needing to obtain a permit to emit.[10] The resulting GHG price alters the cost of technology options for electricity generating firms and reduces GHG emissions. In the area of environmental policy, a GHG price is typically referred to as a carbon price, so from this point forward, the term carbon price will be used.[11]

2.1 Carbon Price

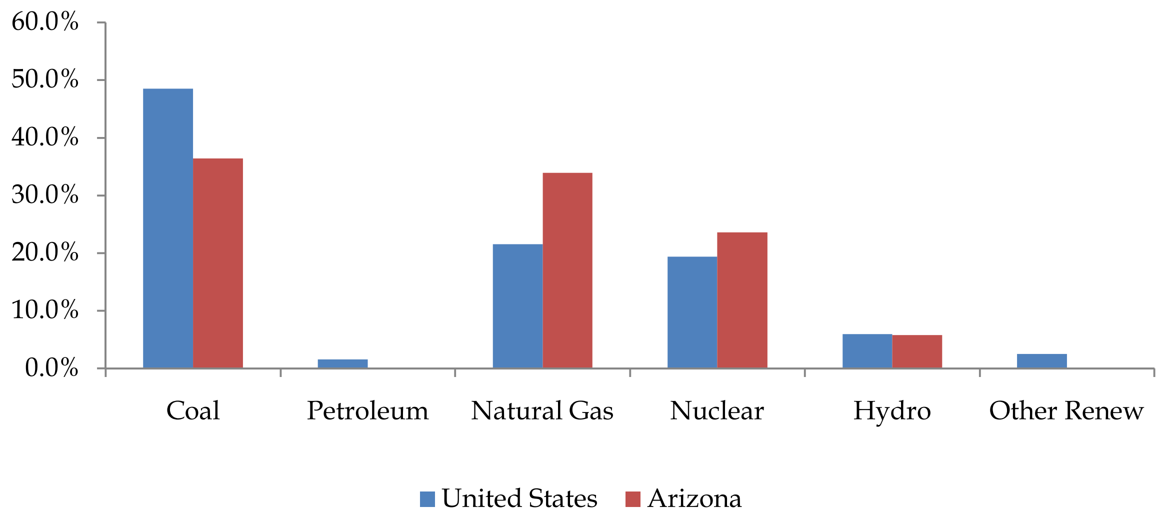
Increasing the cost of GHG-emitting technologies decreases GHG emissions in two ways. The first effect on GHG emissions is the result of a shift in generation technologies from GHG-emitting technologies to technologies that do not emit GHGs.[12] GHG-emitting technologies

[9] The elasticity of demand for electricity is generally low.
[10] Some of these costs can be offset if some (all) of the permits are distributed freely to utilities.

[11] While other GHG gases have potentially deadly consequences for the environment, the size of annual carbon emissions and their impact on the environment result in carbon being the most targeted GHG gas.
[12] The carbon content of every major generation technology is available in Appendix 1. Carbon is the most prevalent GHG emitted, making it the focus of environmental emissions data compiled (EPA, 2010). It is

include coal, petroleum and natural gas, while GHG-free technologies include nuclear, hydro, solar, wind and other renewable energy sources. As Figure 2 illustrates, over 70 percent of electricity generated in the United States and Arizona is from GHG-emitting technologies.

Figure 1: Net Electricity Generation, 2007



Source: Energy Information Administration (EIA)

As the cost of GHG-emitting technologies increases due to a carbon price set in a cap-and-trade system or Pigouvian tax, GHG-free technologies become more cost competitive. Indirect GHG reducing programs gradually increase the carbon price to give electricity generating firms time to adapt to the new cost environment. Given that the electricity market is well-informed and makes decisions largely based on cost of generation, the lowest cost GHG-free technologies will be adopted first.

A secondary effect of setting a carbon price is the impact on electricity consumers. Due to the low current electricity prices driven by GHG-emitting technologies, electricity is being consumed at a rate which is not socially optimal. Electricity consumers do not currently pay for the environmental impact of their electricity use, resulting in overconsumption. By

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important to note that these estimates are for the carbon emitted during the generation process. Estimates of carbon emissions from the manufacturing and construction of the power plant are not included.

implementing a carbon pricing mechanism, electricity prices will increase and consumers will use less electricity.[13] A decrease in electricity demand reduces the generation supply necessary to meet demand, which reduces the need for GHG-emitting technologies.

The advantage of an indirect mechanism is that it allows electricity generating firms to make decisions on which technologies to pursue. These firms will calculate the potential carbon price, its impact on the levelized cost of electricity for each generation technology, and what GHG-limited technologies become cost-competitive at each level of carbon prices. The disadvantage of an indirect mechanism is that they do not promote technologies that are beneficial in areas other than cost. Electricity generating firms do not make generation choices based only on cost. These firms look at energy security, the ability of generation technologies to meet the demand profile, and the future availability of resources when planning their generation mix. For example, if a utility is interested in replacing its coal plants with a GHG-free generating technology, the inability of intermittent resources, such as wind and solar, to replace a base load technology without backup generation is a major factor in their decision.

Working off of the assumption that the levelized cost of each generating technology is one of the most important decision points for an electricity generating firm, we estimate the cost impact of carbon prices ranging from $20 per ton of carbon to $80 per ton. There are three factors which determine the levelized cost impact on each generating technology. The most important is the carbon dioxide content of the fuel source used by the technology.[14] Power plants in the United States use three carbon-emitting fuels: coal, natural gas and petroleum.[15] Carbon dioxide content is reported as metric tons emitted per billion British thermal units (Btu). As Table 2 illustrates, the carbon content of coal and petroleum is significantly greater than that

[13] It is important to note that each individual electricity consumer will be impacted differently by a GHG price. For example, electricity intensive industries will be impacted more by this policy than industries that do not use large amounts of electricity. In the residential case, an increase in electricity prices influences the decisions of individual with less disposable income compared to those with more.
[14] The EIA reports the carbon and carbon dioxide content of each generation fuel. However, emissions are typically measured in terms of carbon dioxide emitted (EIA, 2010).
[15] Petroleum-fired power plants use various petroleum products, including: distillate fuel oil, petroleum liquids and petroleum coke. The carbon content calculated for petroleum assumed a mix of 65% petroleum coke, 25% petroleum liquids and 10% distillate fuel oil (EIA, 2010).

of natural gas. The CCS technology is estimated to eliminate 90% of carbon dioxide emissions (MIT, 2007).

Table 1: CO_2 Emissions Factor

Generation	*Fuel*	*CO_2 Emissions (Metric Tons/Billion Btu)*	*Heat Rate (Btu/kWh)*	*CO_2 Factor (Metric Tons/MWh)*
Scrubbed New Coal	Coal	94.7	9,172.94	0.87
IGCC	Coal	94.7	8,687.65	0.82
IGCC with CCS	Coal	9.47	10,635.47	0.10
Conv. Gas CC	Natural Gas	53.06	7,172.71	0.38
Adv. Gas CC	Natural Gas	53.06	6,727.35	0.36
Adv. CC with CCS	Natural Gas	5.306	8,547.12	0.05
Conv. Gas CT	Natural Gas	53.06	10,788.82	0.57
Adv. Gas CT	Natural Gas	53.06	9,245.53	0.49

Source: EIA, MIT, and Authors' Calculations

Electricity statistics are reported in some scale of watt-hours.[16] The reason why electricity is not reported in Btus is because fuels generate different quantities of megawatt-hours (MWh) based on the fuel's heat rate. The heat rate is a measurement of how many Btus are necessary to generate a certain quantity of MWh. In Table 1, the heat rate of each technology is used to convert CO_2 emissions to a CO_2 factor expressed in metric tons/MWh. In general, the combined cycle (CC) technologies are more efficient[17] than combustion turbine (CT) and scrubbed coal. Any technology equipped with CCS will experience a decrease in heat rate efficiency due to the additional energy required to operate the CCS equipment, which reduces the amount of carbon released by up to 90 percent.

*Metric Tons of CO_2 emitted per MWh = Metric Tons of CO_2 per Billion Btu * (1-CCS) / Heat Rate*

After calculating the CO_2 content of each fuel and the heat rate of each generating technology, the third factor in determining the levelized cost impact of carbon pricing is choosing the carbon

[16] In this case, MWh (1,000,000 watt-hours) are used.
[17] More efficient generation technologies generate more watt-hours of electricity per unit of fuel input.

price. Table 3 lists the impact of four carbon prices ($20, $40, $60 and $80) on each generating technology. The cost impact on each technology will mirror the CO_2 factor in Table 1. The least impacted technology is advanced natural gas combined cycle with carbon capture and sequestration equipment. The most impacted technology is scrubbed coal. In general, natural gas technologies are impacted the least by carbon pricing due to the lower carbon dioxide content of the fuel and efficiency of the CC generation process. These cost impact estimates do not take into account the cost of the technology prior to the imposition of a carbon price. Plants with CCS equipment or natural gas CC plants may have the lowest cost impact due to carbon pricing, but this does not mean they have the lowest overall levelized cost. Estimates of levelized costs that include a carbon price are available in the 6th paper in the Az SMART series, entitled *"Present and Future Cost of New Utility-Scale Generation"*.

