Arizona's Solar Market Analysis and Research Tool

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

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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 the 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 planned 14 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 that 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 that 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 most important step in implementing a Pigouvian tax on carbon 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 that emits

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[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 that take these external costs into account have on electricity generation.

carbon dioxide. 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 ("cap") on the quantity of carbon dioxide emissions allowed by electricity generating firms. Once the limit has been determined, allowances to emit carbon are distributed via some mechanism. The most important criteria in the design of a successful cap-and-trade system are the total amount and distribution method of allowances (by quota or auction), and whether to regulate the emissions upstream, midstream, or downstream.

All else being constant, the competitiveness of electricity generating technologies that rely on fossil fuels without any use of novel technologies, like carbon capture and storage (CCS), would be impacted most by a carbon pricing mechanism. In other words, an explicit carbon price would raise the cost of fossil fuels like coal and natural gas, while lowering the relative cost of all resources that emit less or no carbon (or are carbon neutral). Among the former, coal-fired power plants might see their production costs rise further relative to their natural gas-fired counterparts. The latter group (resources that emit little to no carbon) includes coal and natural gas with carbon capture and storage (CCS) equipment, nuclear and all renewable sources.[3] However, it is important to note that depending on the actual regulatory mechanism (and the effective carbon price level) and characteristics of the regional power market, coal and natural gas-fueled power generation technologies might remain competitive (vis-à-vis renewables) even after a carbon pricing mechanism is put in place.

The impact of carbon pricing on solar energy is not easily quantified. On one hand, carbon pricing would level the playing field by better reflecting the true cost fossil fuel-based generation and make renewable resources, like solar, more competitive. On the other hand, without any direct regulatory requirement for solar, the share of solar power, relative to nuclear and technologies with CCS equipment, would change very little. Therefore, regulation

[3] Referring to GHG emissions from power generation only -- not lifecycle emissions from mining, refining and transport of fuels, and other upstream sources of emissions that might be attributable to all generation technologies, renewable or not.

(additional to a carbon pricing mechanism) that specifically targets solar energy might be necessary to accelerate solar adoption in markets such as Arizona.

***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, such measures may be more successful in promoting solar power 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 for improving the energy efficiency of buildings and electrical appliances, leading to a reduction in electricity demand. In the United States, more than twenty states had programs that either require a certain percentage of electricity supply to be reduced through energy efficiency measures, or allow such measures to qualify as an eligible resource for its RPS (as of September 2011). 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 that seeks to meet increasing electricity demand with a pre-determined set of preferred resources. 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.

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# List of Acronyms

| Abbreviation | Definition |
|---|---|
| Entities | |
| ACC | Arizona Corporation Commission |
| APS | Arizona Public Service Company |
| ARB | California Air Resources Board |
| 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 |
| EU | European Union |
| 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 |
| TEP | Tucson Electric Power |
| 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 |
| CHP | Combined Heat and Power |
| CT | Combustion Turbine |

| Abbreviation | Definition |
|---|---|
| ERS | Electricity Retail Sales |
| ETS | Emissions Trading System |
| GWh | Gigawatthour |
| GHG | Greenhouse Gas(es) |
| IGCC | Integrated Gasification and Combined Cycle |
| MWh | Megawatthour |
| NOx | Nitrogen Oxides |
| PV | Photovoltaic |
| RES | Renewable Energy Standard |
| RET | Renewable Energy Target |
| RPS | Renewable Portfolio Standard |
| $SO_2$ | Sulfur Dioxide |

# 1 Introduction

Currently, the market price of electricity in the United States does not reflect the social cost of generation (production);[4] specifically, the negative externality of greenhouse gas (GHG) emissions. In such cases, improving social welfare[5] may require government intervention in the market. Appropriate policy would create incentives for the private sector (utilities and independent power producers) to invest in those generation technologies with lower or no GHG emissions.

Governments may 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 other mechanisms (such as imposing a "loading order"). Indirect intervention encourages electricity generating firms to adopt technologies by altering the price of generation through the use of Pigouvian taxes,[6] cap-and-trade schemes, and subsidies. Due to their complex nature, subsidies were addressed separately from this paper in Incentives and Taxation, 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. Section 3 discusses 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.

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

[5] Social welfare would be improved in this case by reducing GHG emissions.

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

## 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,[7] 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.[8] 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.[9]

### 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.[10] GHG-emitting technologies

[7] The elasticity of demand for electricity is generally low.

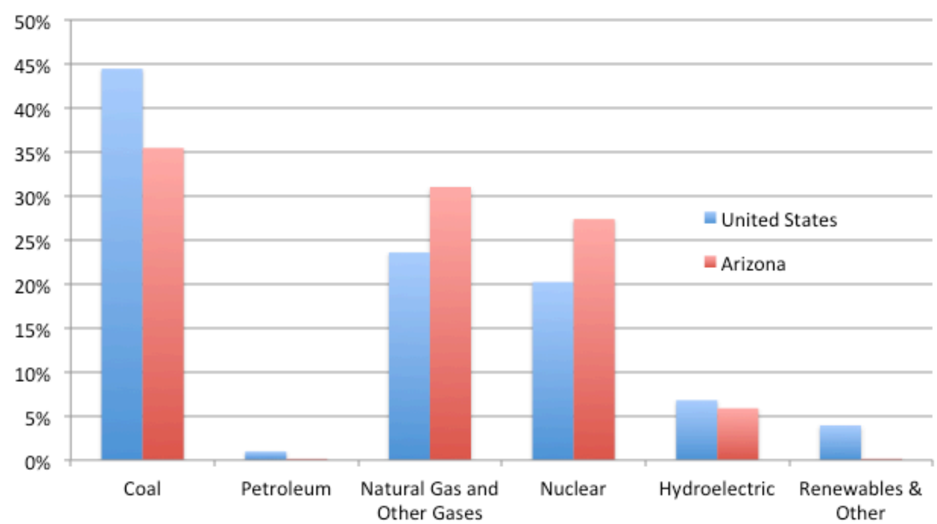
[8] Some of these costs can be offset if some (all) of the permits are distributed freely to utilities.

[9] While other GHG gases also damage the environment, the size of annual carbon emissions and their impact on the environment make carbon dioxide being the most targeted GHG gas.

[10] The carbon dioxide emission factors of major generation technologies are available in Appendix 1. Carbon dioxide is the most prevalent GHG, making it the focus of environmental emissions data compiled (EPA, 2010). It is important to note that these estimates are for the carbon emitted

include coal, petroleum and natural gas, while GHG-free technologies include nuclear, hydro, solar, wind and other renewable energy sources. As Figure 1 illustrates, of the total electricity generated in the United States, nearly 70 percent comes from GHG-emitting technologies. The proportion is somewhat lower in Arizona (66.5 percent).

**Figure 1: Share of Net Electricity Generation by Fuel Type, 2009**




Source: EIA (2010).

As the cost of GHG-emitting technologies increases due to a carbon price set in a cap-and-trade system or imposition of a Pigouvian tax, technologies with no GHG emissions 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. Assuming that the participants in the power sector are well-informed and make 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 that is not socially optimal. Electricity consumers do not currently pay for

during power generation. Estimates of carbon emissions from the manufacturing of parts used and during the construction of the power plant are not included.

the environmental impact of their electricity use, resulting in overconsumption. By implementing a carbon pricing mechanism, electricity prices will increase and consumers will use less electricity.[11] 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 various levels of carbon prices. The disadvantage of an indirect mechanism is that it does not promote technologies that are beneficial in areas other than cost (i.e., have positive externalities). 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 baseload technology without backup generation is a major factor in their decision.

However, all else being the same, the levelized cost of a generating technology is the most important investment criteria. Three factors determine the levelized cost impact on each generating technology: carbon content of the fuel, the heat rate of conversion (power generation) technology, and the carbon price. The most important of these is the carbon content of the fuel source.[12] Power plants in the United States use three carbon-emitting (a.k.a. "fossil") fuels: coal, natural gas and petroleum.[13] Carbon dioxide emissions from the

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[11] 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.

[12] The EIA reports the carbon content of each generation fuel (pre-combustion). However, emissions are post-combustion and therefore are typically reported in terms of carbon dioxide emitted (EIA, 2010).

[13] 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).

combustion of these fossil fuels are then reported as metric tons emitted per billion British thermal units (Btu). As Table 1 illustrates, the carbon content of coal and petroleum is significantly greater than that of natural gas. When incorporated, the CCS technology is estimated to eliminate 90 percent of carbon dioxide emissions (MIT, 2007).

**Table 1: $CO_2$ Emissions Factors from Coal and Natural Gas Fueled Power Generation**

| Power Generating Technology | Fuel | $CO_2$ Emissions (Metric Tons/Billion Btu) | Heat Rate* of Generating Technology (Btu/kWh) | $CO_2$ Emissions Factor (Metric Tons/MWh) |
|---|---|---|---|---|
| Scrubbed New Coal | Coal | 94.7 | 8,800 | 0.83 |
| IGCC | Coal | 94.7 | 8,700 | 0.82 |
| IGCC with CCS | Coal | 9.47 | 10,700 | 0.10 |
| Conv. Gas CC | Natural Gas | 53.06 | 7,050 | 0.37 |
| Adv. Gas CC | Natural Gas | 53.06 | 6,430 | 0.34 |
| Adv. CC with CCS | Natural Gas | 5.306 | 7,525 | 0.04 |
| Conv. Gas CT | Natural Gas | 53.06 | 10,745 | 0.57 |
| Adv. Gas CT | Natural Gas | 53.06 | 9,750 | 0.52 |

(*) Heat rate for new entrant technologies as estimated in the EIA's Annual Energy Outlook (2011).
Source: EIA and MIT (2007).

Electricity output (generation) is measured in some scale of watt-hours,[14] rather than Btus, because each fuel generates a different amount of megawatt-hours (MWh) based on the conversion efficiency of the turbine used in combustion of that fuel. This conversion, or thermal, efficiency of generation is simply referred to as the "heat rate." The heat rate measures how many Btus of fuel are necessary to generate a certain quantity of MWh; the more efficient a given power generating technology is, the lower is its the heat rate.

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.[15] In general, the combined cycle (CC) technologies are more efficient[16] than combustion turbine (CT) and scrubbed coal. While CCS reduces the amount of

[14] In this case, MWh (1,000,000 watt-hours) are used.

[15] Metric Tons of $CO_2$ emitted per MWh = Metric Tons of $CO_2$ per Billion Btu * (1-CCS factor) / Heat Rate.

[16] More efficient generation technologies generate more watt-hours of electricity per unit of fuel input.

carbon dioxide released by up to 90 percent, power plants equipped with CCS will experience a decrease in thermal efficiency (i.e., they will have higher heat rates than their non-CCS versions) due to the additional energy required to operate the CCS equipment.

Combining the carbon content of each fuel and the heat rate (generating efficiency) of each generating technology, it is possible to construct an indicative ranking of the levelized costs and consider the impact of a carbon pricing scheme. All else being constant (financing, construction lead-times, economic life of technology, fuel costs and other operational constraints), the relative cost impact on each technology would closely mirror their $CO_2$ factors in Table 1. Based on that, the least impacted fossil fuel technology would be advanced natural gas combined cycle (CC) with carbon capture and sequestration. This is due to the lower carbon dioxide content of the fuel, the efficiency of the CC generation process, and the ability of CCS to radically reduce emissions actually released into the atmosphere. The most impacted technology would be scrubbed coal.

Figure 2 demonstrates the levelized cost impact of carbon pricing on those generating technologies listed in Table 1. Four different, hypothetical carbon (dioxide) price levels are assumed: $20, $40 and $60 per metric ton. In addition, the levelized price impact is evaluated assuming these plants would be new entrants to the market, using indicative operating characteristics as of 2010-2011.[17] This cost impact is reported in terms of percentage increase over levelized costs with no (zero) carbon pricing.[18]

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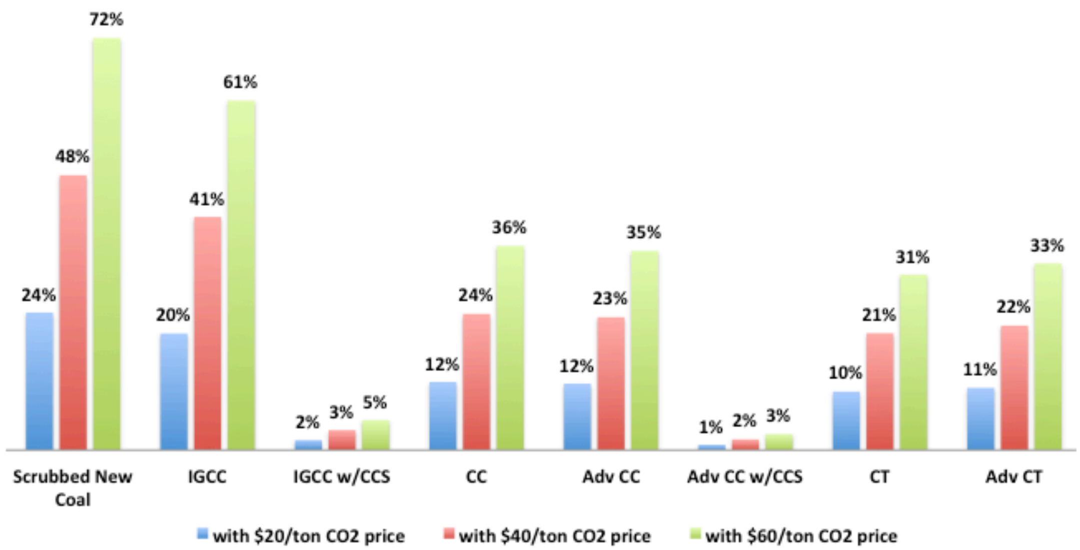
[17] New entrant characteristics by generating technology (typical size/capacity, construction lead time, overnight capital costs, variable and fixed operating and maintenance expenses, and heat rates) obtained from the EIA's Assumptions to Annual Energy Outlook 2011, Electricity Market Module, Table 8.2, retrieved from http://www.eia.gov/forecasts/aeo/assumptions/pdf/electricity.pdf on December 2, 2011. Capacity (load) factors by technology were also obtained from the EIA, retrieved from http://www.eia.gov/oiaf/aeo/electricity_generation.html on December 2, 2011. Delivered natural gas prices were assumed to average $6 per MMBtu, and delivered coal prices were assumed average $2.5 per MMBtu (in real terms), indicative of market outlook for these fuels as of December 2011. Projects were assigned equal economic lives and financing terms.

[18] Note that those plants or technologies, all else being constant, that have the least relative levelized cost impact due to carbon pricing (i.e., percentage increase in the levelized cost *with* carbon pricing over the levelized cost *without* carbon pricing), may not have the lowest overall levelized cost in dollar terms.

**Figure 2: Relative Impact of Carbon Pricing on Levelized Costs of New Entrant Technologies**




Source: EIA (2011) and the authors' calculations.

More detailed discussion on levelized costs that incorporate carbon prices can be found in the sixth paper of the Az SMART series, *"Present and Future Cost of New Utility-Scale Generation"*.

### 2.1.1 Impact on Existing Power Generation

Implementing a carbon price 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.[19] Given that, on average, 44.5 percent of all electricity generation in the United States comes from coal plants, many states will be impacted.[20] Faced with an increase in costs due to a carbon price, electricity generating firms have three options: continue to generate electricity from carbon dioxide-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 dioxide. In each circumstance,

[19] This is due to the high carbon content of coal used as fuel for coal-fired power plants.

[20] Appendix 2 provides a list of electricity generation resource mix by state.

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 2: Electricity Generation Resource Mix in Arizona, Neighboring States and the United States, 2009**[21]

| State | Coal | Petroleum | Natural Gas | Nuclear | Hydro | Renewables & Other |
|---|---|---|---|---|---|---|
| Arizona | 35.5% | 0.1% | 31.0% | 27.4% | 5.9% | 0.2% |
| California | 1.0% | 0.8% | 56.2% | 15.5% | 13.7% | 12.8% |
| Colorado | 62.6% | 0.0% | 27.4% | 0.0% | 3.5% | 6.5% |
| Nevada | 73.4% | 0.1% | 21.8% | 0.0% | 0.7% | 4.0% |
| New Mexico | 20.0% | 0.0% | 68.6% | 0.0% | 6.5% | 4.8% |
| Utah | 81.6% | 0.1% | 14.9% | 0.0% | 1.9% | 1.5% |
| **United States** | **44.5%** | **1.0%** | **23.6%** | **20.2%** | **6.8%** | **3.9%** |

Source: EIA (2010). Natural gas includes other gases. Hydroelectric includes pumped storage.