Table 2: Levelized Cost Impact of Carbon Pricing ($/MWh)

Generation Technology	*$20*	*$40*	*$60*	*$80*
Scrubbed New Coal	$ 17.37	$ 34.75	$ 52.12	$ 69.49
IGCC	$ 16.45	$ 32.91	$ 49.36	$ 65.82
IGCC with CCS	$ 2.01	$ 4.03	$ 6.04	$ 8.06
Conv. Gas CC	$ 7.61	$ 15.22	$ 22.84	$ 30.45
Adv. Gas CC	$ 7.14	$ 14.28	$ 21.42	$ 28.56
Adv. CC with CCS	$ 0.91	$ 1.81	$ 2.72	$ 3.63
Conv. CT	$ 11.45	$ 22.90	$ 34.35	$ 45.80
Adv. CT	$ 9.81	$ 19.62	$ 29.43	$ 39.25

Source: EIA and Authors' Calculations

2.1.2 Current Generation

Implementing a carbon price on current generation will affect regions in the United States differently based on their electricity generation portfolio. For example, those that generate a majority of their electricity from coal and petroleum will experience a significant increase in electricity prices.[18] Given that the average electricity generation from coal plants in the U.S. is

[18] This is due to the high carbon content of coal power plants.

48.5%, many states will be impacted.[19] When experiencing an increase in costs due to a carbon price, electricity generating firms have three options: continue to generate electricity from carbon-emitting sources and pay the carbon premium, reduce total electricity production which increases the price of electricity and reduces demand, or scale back operations and buy electricity from plants that do not emit a large amount of carbon. In each circumstance, electricity costs will increase, a portion of which electricity generating firms will seek to pass on to consumers in the form of higher electricity prices to maintain a sufficient rate of return.

Table 3: Electricity Generation Portfolio, 2007[20]

State	*Coal*	*Petroleum*	*Natural Gas*	*Nuclear*	*Hydro*	*Other Renew.*
Arizona	36.8%	0.0%	32.9%	24.1%	5.9%	0.0%
California	0.0%	0.7%	48.3%	21.1%	16.1%	13.6%
Colorado	68.7%	0.1%	25.8%	0.0%	3.3%	2.5%
Nevada	23.6%	0.0%	65.3%	0.0%	6.7%	4.3%
Utah	81.8%	0.1%	16.6%	0.0%	1.2%	0.4%
U.S.	48.5%	1.6%	21.6%	19.4%	6.0%	2.5%

Source: EIA

Table 5 shows the generation mix for Arizona, the surrounding states, and the national average in 2007. States that rely on coal or petroleum for a majority of their electricity will experience an increase in electricity prices due to a carbon price. States that rely on natural gas will also experience an increase in electricity prices, but not as much as the coal and petroleum states. States that have large amounts of nuclear, hydropower and other renewable resources in their generation portfolio will not experience an increase in electricity prices due to a carbon price. From what is presented in Table 4, we expect Utah and Colorado to experience a large increase

[19] To see the list of states and their electricity generation mixes, see Appendix 2.
[20] It is important to note that the generation mix for a state is different than its consumption mix. For example, Arizona both exports and imports electricity, which changes the consumption balance of consumers in the state. However, since data of this type are not readily available, we estimated the impact of carbon prices using generation numbers.

in electricity prices if a carbon price is implemented. We expect Nevada and Arizona to face a less severe but still substantial increase, and California's electricity price to increase only slightly. On average, we expect the U.S. as a whole to experience a significant increase due to its reliance on coal. The electricity generation portfolios for all the states are available in Appendix 2.

Table 4: Electricity Prices in the Southwest, 2007 ($/MWh)

State	Electricity Price	With $30/ton Carbon Price
Arizona	$ 85.40	$ 100.43
California	$ 128.00	$ 134.75
Colorado	$ 77.60	$ 100.82
Nevada	$ 99.90	$ 115.49
Utah	$ 64.10	$ 89.85
U.S.	$ 91.30	$ 108.99

Source: EIA and Authors' Calculations

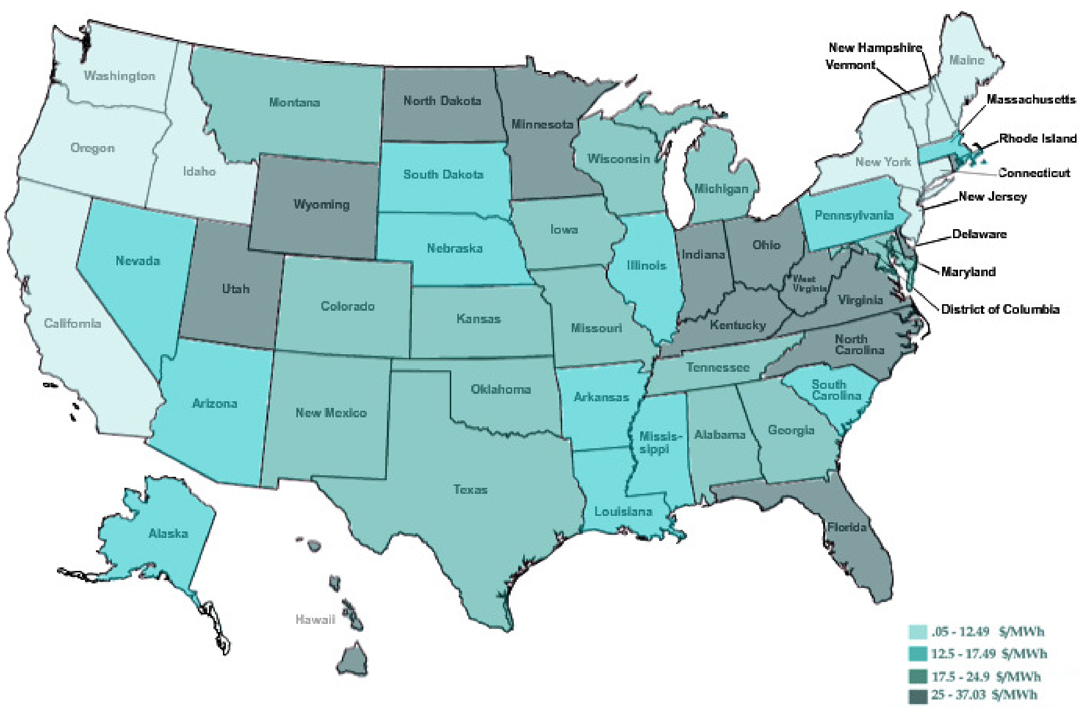
Table 6 presents the average electricity retail price for Arizona, the surrounding states, and the U.S. with and without a $30 per ton carbon price. The electricity price differential between states is consistent with the generation mix of each state.[21] The states that rely the most on coal, Colorado and Utah, have the cheapest average electricity prices, while the state that has invested the most in renewable technologies and the least in coal, California, has the highest average electricity prices.[22] In Arizona's case, the combination of coal, natural gas, and nuclear has kept the state's electricity prices below California and Nevada.

The third column of Table 6 illustrates the impact that a $30 per ton carbon price would have on Arizona, the surrounding states and the U.S. As expected, California will be impacted the least by a carbon price, while Utah and Colorado are impacted the most. Arizona, Nevada and the

[21] This provides some limited evidence that consumption mixes do not drastically differ from the generation mixes used.
[22] This is not to say that generation choice is the only explanation for the variance in electricity prices, only that prices tend to be higher in states that use more expensive generation choices. Other possible explanations for price variation include transmission and distribution costs and energy demand profile.

national average increase by similar amounts due to their comparable electricity portfolio choices. Without a carbon price, Colorado electricity consumers face lower electricity prices than their counterparts in Arizona, while with a carbon price, Arizona electricity consumers pay less than those in Colorado. For simplicity, assuming that the average electricity user in Arizona uses 11.232 MWh of electricity each year,[23] a $30 per ton carbon price would raise the electricity bill for that user by approximately $168.82 annually,[24] which is equivalent to a 17.6 percent increase.

Figure 2: Impact of a $30 per Ton Carbon Price on All 50 States and Washington D.C.



Source: EIA and Authors' Calculations

Figure 4 illustrates the impact of a $30 per ton carbon price on each state. The light-colored states are those that are impacted the least. Each of these states relies on renewable energy sources, nuclear, and natural gas for electricity and less on coal. The dark-colored states are those that use significant amounts of coal and, as a result, are impacted the most by the carbon

[23] This is the national average in 2007 (EIA, 2010).
[24] Annual electricity bill with carbon price, $1,128.03; annual electricity bill without carbon price $959.21.

price. These states have a similar electricity portfolio mix to Utah, which is shown in Table 4. The mix of each state is available in Appendix 2.

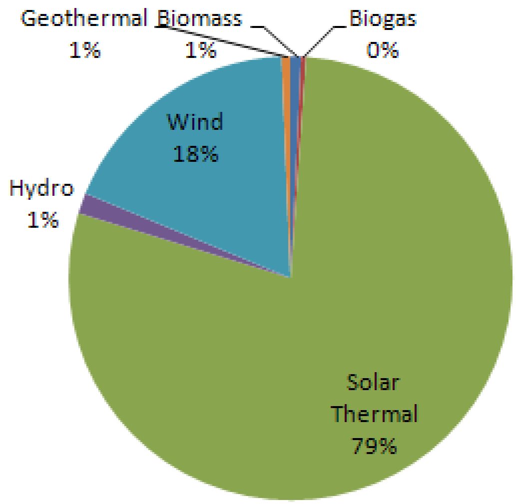
2.1.3 Global Carbon Prices

There have been several carbon tax and cap-and-trade systems in operation around the world over the past decade. Each has generated a carbon price which can be compared to the $30 per ton price we have used in our model. H.R. 2454: American Clean Energy and Security Act of 2009, otherwise known as the Waxman-Markey Bill, is currently in proposal and will create a cap-and-trade scheme that is estimated to have a carbon price starting between $11 to $15 and reaching $22 to $28 in 2025 (Environmental Protection Agency (EPA), 2010). The cap-and-trade system currently in use in the European Union (EU) is expected to reach a price of $20 per ton in 2010 (UNFCCC, 2010). The French carbon tax, which was to be introduced in 2010 until regulatory concerns prevented its launch, would have started at $20 per ton in (Carbon Tax Center, 2010). Lastly, the carbon tax in British Columbia, which is currently $10 per ton, will increase $5 a year until it reaches $30 per ton in 2012 (Lang Michener, 2009).