Table 2 shows the generation mix (by fuel type) for Arizona, the surrounding states, and the national average in 2009. States that rely on coal or petroleum for a majority of their electricity supplies would experience an increase in electricity prices should a carbon price be imposed. States that rely on natural gas would also experience an increase in electricity prices, but not as much as the coal and petroleum states. All else being constant, states with large amounts of nuclear, hydropower and other renewable resources in their generation portfolio would be impacted the least as a result of a carbon price. Based on Table 2, we would expect consumers in Utah, Colorado and Nevada to experience a larger relative increase in electricity prices, should a carbon price scheme is implemented. We would expect electricity consumers in Arizona, California and New Mexico to be impacted less severely. On average, we would expect the U.S. as a whole to experience a measurable increase in power prices due to its reliance on coal.

[21] 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.

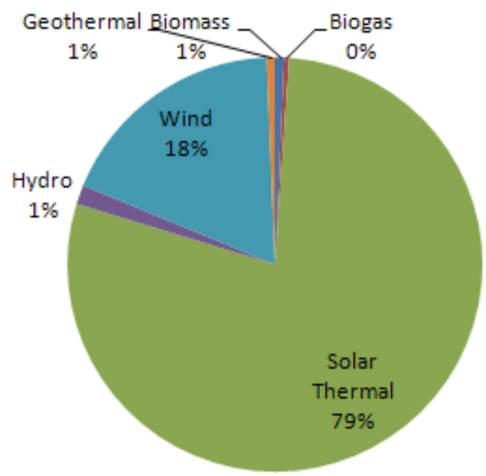
### 2.1.2 Global Carbon Prices

There are several cap-and-trade programs and carbon tax schemes in operation around the world. The European Union Emissions Trading System (EU ETS), the largest GHG cap-and-trade program currently in existence, has been operating since 2005, and will enter its third phase in 2012. Recent (2009-2011) allowance prices under the EU ETS have varied from $14 to $28 per metric ton of carbon dioxide (Bloomberg, 2011). In the United States, several climate bills that featured a cap-and-trade program were introduced since 2007, but none passed. Currently, there are only regional and state-level efforts towards cap-and-trade, such as the Regional Greenhouse Gas Initiative (RGGI) that covers ten northeastern states, active since 2009, and the Western Climate Initiative (WCI), spearheaded by California, which is slated to commence operations in 2012. Allowance prices in RGGI have remained under $5 per ton of $CO_2$ since the program's launch. The French carbon tax, which was to be introduced in 2010 until economic concerns prevented its launch, would have started at €17 per metric ton of $CO_2$ in (Carbon Tax Center, 2010). Lastly, the carbon tax in British Columbia, which is currently C$10 per metric ton of $CO_2$, will increase C$5 a year until it reaches C$30 in 2012 (Lang Michener, 2009). Most recently, Australia introduced a tax on carbon, set at AUS$23 per ton starting in 2012; however, the tax will transition into a cap-and-trade scheme in 2015 (Australian Government, 2011).

### 2.1.3 Impact on Solar Power

Initially, the implementation of a carbon pricing mechanism appears to improve the relative economics of solar power. By raising the cost of coal and natural gas-fired power generation, a carbon price makes resources that do not emit carbon more cost-competitive. The resources that emit little to no carbon are coal and natural gas-fired power plants equipped with CCS technology, nuclear power, and electricity generated from renewable energy sources. Below, Figure 3 illustrates that, besides solar, Arizona does not have many renewable resources suited for large-scale power generation. This leaves nuclear power, coal and natural gas-fired power plants (equipped with CCS technology) and electricity imports (from out of state) as alternatives to solar power in Arizona.

**Figure 3: Renewable Resource Availability in Arizona**[22]




Source: Black and Veatch, 2007.

However, if there is no regulation in place that mandate utilities and power producers to generate a portion of their energy from solar, the relative share of solar power in Arizona's generation resource mix might change very little. (Consider that a carbon pricing scheme would neither substantially increase the levelized costs for coal plants with CCS technology, nor alter the economics of nuclear power). In order to significantly improve the share of solar relative to technologies that do not emit large amounts of carbon dioxide, regulation is required.

## 2.2 Pigouvian Tax on Carbon

A Pigouvian tax on carbon is one of two methods of government intervention currently used to place a cost on carbon dioxide 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 result in an increase electricity prices (or the output prices of other sectors included under such tax, like aviation) higher than

[22] 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).

were required to generate the desired reduction in emissions. Therefore, the ability of a carbon tax to produce the desired outcome depends entirely on choices made by the government. After the level is set, the tax is applied to any power generation technology (or any other sectors of the economy) that emits carbon dioxide. At this point, the tax functions like a price on carbon, increasing the cost of carbon dioxide-emitting generation technologies.

By increasing the cost of carbon dioxide-emitting generation technologies, a carbon tax decreases such emissions by decreasing the relative cost of carbon-free technologies and reducing electricity demand due to higher electricity prices.[23] 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 and have been successfully implemented in several regions and countries around the world. In 1990, Finland was the first country to impose a carbon tax, at €1.12 per metric ton of $CO_2$ (about $1.36) which, by 2010, was raised to €20 (about $27). In January 2011, the carbon tax structure in Finland reverted back to a combined carbon/energy tax (which was the format used from 1994 to 1997). Under this method, fossil fuels are taxed based on both their energy content and their $CO_2$ emissions. Finland raised the tax rates considerably as a result of this revision. For instance, the tax rate for transport fuels is up from €20 per metric ton of $CO_2$ to €50, and to €30 for heating fuels (which will be applied at a 50 percent reduced rate for heating fuels used in CHP facilities). (Finland Ministry of the Environment, 2011).

In 1991, a tax on $CO_2$ was added to the Sweden's existing energy tax system, along with a tax on emissions of sulfur dioxide and nitrogen oxides. The tax is based on the carbon content of all fuels except for biofuels and peat. Since 1991, the tax rate increased several times, reaching SEK 1.05 per kilogram of $CO_2$ (more than $150 per metric ton of $CO_2$) in 2009. However, this rate is reduced significantly (by nearly 80 percent) for industry and agriculture (IEA, 2011).

[23] 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.

The United Kingdom instituted a revenue neutral "climate change levy" in 2001 on energy use in the end-use sectors. Examples of rates for 2011 are 0.169 pence/kWh for gas (about 0.27 cents) and 0.485 pence/kWh (about 0.78 cents) for electricity. Electricity generated from new renewable energy and fuel used for certain combined heat and power (CHP) facilities are exempt (HM Revenue & Customs, 2011). The Netherlands (1990), Norway (1991), Denmark (1992), Switzerland (2008), and Ireland (2010) are other European countries that have instituted some form of carbon tax (IEA, 2011).

Quebec became the first North American state or province to impose a carbon tax, starting on October 1, 2007. The tax mainly affects transport fuels (gasoline and diesel), heating oil, and coal, but is relatively small in amount (the initial average tax rate was about C$3.5 per metric ton of $CO_2$).[24] The tax is expected to generate about C$200 million per year to finance climate change initiatives and public transit projects. In Quebec, only a small portion of electricity is generated from fossil fuels (the primary resource is hydroelectricity), the tax does not have a significant impact on electricity prices (National Renewable Energy Laboratory - NREL, 2009).

British Columbia introduced a revenue-neutral carbon tax in July 2008, applicable to transportation fuels, natural gas, and fossil fuels used in industrial processes. Road, rail, marine, and air transportation within the province are all covered by the tax (but not interstate transportation). The program maintains revenue neutrality by returning the tax revenues to taxpayers as reductions in individual and corporate income taxes. The tax rate started at C$10 per metric ton of $CO_2$ and has increased every year by C$5 per ton, until it reaches the C$30 maximum level in 2012 (NREL, 2009). Further increases beyond the C$30 level are possible, since it has been estimated that a C$75 per ton carbon tax is required to meet British Columbia's emissions reduction commitment, which is 10 percent below 1990 levels by 2020 (Pembina Institute, 2008).

[24] Actual tax rates vary by fuel. For instance, for the initial year (2007), the rates were 0.8 cents/liter for gasoline, 0.9 cents/liter for diesel, about 1 cent/liter for heating oil, 1.3 cents/liter for petroleum coke, 0.5 cents/liter for propane, and C$8/ton for coal (all figures in Canadian Dollars).

Most recently, the lower chamber of the Australian Parliament voted narrowly in favor of a tax of AUS$23 per metric ton of $CO_2$ to be levied on the 500 largest polluters in the country, starting July 2012. This tax rate will rise at 2.5 percent annually, when, in 2015, it will transition into a market-based (cap-and-trade) scheme. In the meantime, many of the impacted sectors (like the household sector) will be directly compensated by the government (i.e., some of the collected tax will be returned to the public). The legislation is expected to become law once it passes the Senate before the end of 2011 (Australian Government, 2011).

The City of Boulder, Colorado implemented the United States' first tax on carbon dioxide emissions from electricity in April 2007. The tax rates are set based on electricity consumption ($ per kWh), and vary for residential, commercial and industrial users. In 2009, the rates were raised to the maximum level allowed by the city ordinance, which corresponds to an average of $12 per ton of $CO_2$. According to the City of Boulder, the tax generates about $1 million annually, with the revenues used to fund the city's climate action plan. The tax is set to expire in March 2013, unless voters choose to extend it (City of Boulder, 2011). A similar city-wide carbon tax was also implemented in the San Francisco metro area[25] in July 2008. The 2009 tax rate was 4.5 cents per metric ton of $CO_2$. The tax revenues are used to support city efforts to reduce GHG emissions (NREL, 2011).

On the other hand, 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).[26] With the momentum of the country behind cap-and-trade systems,[27] it appears unlikely that the United States will implement a carbon tax in the near future (Carbon Tax Center, 2010). In the European Union, an emissions trading scheme

[25] Specifically, the Bay Area Air Quality Management District (BAAQMD), which incorporates nine counties of the San Francisco Bay Area.

[26] The U.S. 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.

[27] The Western Climate Initiative (WCI) and the Regional Greenhouse Gas Initiative (RGGI) (discussed in more detail later in the text), and the Waxman-Markey Bill and the Kerry-Lieberman Act all either utilize or proposed a cap-and-trade scheme.

(i.e., cap-and-trade) has been implemented to achieve GHG emissions reductions, rather than a carbon tax.

## 2.3 Cap-and-Trade

Cap-and-trade systems[28] 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. 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,[29] 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 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 that is greater than the difference between the carbon-emitting source they are moving away from and the carbon-reduced[30] source they are adopting. Firms with high carbon abatement costs will purchase allowances at a price that 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

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[28] Ideally, a cap-and-trade system assumes the market is operating with perfect information, allowing each firm to make the most cost-effective choice.

[29] Examples include by production, population, carbon emissions or electricity produced. In the now defunct Waxman-Markey bill, if a state had an RPS, it would have received more allowances than a state without one.

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

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 allocate allowances freely, they will hold an auction where firms will purchase allowances. If all allowances are 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.[31] 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 that 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 is not, no firm will participate in the auction due to the lower price available in the secondary market. In the case where allowances are auctioned off, the carbon price is a product of the auction price. The government gains revenue from the process and, if the allowances placed into auction are 100 percent sold, the cap-and-trade system will be fundamentally similar to a carbon tax.

When regulators enforce a cap on carbon dioxide 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, such as the residential, commercial and

[31] A purchaser of allowances might 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.

industrial consumers of electricity. 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 avoided carbon dioxide emissions in a sector that is not covered by the cap-and-trade system. Some programs allow carbon offsets to be acquired internationally as well as from uncovered domestic sectors, and others only allow offsets to originate from the same jurisdiction as the emitter. 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 is not 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 3 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 3: 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 3 seek to reverse some of these impacts. The policy examples from Table 3 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 direct financial impact of the carbon price scheme 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.[32] However, this will not lessen the impact of higher electricity prices on businesses and families.

### 2.3.3 Global Adoption

Cap-and-trade systems have been adopted both in the United States and internationally over the past 30 years as a preferred mechanism for reducing harmful emissions from electricity generation.

In the United States, the most successful adoption of a cap-and-trade system has been the acid rain program introduced in the 1990 Clean Air Act Amendments. Designed to influence utilities to invest in technologies that reduce emissions of sulfur dioxide and nitrogen oxides, by 2002 the program resulted in a decrease in sulfur dioxide emissions of more than 41% below 1980 levels, and by 2005, a 57 percent reduction was achieved in emissions of nitrogen oxides from 2000 levels (Environmental Protection Agency (EPA), 2011).[33]

More recently, there have been attempts to develop state or regional cap-and-trade schemes to combat carbon dioxide emissions. For instance, ten New England and Mid-Atlantic states adopted the Regional Greenhouse Gas Initiative (RGGI) to reduce regional carbon dioxide

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[32] 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.

[33] In addition to the requirements of the acid rain program, the EPA has introduced the 2005 Clean Air Interstate Rule (CAIR), which aimed to permanently cap emissions of sulfur dioxide and nitrogen oxides in the 28 eastern states and the District of Columbia. CAIR, which was challenged in federal courts, will expire at the end of 2011. It is expected be replaced by the similar Cross-State Air Pollution Rule (CSAPR). These rules aim to address the upwind/downwind transport of harmful emissions from power generation across state borders (EPA, 2011).

emissions from the power generation sector.[34] RGGI has been operating since 2009, and average allowance prices (at auction and in the secondary market) have ranged from $2 to $3 per short ton of $CO_2$ (RGGI, 2011). A similar initiative, called the Western Climate Initiative (WCI), involves six western states and four Canadian provinces.[35] WCI is slated to become operational by January 2012, under the leadership of California (see below). A third regional initiative, the Midwest Greenhouse Gas Reduction Accord (MGGRA), which would have covered much of the Midwest, was announced in 2007, but has been shelved due to the lingering economic recession (Midwest Energy News, 2011).

California is the only state developing a stand-alone cap-and-trade program targeting GHG emissions. As mandated by the 2006 Assembly Bill 32 (AB 32), the state needs to cut GHG emissions to 1990 levels by 2020, which corresponds to a reduction of nearly 30 percent. The California Air Resources Board (ARB) identified cap-and-trade as one of the key strategies to achieve this reduction. While the ARB is coordinating with the WCI to develop a regional cap-and-trade program that can deliver larger GHG emission reductions at lower cost, instead of a California-only program, it is likely that California will forge ahead regardless of WCI participation. The ARB is expected to finalize a cap-and-trade regulation soon to allow trading to begin in 2012 (California ARB, 2011).

However, these efforts are limited in comparison with the results that could be achieved with a potential federal cap-and-trade scheme. Since 2007, five pieces of legislation[36] have been

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[34] The ten participating states in the RGGI are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. The program caps total emissions from power plants larger than 25 MW (about 200 installations) at 188 million short tons per year until 2014. This cap will decline at a rate of 2.5 percent annually from 2015 until 2018 in line with the 10 percent reduction target. RGGI will complete its first three-year compliance period at the end of 2011 (RGGI, 2011).

[35] The WCI aims to reduce regional GHG emissions to 15 percent below 2005 levels by 2020. The partner jurisdictions are British Columbia, California, Manitoba, Montana, New Mexico, Ontario, Oregon, Quebec, Utah and Washington (WCI, 2011). Arizona, a founding member, withdrew from the WCI in 2010. (See "The Governor's Policy on Climate Change: Executive Order 2010-06," retrieved from http://www.azclimatechange.gov/download/eo-2010-06.pdf.)

[36] Climate Stewardship and Innovation Act of 2007 (S.280) introduced by Senators Lieberman and McCain; Low Carbon Economy Act of 2007 (S.1766) by Senators Bingaman and Specter; Lieberman–Warner Climate Security Act of 2008 (S.2191) by Senators Lieberman and Warner; American Clean Energy and Security Act of 2009 (H.R. 2454) by Representatives Waxman and Markey; and American Power Act of 2010 by Senators Kerry and Lieberman (EPA, 2011).

proposed to the U.S. Congress towards that end; however, none garnered sufficient legislative support. Nonetheless, should any federal climate change-related legislation is enacted in the United States, it is expected to include a GHG emissions regulation scheme of the cap-and-trade variety.