2.1.4 Impact on Solar Power

Initially, the implementation of a carbon pricing mechanism appears to improve the case for the adoption of solar power. By raising the cost of coal and natural gas, a carbon price improves the relative cost of all resources that do not emit carbon. The resources that emit little to no carbon are coal and natural gas with CCS equipment, nuclear and all renewable sources. Figure 5 illustrates the lack of renewable alternatives in Arizona besides solar, leaving only nuclear, coal and natural gas CCS and out of state generation as alternatives to solar in Arizona.

Figure 3: Renewable Resource Availability in Arizona[25]



Source: Black and Veatch, 2007

However, assuming that there is no regulation in place requiring electricity generating firms to generate a portion of their energy from solar, the position of solar power, relative to nuclear and clean coal, will change very little. For example, a $30 per ton carbon price increases the levelized cost of electricity from a new IGCC plant with CCS by 1.7% and does not increase the cost of electricity from nuclear. In order to change the position of solar, relative to technologies that do not emit large amounts of carbon, regulation is required.

2.2 Pigouvian Tax

A Pigouvian tax on carbon is one of two methods of government intervention currently used to place a cost on carbon emissions in the electricity generation sector. The most important step in implementing a carbon tax is for lawmakers to set the correct tax level. If the tax is too low, it will not change the behavior of utilities sufficiently to force a significant decrease in carbon emissions. If the tax is set too high, it will increase electricity prices higher than were required to reduce emissions. Therefore, the ability of a carbon tax to function depends entirely on government decision-makers. After the level is set, the tax is applied to any generation

[25] This report assessed only what resources were sufficient to meet Arizona's forecast renewable energy requirements in 2025. Actual solar potential in Arizona is much greater (Black and Veatch, 2007).

technology which emits carbon. At this point, the tax functions as a price on carbon, increasing the cost of carbon-emitting generation technologies.

By increasing the cost of carbon-emitting generation technologies, a carbon tax decreases carbon emissions by decreasing the relative cost of carbon-free technologies and reducing electricity demand due to higher electricity prices.[26] It may also raise significant amounts of revenue for the government. The potential options for this revenue, and their impact on electricity users, is discussed further in the cap-and-trade section of this paper.

2.2.1 Global Adoption

Carbon taxes have grown in popularity within the past few years. In the sections below, their impact on the national and international levels is discussed.

2.2.1.1 U.S. Adoption

To date a carbon tax has not been implemented in the United States on either the state or federal level. When negotiations were ongoing at the Kyoto Conference, the U.S. delegation showed its preference for a cap-and-trade system over a carbon tax for enforcement reasons (The Economist, 2009).[27] With the momentum of the country behind cap-and-trade systems,[28] it appears unlikely that the U.S. will see a carbon tax in the near future (Carbon Tax Center, 2010).

2.2.3.2 International Adoption

Carbon taxes have been successfully implemented in several regions and countries around the world. British Columbia implemented a carbon tax in July of 2008 which includes nearly all greenhouse gases. The tax rates, which cover all businesses that purchase or use fossil fuels,

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[26] The severity of this increase depends on the amount of the cost increase that the electricity generating firm is able to pass on to its customers.
[27] The delegation assumed that a carbon tax would be harder to pass through the legislature and that a cap-and-trade system would provide more room to maneuver around carbon cuts.
[28] The Western Climate Initiative, Waxman-Markey Bill, Kerry-Lieberman Act, and the Regional Greenhouse Gas Initiative all utilize a cap-and-trade system to reduce emissions.

were based on a $10 per ton carbon price. This price increased to $15 per ton in 2009 and will increase by $5 per ton annually until it reaches $30 per ton in 2012 (Ministry of Small Business and Revenue, 2008). However, further increases in the carbon tax will most likely occur since it has been estimated that a $75 carbon tax is required to reduce emissions in British Columbia to its committed level of carbon emission reduction (Pembina Institute, 2008).[29] The system maintains revenue neutrality by returning tax revenues from the carbon tax to individuals as a lump sum, particularly middle and lower-income families, and a 1% decrease in general and small business corporate income taxes. As a result, individuals in high income brackets will be impacted the most. Other countries with carbon tax programs either in place or in a planning phase include Denmark, Finland, France, Ireland, The Netherlands and Sweden.

2.3 Cap-and-Trade

Cap-and-trade systems[30] allow the market to determine a price for carbon by setting a limit on the quantity of emissions allowed. Once the limit has been determined, allowances to emit carbon are, in most cases, distributed to regulated entities.[31] Allowances can be distributed in two ways: by quota or auction. If the allowances are distributed by quota, the regulating body must determine the manner in which they are distributed. While there are many different ways to distribute allowances,[32] the impact of the distribution on the regulated firms is important to consider. For example, if allowances are distributed by carbon emissions, electricity generating firms that have already reduced their carbon emissions will not receive credit for this in the system.

If allowances are distributed by a quota system, there is only one circumstance in which allowances will not be traded after initial distribution. If allowances are distributed based on ability to switch to less carbon-emitting fuels, there is no opportunity for trade since the allowances will already have been efficiently distributed. However, if this is not the case, a

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[29] British Columbia committed to a level of carbon emissions that is 10% below 1990 levels by 2020 (Pembina Institute, 2008).

[30] It is important to note that the following explanation of cap-and-trade systems assumes the market is operating with perfect information, allowing each firm to make the most cost-effective choice.

[31] Examples include the WCI, RGI, and European cap-and-trade systems.

[32] Examples include by production, population, carbon emissions or electricity produced. In the current Waxman-Markey bill, if a state has an RPS, it will receive more allowances than a state without an RPS.

secondary market for allowances will be created after distribution by quota. Firms with low carbon abatement costs will offer to sell their allowances at a price which is greater than the difference between the carbon-emitting source they are moving away from and the carbon-reduced[33] source they are adopting. Firms with high carbon abatement costs will purchase allowances at a price which is less than the difference between the carbon-reduced option available and the carbon-emitting source they seek to continue using. Over time, the cap is designed to decrease, which will increase the cost of allowances in the secondary market and encourage more firms to adopt carbon-reduced sources. The reason more firms will adopt carbon-reduced sources is because, with higher allowance costs imposing a higher carbon price, carbon-reduced technologies experience a relative price decrease. Due to the cost of allowances, a carbon price emerges from the cap-and-trade system. In this case, the government receives no revenue because allowances are given freely by quota.

If regulators decide to not give allowances away freely, they will hold an auction where firms will purchase allowances. If allowances are 100 percent auctioned, a secondary market for allowance trading will not be created. Each entity purchases allowances at the level of its abatement cost, which leaves no arbitrage opportunities.[34] If a portion of the allowances are auctioned, and the rest distributed by quota, a secondary market will exist and operate in a similar manner to the market which would result from distributing 100 percent of the allowances by quota. The secondary market price will be higher than the auction price because, if it isn't, no firm will participate in the auction due to the lower price available in the secondary market. In the case where allowances are auctioned, the carbon price is a product of the auction price. The government gains revenue from the process and, if the auction are 100 percent sold, the cap-and-trade system will be fundamentally similar to a carbon tax.

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[33] It is important to note that firms will not necessarily choose carbon-free sources. If technologies are available that emit small amounts of carbon at a price which becomes competitive after a carbon price is implemented, firms may choose these technologies. Examples include coal and natural gas plants with CCS equipment.

[34] A purchaser of allowances would hope to take advantage of an arbitrage opportunity by buying allowances in the auction and selling them after for a higher price. However, it is assumed that firms will purchase allowances at their abatement cost, so if they required allowances, they would have bought them for a higher price at auction rather than in the secondary market. Therefore, no arbitrage opportunity exists.

When regulators enforce a cap on carbon emissions, they must determine whether the cap will be enacted upstream, midstream, or downstream. Upstream regulation enforces the cap where carbon-based fuels first enter the economy, so it will impact fuel suppliers in the electricity generation sector. Many systems have been proposed with upstream regulation because the process will not require participation from 99.9% of American companies and 100% of American households (Durning, 2009). Midstream regulation will require compliance from retailers and impact electricity generators directly. Downstream regulation will impact individual consumers who buy carbon-based energy, meaning the customers of electricity generating firms. Typically, the farther down regulation occurs, the harder it is to enforce and the more it impacts individual energy consumers.

2.3.1 Offsets

One feature of cap-and-trade systems that alters the process of obtaining allowance is the use of carbon offsets. A carbon offset represents an amount of carbon emissions that was averted in a sector which is not covered by the cap-and-trade system. Carbon offsets are available internationally as well as in uncovered domestic sectors. After the signing of the Kyoto Protocol, a world market for carbon offsets was created under the direction of the Clean Development Mechanism (CDM), which is a part of the United Nations Framework Convention on Climate Change (UNFCCC). The CDM creates and monitors international offsets to prevent false offsets from entering the market. An example of one of these projects would be a utility in the United States funding a portion of a hydropower plant in Nigeria, which would have built a coal plant if the additional funding was not available. Due to the nature of this exchange, offsets are popular in developing countries because they are a source of income (UNFCCC, 2010).