Internationally, the Kyoto Protocol,[37] which has been the most significant international agreement on global climate change, encouraged the adoption of cap-and-trade programs to reduce GHG emissions. The Protocol set binding targets for 37 industrialized countries for reducing GHG emissions, by an average of five percent from 1990 levels during the first compliance period of 2008 to 2012. .

Today, the European Union's Emissions Trading System (EU ETS), which started operations in 2005, is the largest and the best developed cap-and-trade system. The timing of the EU ETS Phase II (2008-2012) was designed to overlap with the first compliance period under the Kyoto Protocol. During this phase of the program,[38] the overall cap is set at 6.5 percent below 2005 levels. This cap will be tightened to 21 percent below 2005 levels in 2020. At the end of 2010, the program covered nearly eleven thousand facilities that accounted for nearly half of the $CO_2$ emissions in the EU. Aviation sector will be part of the ETS starting in 2012. Coverage of the program will also expand to include GHGs other than carbon dioxide in the third phase.

During Phase II of the EU ETS there was an over-supply of allowances, mainly as a result of the recession (which led to a fall in industrial output and power generation in 2008 and 2009). However, since the caps were tighter (compared to the test phase) and participants were not allowed to bank allowances for use in future trading periods, the allowance prices did not collapse. Allowance prices traded around $35 per metric ton of $CO_2$ during most of 2008. Since 2009, allowances have traded $14 and $28 per metric ton of $CO_2$.

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[37] Adopted on December 11, 1997, the Kyoto Protocol has been ratified by more than 190 countries (United Nations Framework Convention on Climate Change, UNFCCC, 2011). The protocol set biding targets for 37 industrialized countries to reduce their emissions of six main greenhouse gases (carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons and perfluorocarbons) by about 5% from their 1990 levels during the 2008-2012 compliance period. (See http://unfccc.int/essential_background/kyoto_protocol/items/6034.php and http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php).

[38] Phase I of the EU ETS was a trial period that ran from 2005 to 2007.

The stricter emission targets under Phase III are expected to generate higher allowance prices. Moreover, during Phase III, more than half of allowances will be allocated via auctions (starting in 2013) and there will be no free allocation for the power sector. Allowances for Phase I (trial) and Phase II were allocated to participating installations free of charge.[39] In Phase III, the proportion of allowances subject to auction will increase each year, and free allocation of allowances to all sectors will be phased out by 2027 (IEA, 2010).

**Table 4: Phase I and II Emission Caps in the EU ETS (million metric tons of $CO_2$)**

| Member State | Phase I Caps | 2005 Verified Emissions | Phase II Caps (2008-2012) | | |
|---|---|---|---|---|---|
| | | | *Requested Cap* | *Allowed Cap* | *Allowed Cap as % of Requested* |
| Austria | 33.0 | 33.4 | 32.8 | 30.7 | 94% |
| Belgium | 62.1 | 55.6 [a] | 63.3 | 58.5 | 92% |
| Bulgaria | 42.3 | 40.6 [b] | 67.6 | 42.3 | 63% |
| Cyprus | 5.7 | 5.1 | 7.1 | 5.5 | 77% |
| Czech Republic | 97.6 | 82.5 | 101.9 | 86.8 | 85% |
| Denmark | 33.5 | 26.5 | 24.5 | 24.5 | 100% |
| Estonia | 19.0 | 12.6 | 24.4 | 12.7 | 52% |
| Finland | 45.5 | 33.1 | 39.6 | 37.6 | 95% |
| France | 156.5 | 131.3 | 132.8 | 132.8 | 100% |
| Hungary | 31.3 | 26.0 | 30.7 | 26.9 | 88% |
| Germany | 499.0 | 474.0 | 482.0 | 453.1 | 94% |
| Greece | 74.4 | 71.3 | 75.5 | 69.1 | 92% |
| Ireland | 22.3 | 22.4 | 22.6 | 21.2 | 94% |
| Italy | 223.1 | 222.5 | 209.0 | 195.8 | 94% |
| Latvia | 4.6 | 2.9 | 7.7 | 3.3 | 43% |
| Lithuania | 12.3 | 6.6 | 16.6 | 8.8 | 53% |
| Luxembourg | 3.4 | 2.6 | 4.0 | 2.7 | 68% |
| Malta | 2.9 | 2.0 | 3.0 | 2.1 | 71% |
| Netherlands | 95.3 | 80.4 | 90.4 | 85.8 | 95% |
| Poland | 239.1 | 203.1 | 284.6 | 208.5 | 73% |
| Portugal | 38.9 | 36.4 | 35.9 | 34.8 | 97% |
| Romania | 74.8 | 70.8 [b] | 95.7 | 75.9 | 79% |

[39] In Phase II, only 3 percent of allowances were auctioned off.

| Member State | Phase I Caps | 2005 Verified Emissions | Phase II Caps (2008-2012) | | |
|---|---|---|---|---|---|
| | | | *Requested Cap* | *Allowed Cap* | *Allowed Cap as % of Requested* |
| Slovakia | 30.5 | 25.2 | 41.3 | 30.9 | 75% |
| Slovenia | 8.8 | 8.7 | 8.3 | 8.3 | 100% |
| Spain | 174.4 | 182.9 | 152.7 | 152.3 | 100% |
| Sweden | 22.9 | 19.3 | 25.2 | 22.8 | 90% |
| United Kingdom | 245.3 | 242.4 c | 246.2 | 246.2 | 100% |
| **Totals** | **2,057.8** | **1,910.7** | **2,054.9** | **1,859.3** | **90%** |

Notes: (a) Including installations opted out in 2005. (b) Estimate; not verified by the EU. (c) UK's verified emissions for 2005 do not include installations opted out in 2005, which will be covered in Phase II, and are estimated to be about 30 metric tons.

Source: EU official press release dated October 26, 2007. "Emissions trading: EU-wide cap for 2008-2012 set at 2.08 billion allowances after assessment of national plans for Bulgaria," retrieved from http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1614&format=HTML&language=EN.

Other jurisdictions with existing cap-and-trade programs include: the state of New South Wales in Australia, the province of Alberta in Canada,[40] Switzerland, New Zealand, Tokyo prefecture in Japan. The independent cap-and-trade schemes in the UK and Norway were folded into the EU ETS in 2008. Several other jurisdictions, including additional prefectures in Japan and the Japanese national government, Brazil, Chile, South Korea, China, Mexico, Turkey, Ukraine and South Africa are at different stages of exploring (via pilot programs, legislative proposals) cap-and-trade programs (IEA, 2011).

# 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 that cannot be exceeded. The

[40] Some do not consider the Alberta plan a traditional cap-and-trade as there is not a hard cap on emissions. The plan covers the largest emitters in the province, mostly from mining, oil and gas and power generation industries, who are required to reduce their *energy intensity* by 12 percent starting in 2007, from baseline 2003-05 levels. In essence, improvements in energy intensity does not necessitate a decline in absolute emissions levels, and under such a plan, total emissions may increase. In addition to investing in efficiency improvements, the participants have the option to contribute CAD15 per ton of $CO_2$ into a climate fund, or purchase Alberta-based offsets.

region that emits in excess of this 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 that contribute to the problems associated with carbon dioxide emissions, such as weather conditions and other human behavior.

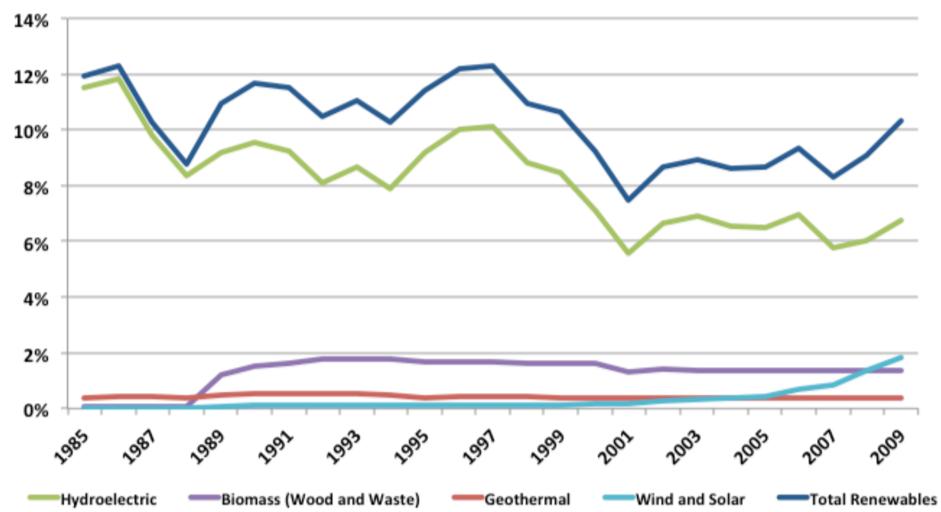
*Technology standards* enforce particular technology solutions or techniques. The introduction of scrubbers to reduce sulfur dioxide emissions was an example of a technology solution in the electricity generation sector. A technology standard is useful due to its simple implementation and direct impact 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 Requirements

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 decade because of their ability to generate electricity without releasing large amounts of carbon dioxide into the atmosphere. However, as Figure 4 illustrates, renewable electricity generation has not been able to sustain its growth, relative to total U.S. electricity generation, since its peak in the mid-1990s. This is due primarily to a reduction in the share of hydropower in the U.S. electricity generation portfolio.

**Figure 4: Share of U.S. Renewable Electricity Generation, 1990 – 2009**




Source: EIA (2011).

Although the total share of renewable electricity has declined over the last decade, the share of electricity generated 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[41] demonstrates the substantial increase in generation capacity of renewable sources still required to displace carbon dioxide-emitting sources, such as coal and natural gas, in power generation.

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

[41] Their combined share was 1.81 percent of total electricity generated in the United States in 2009 (EIA, 2011).

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,[42] 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 scheme is that it focuses the utilities' resources 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 that 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 that do not emit large amounts of carbon but are not renewable.

[42] The percentage of ERS regulatory approach is based on actual electricity generation, while the renewable capacity regulatory approach targets a certain amount of power generation capacity to be installed. For those resources / technologies that have a lower capacity factors (under 40 percent, like wind and solar), the difference in actual contribution of renewables to a jurisdiction's power resource mix would be significant.

### 3.1.1 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 shown in Figure 3, Arizona's potential for non-solar renewable power generation is limited. In order to meet the State's renewable energy requirement (discussed further in the following section), Arizona utilities (that are bound by the requirement) are expected to rely heavily on solar power.[43] In addition to promoting solar through requiring renewable generation, several states, including Arizona,[44] have a distributed generation requirement. Given the advantage of solar photovoltaic (PV) over other distributed generation technologies,[45] distributed requirements will generate increased investment in solar power technology and encourage large-scale commercial adoption.

### 3.1.2 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 portfolio. 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.

Due to the widespread adoption of these programs, renewable use in the United States has substantially increased (NREL, 2010). In the United States, renewable energy requirement

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[43] Assuming Arizona utilities will not purchase a significant amount of their renewable requirement from outside the state. Arizona utilities currently have power purchase agreements with wind and geothermal energy producers in New Mexico and California.

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

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

programs are typically called Renewable Portfolio Standards (RPS). In absence of a federal RPS measure in the United States,[46] the current adoption of such programs is only at the state level. As of September 2011, twenty-nine U.S. states and the District of Columbia had an RPS program in place, and another eight states declared non-mandatory "renewable portfolio goals". Among these, a majority of states and the District of Columbia have a percentage ERS requirement, while four states have a specific capacity or generation amount requirement, or a combination. The state with the most aggressive RPS target is California, which aims for 33 percent of its ERS to come from renewable resources by 2020 (Database of State Renewable Energy Incentives, 2011). The full list of state RPS programs is provided in Appendix 3.

The Arizona Renewable Energy Standard (RES), which was enacted in 2006 and became effective in August 2007, requires that renewable resources constitute 15 percent of electricity retail sales (ERS) of regulated utilities.[47] The program further requires that output from distributed resources (i.e., non-utility) meet a portion of the total RES. Arizona Public Service (APS), the largest utility in Arizona, plans to exceed the RES guideline of 5 percent by 2015 by generating 10 percent of its ERS from renewable sources by 2015 (APS, 2009). 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).[48] The state's third largest utility, Tucson Electric Power (TEP), also exceeded its 2010 requirements under the RES (TEP, 2011). Table 5 summarizes the annual renewable energy requirements for the Arizona utilities.[49]

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[46] For instance, had it been enacted, the Waxman-Markey bill would have created a federal RPS target of 20 percent by 2020, along with a provision for up to 40 percent of this target to be met through investment in energy efficiency measures (All Business, 2009).

[47] The Arizona RES superseded a similar rule called the "Environmental Portfolio Standard."

[48] SRP already has significant hydroelectric resources that account for about 6 percent of its ERS.

[49] The two investor-owned utilities in Arizona (APS and TEP) constitute 51 percent of ERS in Arizona and SRP accounts for 36 percent (2009 data).

**Table 5: Arizona's Renewable Energy Standard**

| Year | Renewable Electricity Req. (%) | Distributed Generation | |
|---|---|---|---|
| | | % of RE* | Req. (%) |
| 2010 | 2.5% | 20% | 0.50% |
| 2011 | 3.0% | 25% | 0.75% |
| 2012 | 3.5% | 30% | 1.05% |
| 2013 | 4.0% | 30% | 1.20% |
| 2014 | 4.5% | 30% | 1.35% |
| 2015 | 5.0% | 30% | 1.50% |
| 2016 | 6.0% | 30% | 1.80% |
| 2017 | 7.0% | 30% | 2.10% |

| Year | Renewable Electricity Req. (%) | Distributed Generation | |
|---|---|---|---|
| | | % of RE* | Req. (%) |
| 2018 | 8.0% | 30% | 2.4% |
| 2019 | 9.0% | 30% | 2.7% |
| 2020 | 10.0% | 30% | 3.0% |
| 2021 | 11.0% | 30% | 3.3% |
| 2022 | 12.0% | 30% | 3.6% |
| 2023 | 13.0% | 30% | 3.9% |
| 2024 | 14.0% | 30% | 4.2% |
| 2025 | 15.0% | 30% | 4.5% |

Notes: "Req." stands for requirement. (*) The distributed generation requirement is defined as a proportion of the renewable electricity requirement. Half of the distributed generation requirement must be met through residential applications, and the other half through a non-residential, non-utility application.

Source: Arizona Corporation Commission (ACC), 2006.

Renewable energy requirement programs have been adopted in many countries over the past decade. In the European Union, whose goal is to reduce greenhouse gas (GHG) emissions by 20 percent (from 1990 levels) by 2020, the latest (2009) package of measures consists of six different legislations, including a renewable energy requirement.[50] The specific Directive[51] requires that, by 2020, the share of renewables in the EU's final consumption of energy must reach 20 percent, and sets a mandatory national renewables target for each member state (reflecting each member's different starting points), as listed in Table 6. Moreover, the directive also calls for 10 percent of each member state's transport energy consumption to come from renewables by 2020 (IEA Global Renewable Energy Policies and Measures Database, 2011).

[50] The other five component legislations are on: (1) the revision of the EU emissions trading scheme (ETS); (2) the development of emissions reduction targets for sectors not participating in the ETS; (3) the development of a framework for carbon capture and storage (CCS); (4) new standards for fuel quality; and (5) regulation of carbon dioxide emissions from new passenger vehicles.

[51] Directive 2009/28/EC (April 23, 2009).

**Table 6: Renewable Energy Targets for EU Members (% of Gross Energy Consumption)**

| Member State | 2005 Share of Renewable Energy (%) | Target for 2020 (%) | Member State | 2005 Share of Renewable Energy (%) | Target for 2020 (%) |
|---|---|---|---|---|---|
| Austria | 23.3% | 34.0% | Latvia | 32.6% | 40.0% |
| Belgium | 2.2% | 13.0% | Lithuania | 15.0% | 23.0% |
| Bulgaria | 9.4% | 16.0% | Luxemburg | 0.9% | 11.0% |
| Cyprus | 2.9% | 13.0% | Malta | 0.0% | 10.0% |
| Czech Republic | 6.1% | 13.0% | Netherlands | 2.4% | 14.0% |
| Denmark | 17.0% | 30.0% | Poland | 7.2% | 15.0% |
| Estonia | 18.0% | 25.0% | Portugal | 20.5% | 31.0% |
| Finland | 28.5% | 38.0% | Romania | 17.8% | 24.0% |
| France | 10.3% | 23.0% | Slovakia | 6.7% | 14.0% |
| Germany | 5.8% | 18.0% | Slovenia | 16.0% | 25.0% |
| Greece | 6.9% | 18.0% | Spain | 8.7% | 20.0% |
| Hungary | 4.3% | 13.0% | Sweden | 39.8% | 49.0% |
| Ireland | 3.1% | 16.0% | UK | 1.3% | 15.0% |
| Italy | 5.2% | 17.0% | **EU 27** | **8.5%** | **20.0%** |

Source: European Commission, Renewable Energy: Targets. Retrieved from http://ec.europa.eu/energy/renewables/targets_en.htm.