Developed countries favor offsets as a cost-effective method of compliance with regulation. A firm in the United States operating under a cap-and-trade system will enter the market for carbon offsets if there are projects available that are less expensive than the cost of an allowance. As a result, offsets may reduce the price of allowances in a potential cap-and-trade system. One of the most important issues with offsets, from a regulation standpoint, is ensuring that the offsets are legitimate.

This process has proven difficult, as it isn't easy to determine what would have happened to certain projects if funding was not available through carbon offsets (Bradsher, 2007). For example, the CDM has received criticism for financing a portion of 20 gas-fired power plants in China (The Economist, 2009). Although it is true that these plants prevented the construction of more coal-fired power plants, China had previously announced an energy policy angled away from coal for reasons other than climate change. Carbon offsets serve a useful purpose in the development of a cost-effective cap-and-trade system, but if they are not carefully monitored, offsets will negatively impact the overall goal of the system, which is to limit carbon emissions.

2.3.2 Carbon Price Revenue Alternatives

As Table 7 indicates, there are several options available for the government to use the revenue generated from either a carbon tax or cap-and-trade system. These options can be split into two categories: revenue neutral and revenue increasing. Revenue neutral options distribute all the revenue gathered by the government back to the tax base in some form. Revenue increasing options enable the government to spend the increased revenue on any program it desires.

Table 5: Carbon Tax and Cap-and-trade Revenue Alternatives

Revenue Neutral	Income tax reduction
	Carbon Rebates for low and middle income families
	Rebate for energy intensive businesses
	Carbon rebates for all energy users
	Corporate tax reduction
Revenue Increasing	Investment in carbon free energy research
	Investment in energy efficiency programs
	Balance the budget

The issue of distribution of the revenue garnered through a carbon pricing mechanism is important because of the impact of the increase in electricity prices on consumers and businesses. A rise in the price of electricity increases costs for businesses and households alike. Energy intensive businesses are hit the hardest and will react by decreasing production and increasing prices. Households will reduce consumption of other goods to compensate for the increase in electricity cost. On the individual level, low-income families will be the worst off because electricity bills take up a larger percentage of their income than middle and higher-income families. Therefore, the options in Table 6 seek to reverse some of these impacts. The policy examples from Table 6 are explained below.

Income tax reduction - Applied across the board, an income tax reduction gives each income tax filer a percentage of their annual tax back. However, it is not distributed based on the impact of higher electricity prices and favors high-income individuals. Additionally, it does not compensate businesses for their higher electricity expenses.

Carbon rebates for low and middle-income families- The rebate amount is based on income level, with low-income families receiving more than middle-income families. The advantage of this tax is that it offsets some of the impact of higher electricity prices on the individuals that are affected the most. However, it does not compensate businesses for their higher electricity expenses.

Rebate for energy-intensive businesses- The rebate is based on the level of energy use by each business. The rebate is advantageous because it compensates for the increase in business operating costs, which are higher due to electricity price increases. However, this rebate doesn't help individuals that face higher electricity bills, particularly low-income families.

Carbon rebates for all users- This tax rebate is applied to all individuals and firms based on their electricity use. While it does partially offset the increase in electricity costs for all parties affected, low-income families will be worse off because the rebate will not be able to cover the entire impact of the increase in electricity prices.

Corporate tax reduction- Drawing on the British Columbia model, corporate tax reduction lowers costs for businesses. However, it does not lessen the impact of electricity prices on individual families or businesses.

Investment in carbon-free energy research- Rather than refunding individuals impacted by electricity price increases, an investment in carbon-free energy research is designed to improve carbon-free technology so electricity prices will decline in the future. While the additional investment will aid carbon-free technology, it will be offset by the impact on businesses and families of higher electricity prices.

Investment in energy-efficiency programs- Investing in energy-efficient appliances and processes will reduce the demand for energy and reduce the need for additional electricity generating power plants. However, this program will not lessen the impact on businesses and families.

Balancing the federal budget- Due to recent assistance for the financial sector and fiscal stimulus, the federal deficit has substantially increased. As a result, there has been a call to balance the budget using revenues from a carbon pricing mechanism.[35] However, this will not lessen the impact of higher electricity prices on businesses and families.

2.3.4 Global Adoption

Cap-and-trade systems have been adopted both nationally and internationally over the past 30 years as a preferred mechanism for reducing carbon emissions in the electricity generation sector. The widespread adoption of the cap-and-trade system is apparent in the sections below.

2.3.4.1 U.S. Adoption

The most successful adoption of a cap-and-trade system in the U.S. was the acid rain cap-and-trade program included in the 1990 Clean Air Act Amendments. Designed to influence utilities to adopt techniques that decrease sulfur dioxide emissions, the program resulted in a decrease in sulfur dioxide of more than 40% from 1990 to 2000 (Environmental Defense Fund, 2010). In this decade, the 10 states of the New England area adopted the Regional Greenhouse Gas Initiative (RGGI) to reduce carbon emissions in that region. The Western Climate Initiative (WCI), involving seven U.S. states and four Canadian provinces, and the Midwest Greenhouse Gas Reduction Accord (MGGRA), including much of the Midwest, are in the planning process. However, these efforts are small in comparison with the federal cap-and-trade system currently in the legislative process as a part of the Waxman-Markey bill. If passed, the bill will create a cap-and-trade system encompassing all 50 states.

2.3.4.2 International Adoption

The Kyoto Protocol is the most significant international agreement on global climate change in place today. Adopted on December 11, 1997, it has been ratified by 187 countries (UNFCCC, 2010). This group includes 37 industrialized countries which pledged reductions of four greenhouse gases,[36] as well as two gases produced by them,[37] by 5.2% from their 1990 level. The

[35] The proposal to use funds from a carbon price program to reduce the deficit has appeared as an option in both the Waxman-Markey Bill and the Kerry-Lieberman Act.
[36] Carbon dioxide, methane, nitrous oxide, and sulphur hexafluoride.

Kyoto Protocol encouraged the adoption of cap-and-trade systems as a method for reduction in greenhouse gases. The largest program to date is the European Union (EU) cap-and-trade system, which commenced operation in January 2005. Covering over 12,000 emitting facilities, the allowances have been distributed freely to the regulated sectors, which include the power sector, specified industrial sectors, and all combustion facilities with a thermal input greater than 20 MW (Ellerman, 2008). The program is currently in its second phase, with allowance market analysts forecasting a price of $20.07 per ton of carbon dioxide. They are expected to rise to $25.80 in 2011, $34.41 in 2012 and average $57.34 in 2013 through 2020 (UNFCCC, 2010). The increase in price is due to the number of allowances being tightened to comply with the EU goal of a 21 percent cut below 1990 levels in industrial carbon emissions by 2020.

Countries with similar programs include: Australia, Canada, Chile, China, Mexico, The Netherlands, and South Korea. Dozens of other countries, including Japan (Business Green, 2008) and South Africa (Creamer, 2008), have begun introducing legislation that would enact similar systems.

[37] Hydrofluorocarbons and perfluorocarbons.

3. Government-Mandated Direct Mechanisms

When governments intervene directly in the electricity market due to environmental policy, they do so in three ways: ambient standards, emissions standards and technology standards (Syracuse University, 2010). *Ambient standards* regulate the amount of a particular pollutant present in the environment. In this context, the government will measure the amount of carbon dioxide and its equivalents in the atmosphere and set a limit which can't be exceeded. The region which is in excess of the standard is required to formulate and execute a plan of action to attain compliance. However, this is difficult with carbon dioxide emissions for two reasons. First, the responsible region is the entire planet, which requires the participation and agreement of the countries responsible for significant carbon dioxide emissions. As the Kyoto Conference illustrated, this is not an easy task. The second problem is that carbon dioxide emissions are retained in the atmosphere for a period of 50 years or longer (EPA, 2009). Any attempt to achieve compliance by reducing emissions will not have an effect for years, if not decades.

Emissions standards regulate the level of emissions, which are enforced at the source. For the electricity generation sector, this would impact the emissions of a plant as well as suppliers of coal and natural gas. The advantage of this system is its regulatory simplicity. In comparison to an ambient standard, an emissions standard can be easily measured, does not require international cooperation, and can target particular companies and regions for enforcement. However, ambient standards are unable to account for other factors which contribute to the problems associated with carbon dioxide emissions, such as weather conditions and other human behavior.

Technology standards enforce particular technology solutions or techniques. The introduction of scrubbers to reduce sulfur dioxide emissions was an example of a technology solution in the electricity generation sector. A technology standard is useful due to its simple implementation and direct impact on carbon dioxide emissions. However, it is only useful when the government has a clearly defined better available control technology. This is often not the case. In the case of the electricity generation sector, the government chooses a particular generation technology or piece of equipment that it has decided is preferable over what the market would choose without the regulation. There are three technology standards that national or state governments have imposed on the electricity market. Each will be explained below, along with their impact on solar power and the global adoption of each type of mechanism.

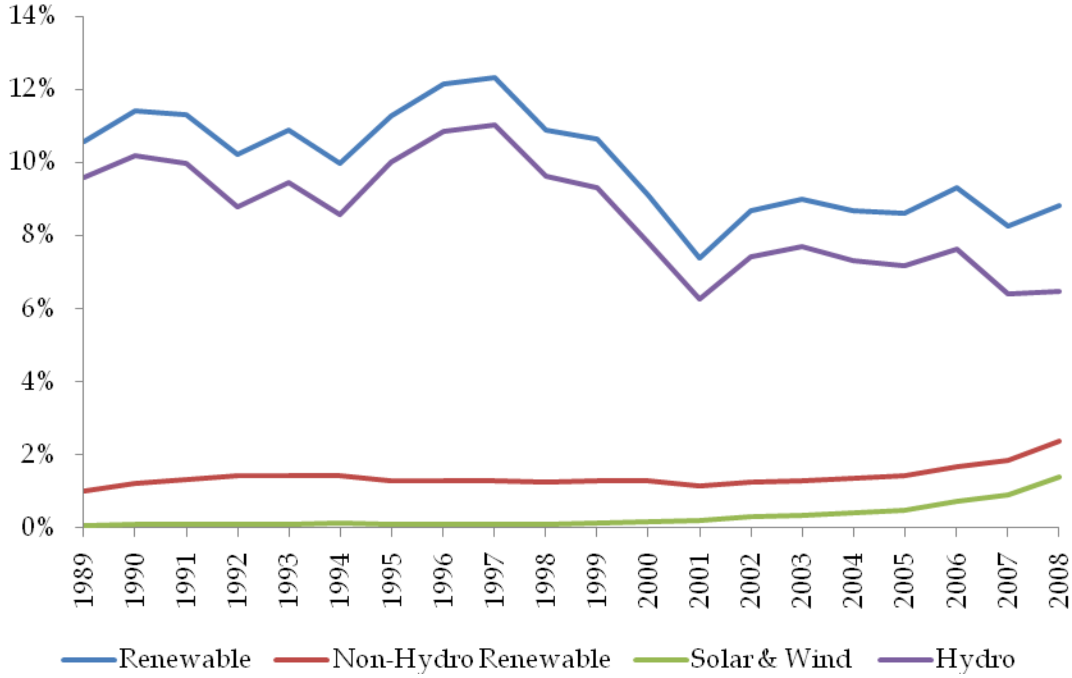
3.1 Renewable Energy Requirement

The EIA defines a renewable resource as an energy resource that is naturally replenishing but flow-limited. These include bio-fuels, biomass, geothermal, hydro, solar, tidal, wave, and wind. Renewable resources have been publicized greatly over the last 10 years because of their ability to generate electricity without releasing large amounts of carbon into the atmosphere. However, as Figure 6 illustrates, renewable electricity generation has actually declined, relative to total U.S. electricity generation, since its peak in the late 1990s. This decline is due to a reduction in the share of hydropower in the U.S. electricity generation portfolio.

Although the total share of the portfolio has declined over the last decade, the share of electricity generation from wind and solar has substantially increased since 2001. This is largely due to the increases in wind power in states such as Texas. Despite this growth, the small amount of total U.S. electricity generation that wind and solar provide[38] demonstrates the increase in generation capacity of renewable sources required to begin replacing carbon-emitting sources, such as coal and natural gas.

[38] 1.4 percent in 2008 (EIA, 2010).

Figure 4: U.S. Renewable Electricity Generation, 1989-2008



Source: EIA

Renewable energy requirements began to appear, both nationally and internationally in the late 1990s, as governments responded to pressure from public and private organizations concerning climate change due to GHG emissions (NREL, 2010). By mandating the amount of electricity to be generated from renewable sources by a certain date, governments seek to work with electricity-generating firms to steadily introduce renewable sources into the electricity generation portfolio.

Renewable energy requirements are relatively simple to monitor and enforce. They require regulated utilities to generate a certain amount of their total electricity generation from renewable resources. The standard method of measurement is a percentage of electricity retail sales (ERS) generated by renewable resources by a target year. Regulators provide rates of generation required each year to prevent utilities from ramping up renewable generation in the final year and creating regulatory and production complications. An alternative method of measurement in use is a required amount of renewable capacity available by a certain date. The only difference in these two approaches is actual generation versus available capacity,[39] which can be a significant issue for intermittent sources like wind and solar. However, both satisfy the overall goal of encouraging electricity generation from renewable resources.

The advantage of a regulatory system is that it requires utilities to focus on a particular technology, or group of technologies. In the case of a renewable energy requirement, it ensures that a percentage of electricity retail sales, or installed capacity, of a particular resource which is in line with the goals of regulators, will be in use. However, it excludes potential carbon-reduced sources, such as nuclear and clean coal. The adoption of this mechanism, in conjunction with a carbon tax or cap-and-trade system, limits the effectiveness of carbon-pricing mechanisms. By imposing particular technology solutions on the electricity market, electricity generating firms will be forced to adopt renewable sources, even if they are more expensive and less effective at meeting the demand profile than potential low-cost forms of generation which do not emit large amounts of carbon but are not renewable.

3.1.2 Impact on Solar Power

A renewable energy requirement can be a very effective policy for increasing adoption of solar power. By requiring electricity-generating firms to generate a certain percentage of their electricity from renewable sources, it eliminates lower cost carbon-free competitors, such as nuclear. A renewable energy requirement has a greater effect on the adoption of solar power in states which lack sufficient renewable alternatives to solar, provided they do not purchase electricity from renewable sources outside the state. As Figure 4 illustrated in section 2.1 of this paper, Arizona's non-solar renewable capacity is limited. With utilities seeking to acquire renewable resources to meet 15 percent of ERS by 2025, solar power is expected to be relied on by Arizona utilities to meet the majority of their requirement.[40] Table 8 shows the expected renewable requirements from 2009-2025 for regulated Arizona utilities.[41]

[39] The percentage of ERS regulatory approach measures actual electricity generation while the renewable capacity regulatory approach measures installed capacity. For sources with a small capacity factor (30 to 40 percent), the difference is significant.
[40] SRP is an exception to this statement. In addition to not being subject to the Arizona RES, SRP already has significant hydro resources that that equal approximately 6% of its ERS. This statement also assumes that Arizona will not purchase a significant amount of their renewable requirement from outside the

Table 6: Arizona's Renewable Energy Standard

Year	*Renewable*	*Distributed*	*Year*	*Renewable*	*Distributed*
2010	2.5%	0.5%	2018	8%	2.4%
2011	3%	0.8%	2019	9%	2.7%
2012	3.5%	1.1%	2020	10%	3.0%
2013	4%	1.2%	2021	11%	3.3%
2014	4.5%	1.4%	2022	12%	3.6%
2015	5%	1.5%	2023	13%	3.9%
2016	6%	1.8%	2024	14%	4.2%
2017	7%	2.1%	2025	15%	4.5%

Source: Arizona Corporation Commission (ACC)

In addition to promoting solar through requiring renewable generation, several states, including Arizona,[42] have a distributed generation requirement. Given the advantage of solar photovoltaic (PV) over other distributed generation technologies,[43] distributed requirements will generate increased investment in solar power technology and encourage large-scale commercial adoption.

3.1.3 Global Adoption

Renewable energy requirement programs have been adopted by states and countries to compel electricity generating firms to increase the amount of renewable resources in their generating

state. Arizona utilities currently have power purchase agreements with wind and geothermal energy producers in New Mexico and California.

[41] The two regulated utilities in Arizona (APS and TEP) constitute 50.2 percent of ERS in Arizona. SRP accounts for 35.4 percent.

[42] Arizona's PV requirement is split 50/50 between commercial and residential.

[43] In parts of the country, distributed wind generation is available. However, distributed wind turbines pose significant technical and land issues. Fuel cell technology has distributed potential but has yet to be adopted commercially (NREL, 2010).

portfolio. Due to the widespread adoption of these programs, renewable use in the United States has substantially increased (NREL, 2010). By looking at the adoption of these programs, both nationally and internationally, we can determine how widespread their use is and how important they are to the global movement to reduce carbon emissions.

3.1.3.1 U.S. Adoption

In the United States, renewable energy requirement programs are typically called Renewable Portfolio Standards (RPS). Barring passage of a federal RPS in the Waxman-Markey bill,[44] the current adoption of these programs in the United States is only at the state level. At the end of 2009, 41 U.S. states and the District of Columbia had an RPS in place. 37 states and the District of Columbia have a percentage of ERS requirement, while four states have a specific generation amount requirement or combination of the two. The most aggressive state is California, which aims for 33 percent of its ERS from renewable resources by 2020. The Arizona Renewable Energy Standard (RES) requires renewable resources to generate 15% of electricity retail sales for regulated utilities. Salt River Project (SRP), the second largest utility in Arizona, is not bound by the RES, but has agreed to mirror its requirements (SRP, 2010). Arizona Public Service (APS), the largest utility in Arizona, is currently aiming to exceed the RES guideline of 5 percent by 2015 by generating 10 percent of its ERS from renewable sources by 2015 (APS, 2009). The full list of RPS programs is available in Appendix 3.

3.1.3.2 International Adoption

Adoption of renewable energy requirement programs occurred in many countries over the past decade. Australia updated their Renewable Energy Target (RET) in 2007 to achieve a goal of 20% of the country's electricity supply from renewable sources. A national program was enforced to bring together multiple state programs and reduce inefficiency (Australian Department of Climate Change, 2010). Great Britain has a renewable energy target of 10% by 2010, which has caused the country to invest significantly in offshore wind power (IEA, 2010). Austria implemented an aggressive renewable target in 2008 of 15%by 2015 which excludes

[44] The bill will create a federal RPS target of 20 percent renewable energy by 2020. The bill includes a provision for up to 40 percent of the renewable target to be met by energy efficiency (All Business, 2009).

large hydro. The target is to be met with mostly wind, biomass, and smaller hydro electricity generation facilities (IEA, 2010).

3.2 Energy Efficiency

In the context of regulation, an energy efficiency program is a government-mandated method of reducing electricity demand. 16 states[45] have current or pending programs that either require a certain percentage of energy efficiency or allow it qualify as an eligible resource for its RPS. The ability of energy efficiency gains to offset state RPS requirements[46] is important for states with limited low-cost renewable resources.