Australia updated their Renewable Energy Target (RET) in 2007 to achieve a goal of 20 percent of the country's electricity supply from renewable sources (Australian Department of Climate Change, 2010). Other country examples include Argentina, which has a renewable power target of 8 percent by 2016. Brazil has mandated the share of renewable power to rise to 10 percent within 20 years starting from 2007. In Mexico the installed renewable electric generating capacity was legislated to reach 7.6 percent by 2012. South Africa set individual capacity targets for each renewable technology to be reached by 2030: 4,759 MW hydroelectric (12.7 percent of total) capacity, 9,200 MW of wind (10.30 percent), 1,200 MW of concentrated solar power (1.3 percent) and 8,400 MW of solar photovoltaics (9.4 percent). China also has set several targets[52] to increase the share of renewable energy in the country's energy portfolio. One of these targets involves increasing the share of energy from renewable sources in the total primary energy

[52] As laid out in the eleventh five-year plan and the 2007 National Climate Change Program (IEA, 2011).

consumption to 15 percent by 2020.[53] (IEA Global Renewable Energy Policies and Measures Database, 2011).

## 3.2 Energy Efficiency

In the context of regulation, an energy efficiency program is a government-mandated method of reducing electricity demand. Specifically, the so-called "Energy Efficiency Resource Standards" (EERS) are programs that either require a certain percentage of energy efficiency, or allow it qualify as an eligible resource towards meeting that jurisdiction's RPS target. In the United States, more than twenty states have enacted legislation towards an EERS, and a number of other states announced non-mandatory energy efficiency goals.[54] The ability of energy efficiency gains to offset state RPS requirements[55] is important for states with limited low-cost renewable resources.

Table 7 is a breakdown of residential electricity usage by item in Arizona.[56] 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 percent of Arizona's residential electricity usage in 2007 (EIA, 2010).

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[53] Other targets are: building 30 large-scale wind farms each with a capacity of 100 MW or more by 2010; achieving grid-connected wind power capacity of 10 GW by 2010, 20 GW by 2015 and 30 GW by 2020; installing more than 5.5 GW of biomass and waste fueled generation of by 2010 (IEA, 2011).

[54] As of September 2011, the following states have mandatory EERS programs: Arizona, Arkansas, California, Colorado, Connecticut, Hawaii, Illinois, Indiana, Iowa, Maryland, Massachusetts, Michigan, Minnesota, New Mexico, New York, Ohio, Pennsylvania, Rhode Island, Texas, Washington, and Wisconsin. In addition, there are states where the EERS program is bundled with the RPS, like Nevada and South Carolina. Delaware, Florida, Maine, New Jersey, North Carolina, Oregon, Utah, and Vermont have --currently-- non-binding energy efficiency resource goals. Some of these "goals" states have the ultimate intention of making these voluntary targets mandatory once regulatory funding is secured. (Sources: DSIRE and American Council for an Energy Efficient Economy, ACEEE, 2011).

[55] 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.

[56] 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: Breakdown of Residential Electricity Usage in Arizona, 2007[57]**

| Appliance | Usage |
|---|---|
| Central Air Conditioning | 39.3% |
| Hot Water Heating | 10.3% |
| Refrigeration | 9.6% |
| Space Heating | 8.5% |
| Room Air Conditioning | 4.4% |
| Lighting | 3.5% |
| Freezer | 2.7% |
| Clothes Washer | 2.7% |
| Dishwasher | 2.7% |
| Pool Pump | 2.7% |
| Other[58] | 13.8% |

Source: ICF International. The total may be different from 100% due to independent rounding of categories.

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 potential for significant gains from energy efficiency was suggested by the Waxman-Markey bill, which would have allowed up to 40 percent of the national renewable target to be met from such programs. The reason significant energy efficiency gains are available is because electricity consumers, who have the greatest incentive to buy energy efficient devices, do not always 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 electronic gadgets. Until five years ago, a copper wire was used in this conversion and as much

[57] 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.

[58] Other includes plug load, computer equipment, etc.

as 80 percent of electricity was lost. Converting the energy using integrated circuits only cost 30 percent more than the copper wiring and reduced losses to less than 20 percent. 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 adopted rules that required integrated circuits for use in the United States. The switch, which was adopted globally, has decreased power consumption worth around $2 billion each year, or 13 million tons of carbon dioxide (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.

### 3.2.1 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 net environmental benefit of energy efficiency programs might be less than it would be in a state like Utah, which generates a majority of its electricity from coal and does not have a mandatory RPS program. In other words, each state (or jurisdiction) would evaluate the environmental benefits of energy efficiency differently with respect to solar, depending on the existence and structure of an RPS program and its existing 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 8. However, since energy efficiency does not qualify as part of the state RES, the impact of this ACC ruling on solar power is expected to be limited to reducing the load requirement of regulated utilities. This, in turn, reduces the amount of solar power generation that Arizona regulated utilities would need to build (or otherwise acquire) as part of the RES.

**Table 8: Energy Efficiency Standard for Regulated Utilities in Arizona[59]**

| Year | Target (%) |
|---|---:|
| 2011 | 1.25% |
| 2012 | 3.00% |
| 2013 | 5.00% |
| 2014 | 7.25% |
| 2015 | 9.50% |

| Year | Target (%) |
|---|---:|
| 2016 | 12.00% |
| 2017 | 14.50% |
| 2018 | 17.00% |
| 2019 | 19.50% |
| 2020 | 22.00% |

Source: ACC.

### 3.2.2 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 sustainable energy policy (Prindle, 2007). Below, examples of energy efficiency programs, both nationally and internationally, are discussed.

[59] 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.

The energy efficiency movement in the United States has led to 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). While there are a multitude of federal programs in the United States supporting energy efficiency,[60] none of these directly mandate an energy efficiency target towards reducing aggregate energy or electricity consumption. It is anticipated that a national energy efficiency target would be a key component of future federal climate change legislation.

Worldwide, energy efficiency programs have been adopted in many countries for both environmental and financial reasons. The EU implemented its first energy efficiency standards in 1992, and issued the "Energy End-Use Efficiency and Energy Services Directive" (ESD) in 2006.[61] The Directive called for member countries to reach a minimum of 9 percent annual in energy savings by 2016,[62] required each Member State to enact the Directive into national legislation, and develop periodic energy efficiency action plans. Meeting the targets is not mandatory, however, and many Member States have chosen to limit their targets to the minimum recommended target of 9 percent (see Table 9).

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[60] These range from mandatory standards (for vehicles, appliances, buildings, etc.), favorable tax treatment of energy efficiency investments, research grants to develop energy efficient products and practices, preferred purchasing policies by the federal government, and various labeling and certification programs to inform and educate consumers. (Source: EERE and IEA Energy Efficiency Policies and Measures Database, 2011).

[61] Directive 2006/32/EC (April 5, 2006).

[62] Measured in terms of percent reduction in total end-use electricity consumption.

**Table 9: Energy Savings Targets of EU Member States until 2016**

| Member State | Target for 2016 |
|---|---|
| Austria | 9.0% |
| Belgium | 9.0% |
| Bulgaria | 9.0% |
| Cyprus | 10.0% |
| Czech Republic | 9.0% |
| Denmark* | 9.2% - 10.7% |
| Estonia | 9.0% |
| Finland | 9.0% |
| France | 9.0% |
| Germany | 9.0% |
| Greece | 9.0% |
| Hungary | 9.0% |
| Ireland | 9.0% |
| Italy | 9.6% |

| Member State | Target for 2016 |
|---|---|
| Latvia | 9.0% |
| Lithuania | 9.7% |
| Luxemburg | 9.0% |
| Malta | 9.0% |
| Netherlands | 9.0% |
| Poland | 9.0% |
| Portugal | 9.8% |
| Romania | 13.5% |
| Slovakia | 9.0% |
| Slovenia | 9.0% |
| Spain | 11.4% |
| Sweden | 9.0% |
| UK | 9.0% |
| **EU 27** | **9.5% - 10.7%** |

(*) Denmark has developed a high and a low target.