Table 9 is a breakdown of residential electricity usage by item in Arizona.[47] While air conditioning and heating are two of the biggest electricity users, the most substantial energy efficiency improvements are being made in electricity usage by computers, televisions, and other electronics equipment, which accounted for 14.3% of Arizona's residential electricity usage in 2007 (EIA, 2010).

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[45] Texas (1999), Vermont (2000), California, Hawaii, Pennsylvania (2004), Connecticut, Nevada (2005), Colorado, Washington (2006), Minnesota, Virginia, Illinois, North Carolina (2007), Arizona (2009), New Jersey and New York (pending).

[46] Either as a one-to-one percentage point replacement within the RPS or partial credit by lowering the overall amount of retail sales that is used to calculate the RPS requirement.

[47] The original usage numbers were for APS customers and extrapolated for the entire state using the breakdown in high-country versus low-country usage and county population estimates (U.S. Census Bureau, 2010).

Table 7: Residential Electricity Usage in Arizona, 2007[48]

Appliance	*Usage*
Central Air Conditioning	39.3%
Room Air Conditioning	4.4%
Heating	8.5%
Lighting	3.5%
Refrigerator	9.6%
Freezer	2.7%
Hot Water Heater	10.3%
Clothes Washer	2.7%
Dishwasher	2.7%
Pool Pump	2.7%
Other[49]	13.8%

Source: ICF International

Energy efficiency programs are not specifically a technology standard, since the government does not specify the technology used to reduce electricity demand. Rather, electricity generating firms are allowed the freedom to encourage any program or technology necessary to reduce demand to stipulated levels. Intervening in the market may leads to inefficiency, but in the case of energy efficiency programs, it has turned out to be efficient due to the flexibility of each program. The significant gains available are evident by the inclusion of a clause in the Waxman-Markey bill that allows up to 40% of the national renewable target to be met by energy efficiency. The reason significant energy efficiency gains are available is because electricity consumers, who have the greatest incentive to buy energy efficient devices, do not make the efficient choice, largely due to information deficiencies (U.S. DOE Energy Efficiency and Renewable Energy (EERE), 2010).

An example of the lack of consumer oversight creating inefficiency is the power adaptor, which converts high-voltage alternating current from the main line to low-voltage direct current for

[48] The data are taken from a study of APS service areas and, therefore, do not include any SRP, TEP, or co-op customers. However, given that APS serves both low and high country customers, the numbers are good estimates of overall state consumption.
[49] Other includes plug load, computer equipment, etc.

electronic gadgets. Until five years ago, a copper wire was used in this conversion and as much as 80% of electricity was lost. Converting the energy using integrated circuits only cost 30% more than the copper wiring and reduced losses to less than 20%. However, these devices cost $2 or less, making a 30% increase in cost unnecessary, provided that the market did not value integrated circuits over copper wires. Noticing the inefficiency in the process, regulators in the U.S. stepped in and adopted regulations which required integrated circuits for use in the U.S. The switch, which was adopted globally, has decreased power consumption worth around $2 billion each year, or 13 million tones of CO_2 (The Economist, 2009).

A concern regarding energy efficiency programs, known as the rebound effect, is that improvements in energy efficiency actually lead to greater use of energy. First used to describe the phenomenon of a more efficient steam engine increasing coal use in Britain in 1865, the theory is applicable to energy efficiency gains. By making energy appear cheaper than other inputs and increasing economic growth, energy efficiency increases the use of energy. For example, if there is an improvement in the energy use of air conditioners, individuals who are deterred by the cost of electricity due to running the air conditioner will use it more because it is cheaper. As a result, the reduction in energy use due to improvements in efficiency is less than one to one.

3.2.3 Impact on Solar Power

Without considering RPS requirements, energy efficiency programs are an alternative method of satisfying electricity demand without emitting carbon. Each watt-hour of electricity saved through efficiency techniques is one less watt-hour that electricity generating firms must provide. In a state like California, which generates most of its electricity from natural gas, renewable sources, and nuclear, the environmental benefit of energy efficiency programs is less than in a state such as Utah, which generates a majority of its electricity from coal. Therefore, a state without an RPS requirement will measure the environmental benefits of energy efficiency, in comparison with solar, differently depending on its generation portfolio.

In states that allow energy efficiency gains to satisfy their RPS requirement, energy efficiency programs can be viewed as a competing technology with solar. In these states, implementation of energy efficiency measures will have a variable negative impact on solar adoption depending largely on the cost of the energy efficiency measures. In states that do not allow energy efficiency gains to satisfy their RPS requirement, the only negative impact on solar adoption will be the decrease in electricity retail sales due to declining electricity demand. In Arizona, the ACC set an energy efficiency standard for all Arizona regulated utilities beginning in 2011. The details of this standard are available in Table 10. However, since energy efficiency does not qualify as part of the state RES, the impact of this ACC ruling on solar power is limited to reducing the load requirement of regulated utilities. This reduces the amount of solar power that Arizona regulated utilities are required to build as part of the RES.

Table 8: Energy Efficiency Standard for Regulated Utilities in Arizona[50]

Year	*Standard*
2011	1.25%
2012	3.00%
2013	5.00%
2014	7.25%
2015	9.50%
2016	12.00%
2017	14.50%
2018	17.00%
2019	19.50%
2020	22.00%

Source: ACC

3.2.4 Global Adoption

Over the past decade, energy efficiency programs have increased in use around the world to the point that they are considered by some to be, along with renewable sources, the twin pillars of

[50] Cumulative annual energy savings in each calendar year are presented as a percent of retail energy sales in the prior calendar year. The energy efficiency estimates are based on 2009 load data.

sustainable energy policy (Prindle, 2007). In the sections below, examples of energy efficiency programs, both nationally and internationally, are presented.

3.2.4.1 U.S. Adoption

The energy efficiency movement in the United States has resulted in the creation of multiple public and private organizations that provide funding, information, research, and technical expertise in energy efficiency. The first attempt by the U.S. government to encourage energy efficiency measures was the creation of the State Energy Conservation Program (SECP) and the Institutional Conservation Program (ICP) in 1975. The SECP provided states with funding for energy efficiency and renewable projects, while the ICP identified potential energy savings for hospitals and schools (EERE, 2010). These programs were combined into the State Energy Program in 1996. The State Energy Program and the Department of Energy's EERE program increase energy efficiency in the U.S. economy and reduce energy costs. The State Energy Program claims to save $7.23 from energy bills for each dollar of federal investment (EERE, 2010).

3.2.4.2 International Adoption

Energy efficiency programs have been adopted in many countries for both environmental and financial reasons. Germany has been a world leader in solar PV adoption for the last decade and has recently expanded its energy efficiency programs. Its most recent energy efficiency plan entails an 11 percent reduction in electricity use by 2020 (Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, 2010). France has over 35 energy efficiency measures in place, ranging from reducing building electricity consumption to loan guarantees for energy efficiency investment (IEA, 2010). China has made energy conservation a primary focus in its five-year plan for 2006 through 2010. The country is hoping to focus particularly on highly-consuming industries in the industrial sector, which include power, iron, steel, and others. The focus will be particularly beneficial to the environment due to China's reliance on coal for much of its energy (Post Carbon Institute, 2010).

3.3 Loading Order

Loading order is a method of regulation which seeks to meet increasing electricity demand with a set of preferred resource options over traditional generation technologies. California developed the first loading order system in 2003 with the goal of shifting the priorities of the electricity generation sector (California Energy Commission (CEC), 2005). In the California loading order system, energy efficiency, demand response, renewable resources, and distributed generation are given preference over other resources for meeting increases in future electricity demand. The other resources would include nuclear as well as coal, natural gas, and petroleum with or without carbon emission reducing technology. By making this distinction, California regulators are signaling their preference for renewable resources and reducing electricity demand as tools for mitigating carbon emissions over nuclear and clean coal and natural gas.

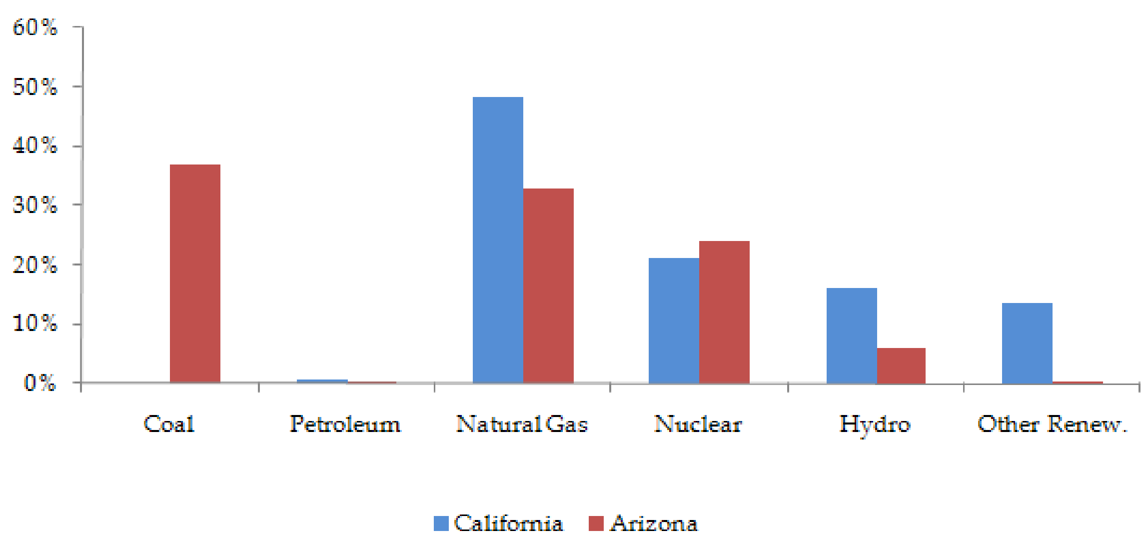
Load ordering faces significant challenges which prevent it from being a perfect system. Similar to any regulatory system, it is dangerous to restrict utilities from making generation mix decisions. Utilities have been reticent in embracing the methods of meeting future electricity demand detailed in the loading order for several reasons. First, integrating loading order resources requires significantly increased cooperation and planning which has been difficult to coordinate and puts further strain on regulatory and utility resources. Second, regulatory and legal challenges, such as low demand response to current regulation, intricate building codes and lack of incentives for utility participation, prevent the California system from running optimally. The third reason for utility reticence is the significant pressure placed on the infrastructure. Examples include the requirement of metering for demand response and the ability of utilities to manage significant amounts of power from intermittent resources. Lastly, a system for monitoring and evaluating demand response and distributed generation systems is not in place, making the process extremely difficult to manage.

3.3.1 Impact on Solar Power

Loading order is a policy which will lead to increased construction of renewable resources in California, including solar. By eliminating potential carbon emissions free competitors, such as nuclear and clean coal, electricity generating firms will be more likely to construct solar. However, utilities have several renewable options in California, making it more likely that utilities would choose to invest in a low cost, base load, renewable resource, such as geothermal, over solar (CEC, 2010). In addition, decreases in electricity demand through energy efficiency and demand response programs are also part of the loading order, which reduces the demand for new generation.

In Arizona, which lacks significant in-state renewable resources other than solar, a loading order program would encourage solar growth. This assumes that electricity generating firms would have difficulty meeting all future electricity demand increases with out of state generation, energy efficiency and demand response programs.

Figure 5: Generation Mix for California and Arizona, 2007



Source: EIA

Figure 7 illustrates the difference between California and Arizona in electricity generation mix. Of the generation technologies, coal and other renewable stand out from the others. Arizona generates almost 40% of its electricity from coal, while California doesn't generate any electricity from coal. On the other hand, California generated over 13% of its electricity from renewable resources other than hydropower, compared to less than 0.1% for Arizona. Therefore, because of the difference in electricity generation mix, it can be expected that California will have success in implementing a loading order system, while Arizona will meet stiff opposition to a system which moves away from its primary sources of electricity.

3.3.2 Global Adoption

To date, California is the only region that has adopted a loading order. However, given the worldwide impetus for increased renewable usage and energy efficiency improvements, several other states and countries may follow suit. Following the implementation of this program in California, Nevada and Oregon began considering implementing a similar program but, up to this point, have not (CEC, 2010).

4. Conclusion

Government intervention in the electricity generation market is one option to correct for electricity generation and consumption choices that are not socially optimal. Regulators have the choice of intervening directly, through renewable requirements, energy efficiency programs, and loading order, or indirectly, through carbon taxes and cap-and-trade. The impact of these programs on electricity prices and the economy are at the center of the debate concerning which policy to adopt. In the case of either carbon pricing scheme and renewable requirement programs, intervention in the market will move electricity generating firms away from low-cost, carbon-emitting sources, such as coal, to more costly, carbon-reduced sources, such as solar. This shift will result in higher electricity prices, which will decrease electricity consumption as individuals respond to the increasing cost of electricity.

The severity of the impact on electricity prices depends on the difference in levelized cost between the existing generation portfolio and the future portfolio. The new portfolio will be shaped by the technologies determined by the intervention mechanism in use. Therefore, the decision of which intervention mechanism to promote has far-reaching consequences. The indirect mechanism uses a carbon price to shift electricity generation away from carbon-emitting sources. The implementation of an effective carbon price leaves generation mix decisions to electricity generating firms by setting a price which is high enough for these firms to choose generating technologies which emit lower amounts of carbon.

Direct intervention mechanisms dictate particular technologies or standards for the market to adopt. In the movement to reduce carbon emissions, direct mechanisms have changed the decision-making process for electricity generating firms. By not allowing particular technologies, regulators have decided that electricity generating firms will not choose the technologies which regulators determine to be correct.

In choosing which mechanism is the preferred method for lowering carbon emissions from the electricity industry, the answer lies in determining the better decision-maker: the electricity market or the regulating body. If the only goals of a carbon-reduction policy are to reduce carbon while limiting the increase in electricity prices, then the electricity market is best suited for this task. The market has chosen low-cost electricity generating technologies for decades and, provided that there is a deterrent in place for carbon emissions, will choose the correct technology. However, if there are additional factors involved, such as national security and concerns over nuclear waste disposal, then there is a purpose for direct government intervention.

Implications for Solar Power

The decision between direct and indirect mechanisms has a significant effect on solar adoption. The spread of renewable energy requirements, in both the U.S. and internationally, has been important for the development of solar (NREL, 2010). The existence of these re quirements prevents low-cost technologies, such as coal, natural gas, and nuclear, from competing with solar. The continued use of renewable energy requirements, particularly in solar friendly states like Arizona and California, will spur development in solar power. However, if these requirements are replaced with a carbon pricing mechanism, solar will be competing with nuclear, natural gas, clean coal, and clean natural gas as well as other renewable energy sources. Therefore, a direct mechanism to reduce carbon emissions is more preferable for the development of solar power than an indirect mechanism.

Glossary[51]

Base load plant: A plant which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

British thermal unit: The quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit).

Carbon cycle: All carbon sinks and exchanges of carbon from one sink to another by various chemical, physical, geological, and biological processes.

Carbon dioxide (CO_2): A colorless, odorless, non-poisonous gas that is a normal part of Earth's atmosphere. Carbon dioxide is a product of fossil-fuel combustion as well as other processes. It is considered a greenhouse gas as it traps heat (infrared energy) radiated by the Earth into the atmosphere and thereby contributes to the potential for global warming. The global warming potential of other greenhouse gases is measured in relation to that of carbon dioxide, which by international scientific convention is assigned a value of one.

Carbon intensity: The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per British thermal unit (Btu) of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels.

Carbon sequestration: The fixation of atmospheric carbon dioxide in a carbon sink through biological or physical processes.

[51] Glossary terms retrieved from the EIA Glossary.

Clean Development Mechanism (CDM): A Kyoto Protocol program that enables industrialized countries to finance emissions-avoiding projects in developing countries and receive credit for reductions achieved against their own emissions limitation targets.

Climate change: A term used to refer to all forms of climatic inconsistency, but especially to significant change from one prevailing climatic condition to another. In some cases, "climate change" has been used synonymously with the term "global warming"; scientists, however, tend to use the term in a wider sense inclusive of natural changes in climate, including climatic cooling.

Combined cycle: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

Global warming: An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is today most often used to refer to the warming some scientists predict will occur as a result of increased anthropogenic emissions of greenhouse gases.

Greenhouse effect: The result of water vapor, carbon dioxide, and other atmospheric gases trapping radiant energy, thereby keeping the earth's surface warmer than it would otherwise be. Greenhouse gases within the lower levels of the atmosphere trap this radiation, which would otherwise escape into space, and subsequent re-radiation of some of this energy back to the Earth maintains higher surface temperatures than would occur if the gases were absent.

Greenhouse gases: Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface.

Heat rate: A measure of generating station thermal efficiency commonly stated as Btu per kWh.

Hydrofluorocarbons (HFCs): A group of man-made chemicals composed of one or two carbon atoms and varying numbers of hydrogen and fluorine atoms. Most HFCs have 100-year Global Warming Potentials in the thousands.

Integrated gasification-combined cycle technology: Coal, water, and oxygen are fed to a gasifier, which produces syngas. This medium-Btu gas is cleaned (particulates and sulfur compounds removed) and is fed to a gas turbine. The hot exhaust of the gas turbine and heat recovered from the gasification process are routed through a heat-recovery routed through a heat-recovery generator to produce steam, which drives a steam turbine to produce electricity.

Kyoto Protocol: The result of negotiations at the third Conference of the Parties in Kyoto, Japan, in December of 1997. The Kyoto Protocol sets binding greenhouse gas emissions targets for countries that sign and ratify the agreement. The gases covered under the Protocol include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride.

Levelized cost: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars.

Perfluorocarbons (PFCs): A group of man-made chemicals composed of one or two carbon atoms and four to six fluorine atoms, containing no chlorine. PFCs have no commercial uses and are emitted as a byproduct of aluminum smelting and semiconductor manufacturing. PFCs have very high 100-year Global Warming Potentials and are very long-lived in the atmosphere.

Sulfur dioxide (SO_2): A toxic, irritating, colorless gas soluble in water, alcohol, and ether. Used as a chemical intermediate, in paper pulping and ore refining, and as a solvent.

Appendix 1: Carbon Dioxide Content of Electricity Generation Technologies

The amount of carbon dioxide present in generation fuel sources is used to calculate the levelized cost impact of a carbon price. Table 1 illustrates the amount of carbon dioxide emitted by each technology. Below the table, each technology's emissions factor is put in context.

Table 9: CO_2 Emissions Factor (metric tons/MWh)

Generation Technology	*CO_2*
Scrubbed New Coal	0.87
IGCC	0.82
IGCC w/ CCS	0.10
Conv. Gas CC	0.38
Adv. Gas CC	0.36
Adv CC w/ CCS	0.05
Conv. CT	0.57
Adv. CT	0.49
Fuel Cells	-
Adv Nuclear	-
Biomass	-
MSW - Landfill Gas	0.57
Geothermal	0.26
Conv. Hydro	-
Wind	-
Wind Offshore	-
Solar Thermal	-
Solar PV	-

Source: EIA and Authors' Calculations

Coal

Scrubbed coal power plants emit the most CO_2 in Table 10 due to the high CO_2 content of the fuel. IGCC power plants emit approximately the same amount of CO_2 as new supercritical scrubbed coal plants. Adding CCS equipment to a coal plant reduces efficiency but is expected to decrease carbon dioxide emissions by 90% (MIT, 2007).

Natural Gas

Natural gas is used as fuel in both CT and combined cycle CC plants. The increased efficiency of CC plants reduces carbon emissions in comparison with CT plants. CCS is expected to decrease carbon emissions from natural gas plants by 90%.

Oil/Petroleum

Petroleum-fired power plants are used mainly in the United States as peaking plants due to the rising price of oil. Oil is only suitable for combustion turbine plants and uses several different types of oil to fuel petroleum-fired power plants, including petroleum coke, distillate oil, residual oil, and others. The high carbon dioxide emission level is due to petroleum coke, which emits greater than 112 metric tons/billion Btu (EIA, 2009).

Fuel Cell

Fuel cells are able to use natural gas as well as hydrogen as a fuel. In this paper, we focus on hydrogen-fueled cells due to their lack of carbon emissions. It is important to note that, although hydrogen does not emit carbon dioxide, it is made with mostly natural gas or coal (National Hydrogen Association, 2009). It is possible to make hydrogen using renewable sources such as solar, wind and biomass, but the hydrogen production industry is currently dominated by fuels that emit carbon dioxide.

Uranium

Nuclear power plants use uranium-235 as a fuel source (EIA, 2009). While there are safety concerns with the disposal of nuclear waste, the electricity generation process in nuclear plants emits no carbon dioxide. Of all the non-carbon emitting resources used to generate electricity in the United States, nuclear is the most used.[52]

Biomass

Biomass power plants burn wood and wood waste to generate electricity. While this process does emit carbon, it is part of the living carbon cycle and does not contribute to the buildup of greenhouse gas (EPA, 2009).

MSW-Landfill Gas

Municipal solid waste (MSW) and landfill gas are used as bio-fuels to generate electricity. Both types of power plants are useful in capturing and burning potentially harmful methane from reaching the atmosphere. The process does emit a substantial amount of carbon dioxide into the atmosphere.

Geothermal

Geothermal power plants use geothermal heat from under the Earth's surface to generate electricity. This process emits a small amount of carbon dioxide into the atmosphere.

Wind

Wind turbines are driven by wind currents and are carbon dioxide emission free.

[52] In 2008, the United States generated 20.3% of its electricity from nuclear power. Hydro is the second most used non-carbon emitting resource (6%) (EIA, 2009).

Water

Hydro power plants are located on rivers and use the current of the water to generate electricity. This process emits no carbon dioxide.

Solar Radiation

Energy from the sun is used to generate electricity in two ways. Solar PV panels convert sunlight directly into electricity while solar thermal devices use the sun's heat to indirectly generate electricity. Both processes emit no carbon dioxide.

Appendix 2: State Electricity Generation Portfolio (2007)[53]

State	*Coal*	*Petroleum*	*Natural Gas*	*Nuclear*	*Hydro*	*Non-Hydro Renewable*
Alabama	58.1%	0.1%	13.0%	25.7%	3.1%	0.0%
Alaska	3.4%	15.0%	60.8%	0.0%	20.7%	0.0%
Arizona	**36.8%**	**0.0%**	**32.9%**	**24.1%**	**5.9%**	**0.0%**
Arkansas	49.5%	0.1%	14.1%	29.9%	6.2%	0.1%
California	0.0%	0.7%	48.3%	21.1%	16.1%	13.6%
Colorado	68.7%	0.1%	25.8%	0.0%	3.3%	2.5%
Connecticut	7.5%	4.1%	30.0%	52.6%	1.2%	2.3%
Delaware	73.8%	2.7%	22.8%	0.0%	0.0%	0.0%
Florida	29.5%	9.4%	45.6%	13.8%	0.1%	0.9%
Georgia	64.1%	0.1%	11.2%	23.3%	1.6%	0.0%
Hawaii	0.0%	93.0%	0.0%	0.0%	0.7%	6.3%
Idaho	0.0%	0.0%	14.2%	0.0%	84.2%	1.6%
Illinois	47.3%	0.1%	3.1%	48.8%	0.1%	0.7%
Indiana	97.4%	0.1%	2.0%	0.0%	0.4%	0.2%
Iowa	75.6%	0.6%	6.4%	9.4%	2.0%	6.0%
Kansas	72.3%	0.4%	4.2%	20.7%	0.6%	1.7%
Kentucky	93.6%	2.9%	1.7%	0.0%	1.7%	0.1%
Louisiana	37.6%	3.3%	29.8%	27.9%	1.3%	0.1%
Maine	0.0%	3.8%	48.8%	0.0%	30.0%	16.5%

[53] It is important to note that this table illustrates the breakdown of electricity generation in each state versus electricity consumption.

State	*Coal*	*Petroleum*	*Natural Gas*	*Nuclear*	*Hydro*	*Non-Hydro Renewable*
Maryland	60.2%	2.0%	2.5%	31.0%	3.6%	0.5%
Massachusetts	27.3%	6.7%	50.0%	11.7%	1.8%	2.8%
Michigan	64.5%	0.4%	4.1%	29.2%	1.2%	1.4%
Minnesota	60.5%	0.8%	5.5%	25.4%	1.1%	6.2%
Mississippi	36.2%	0.8%	43.6%	19.4%	0.0%	0.0%
Missouri	82.4%	0.1%	5.4%	10.3%	1.3%	0.0%
Montana	64.8%	0.1%	0.3%	0.0%	33.1%	1.8%
Nebraska	60.5%	0.1%	3.4%	34.1%	1.1%	0.8%
Nevada	23.6%	0.0%	65.3%	0.0%	6.7%	4.3%
New Hampshire	17.0%	1.5%	24.4%	46.5%	5.5%	4.9%
New Jersey	13.0%	0.7%	21.7%	62.5%	0.0%	1.6%
New Mexico	77.9%	0.1%	17.3%	0.0%	0.8%	3.9%
New York	15.2%	6.0%	25.8%	32.3%	19.1%	1.6%
North Carolina	61.3%	0.2%	3.5%	32.1%	2.4%	0.4%
North Dakota	93.6%	0.2%	0.0%	0.0%	4.2%	2.0%
Ohio	86.3%	0.7%	2.5%	10.2%	0.3%	0.0%
Oklahoma	45.8%	0.2%	47.1%	0.0%	4.4%	2.7%
Oregon	9.2%	0.0%	17.4%	0.0%	70.8%	2.7%
Pennsylvania	54.4%	0.6%	7.1%	36.2%	1.0%	0.7%
Rhode Island	0.0%	0.3%	97.4%	0.0%	0.1%	2.2%
South Carolina	41.0%	0.2%	5.3%	52.8%	1.5%	0.4%

State	*Coal*	*Petroleum*	*Natural Gas*	*Nuclear*	*Hydro*	*Non-Hydro Renewable*
South Dakota	43.3%	1.0%	5.7%	0.0%	47.5%	2.4%
Tennessee	63.6%	0.2%	0.6%	31.0%	5.3%	0.1%
Texas	45.7%	0.0%	38.0%	12.7%	0.5%	2.9%
Utah	81.8%	0.1%	16.6%	0.0%	1.2%	0.4%
Vermont	0.1%	0.0%	0.0%	80.8%	11.1%	8.0%
Virginia	43.5%	2.6%	14.2%	38.5%	1.8%	1.4%
Washington	8.2%	0.0%	5.4%	7.8%	75.5%	3.0%
West Virginia	98.4%	0.2%	0.4%	0.0%	0.9%	0.2%
Wisconsin	65.0%	1.2%	8.7%	21.6%	2.2%	1.2%
Wyoming	96.2%	0.1%	0.4%	0.0%	1.6%	1.7%
U.S. Total	**48.5%**	**1.6%**	**21.6%**	**19.4%**	**6.0%**	**0.0%**
Washington D.C.	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%

Source: EIA

Appendix 3: State Renewable Portfolio Standards

State/District	*%*	*Date*		*State/District*	*%*	*Date*
Alabama				Nebraska		
Alaska				Nevada	25	2025
Arizona	15	2025		New Hampshire	23.8	2025
Arkansas				New Jersey	22.5	2021
California	33	2020		New Mexico	20	2020
Colorado	20	2020		New York	24	2013
Connecticut	23	2020		North Carolina	12.5	2021
Delaware	20	2019		North Dakota	10	2015
Florida				Ohio	25	2025
Georgia				Oklahoma		
Hawaii	40	2030		Oregon	25	2025
Idaho				Pennsylvania	18	2020
Illinois	25	2025		Rhode Island	16	2020
Indiana				South Carolina		
Iowa	105MW			South Dakota	10	2015
Kansas	20	2020		Tennessee		
Kentucky				Texas	5880 MW	2015
Louisiana				Utah	20	2025
Maine	30	2000		Vermont	20	2017
Maryland	20	2022		Virginia	15	2025

State/District	%	*Date*		*State/District*	%	*Date*
Massachusetts	15	2020		Washington	15	2020
Michigan	10 +1100MW	2015		Washington D.C.	20	2020
Minnesota	30	2020		West Virginia	25	2025
Mississippi				Wisconsin	10	2015
Missouri	15	2021		Wyoming		
Montana	15	2015				

Source: Database of State Incentives for Renewables & Efficiency(DSIRE)

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