Source: European Council for an Energy Efficient Economy, Energy Efficiency Watch Project (2009).

In June 2011, the European Commission has put forth a new plan with much stricter energy efficiency targets that calls for a 20 percent reduction in primary energy consumption by 2020 (European Commission, 2011). Under this proposal, the member country targets would remain voluntary until 2014, and should the Commission decide they are not sufficient to achieve the EU-wide 20 percent goal, mandatory energy efficiency targets would replace them.

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). Among other examples, we can cite Brazil's plans for a 10 percent reduction in electricity consumption by 2030; South Africa's 12 percent reduction target of total energy demand; and Australia and Japan's national strategy/policy declarations to improve energy efficiency.

## 3.3 Loading Order

Loading order is a method of regulation that seeks to meet incremental electricity demand first with a set of preferred resource options that take priority over other, less preferred 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.

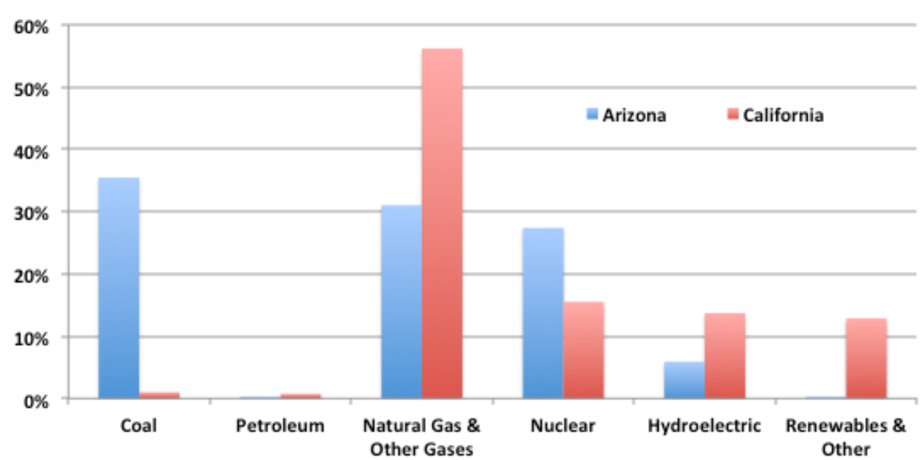
Load ordering is not a perfect system. Like any other regulatory mechanism that restricts utilities from making independent generation mix decisions, it might lead to distorted or unintended economic (consumption and investment) outcomes. Utilities have been reticent in embracing the methods of meeting 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 that will lead to increased construction of renewable resources in California, including solar, by prioritizing such resources over the potential low or no carbon dioxide emitting competitors, such as nuclear and clean coal. On the other hand, utilities have several renewable options in California, making it more likely that utilities would choose to invest in a low cost, baseload, 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, aimed at reducing the aggregate power demand.

However, in Arizona, which lacks significant in-state renewable resources other than solar, a loading order program would directly 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: Electricity Generation Resource Mix for California and Arizona, 2009**




Source: EIA (2010).

Figure 5 illustrates the difference between California and Arizona in electricity generation mix, where the difference in the shares of coal and other renewables in the two states stand out: Arizona generates nearly 36 percent of its electricity from coal, while California scarcely has any coal-fired generation. On the other hand, California generates 13 percent of its electricity from renewable resources (other than hydropower), compared to 0.2 percent for Arizona. Therefore, the difference in the electricity generation resource mix suggests that a loading order system would be more successful in California than Arizona, where such a program could meet stiff opposition as it would aim to displace the state's primary source of electricity.

### 3.3.2 Global Adoption

To date, California has the longest experience with a loading order program. Following in California's footsteps, Rhode Island and Maine have also enacted loading order programs (in 2007 and 2010, respectively), and Massachusetts is considering a loading order program (American Council for an Energy Efficient Economy, ACEEE, 2011). Other states and jurisdictions require energy efficiency to factor into the long-term resource plans of regional utilities, and such plans may eventually transform into mandatory loading order programs. For instance, the four-state[63] Northwest Power and Conservation Council identified energy efficiency as "the cheapest and most readily available energy resource for meeting load growth—enough to meet all load growth through 2012 and about 50 percent of load growth through 2024" (ACEEE, 2011). Given the worldwide impetus for increased renewable energy usage and the potential gains available from energy efficiency, more states and countries may consider loading order programs to secure gains from energy efficiency in the future.

# 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.

[63] Washington, Oregon, Idaho, and Montana.

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 that is high enough for these firms to choose generating technologies that 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 essentially signal that electricity generating firms will not independently choose those technologies desired by regulators.

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 choice 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 requirements 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 resource-rich 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, for the express purpose of developing of solar power, a direct mechanism to reduce carbon dioxide emissions is preferable to an indirect mechanism.

# Glossary[64]

**Baseload 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.

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[64] 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 (GHG):** 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 Emission Factors of Generation Technologies

The amount of carbon present in generation fuel sources is an important determinant of the cost impact (on levelized cost for new build or retrofits, and marginal cost for existing plants) of a carbon price. Table 10 provides the carbon dioxide emission factors by technology.

**Table 10: $CO_2$ Emissions Factors (metric tons/MWh)**

| Generation Technology | $CO_2$ Emissions Factor |
|---|---|
| Scrubbed New Coal | 0.83 |
| IGCC | 0.82 |
| IGCC w/ CCS | 0.10 |
| Conv. Gas CC | 0.37 |
| Adv. Gas CC | 0.34 |
| Adv CC w/ CCS | 0.04 |
| Conv. CT | 0.57 |
| Adv. CT | 0.52 |
| 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 the authors' calculations.

***Coal***: Scrubbed coal power plants emit the most $CO_2$ (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 thought to decrease carbon dioxide emissions by as much as 90 percent (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 thought to decrease carbon dioxide emissions from natural gas power plants by as much as 90 percent (MIT, 2007).

***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 per billion Btu (EIA, 2009).

***Fuel Cells***: Fuel cells are able to use natural gas as well as hydrogen as a fuel. Hydrogen-fueled cells do not have carbon dioxide emissions during their operation. However, hydrogen itself is generally obtained from either natural gas or coal (National Hydrogen Association, 2009), and this refining process does result in carbon dioxide emissions. It is possible to make hydrogen using renewable sources such as solar, wind and biomass, but hydrogen production 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. Among all the non-carbon dioxide emitting resources used to generate electricity in the United States, nuclear energy is the most used.[65]

***Biomass***: Biomass power plants burn wood and wood waste to generate electricity. While this process does emit carbon dioxide, since the resources are part of the living carbon cycle, the process is considered not to add to the build-up of greenhouse gases (EPA, 2009). This "carbon-neutral" feature of biomass has been subject of debate as more and more jurisdictions treat their biomass stock (forests) as a renewable resource.[66]

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[65] In 2009, the United States generated 20.2% of its electricity from nuclear power. Hydroelectricity is the second most used non-carbon dioxide emitting resource (6.8%) (EIA, 2011).

[66] In a 2010 study, researchers found that the use of forests as biomass for power generation (mainly due to the low thermal efficiency of the process) created a larger "carbon debt" over coal, and that debt took longer to pay (via the growth of new forest), than originally thought. The study also

***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.

***Water***: Hydroelectric generating stations 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.

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found that the use of forest biomass for heating (or cogeneration) is more efficient compared to power generation. (Massachusetts Department of Energy Resources, 2010.)

## Appendix 2: State Electricity Generation Resource Mix (2009)[67]

| State/District | Coal | Petroleum | Natural Gas[a] | Nuclear | Hydro[b] | Non-Hydro Renewables and Other[c] |
|---|---|---|---|---|---|---|
| Alabama | 39% | 0% | 22% | 28% | 9% | 2% |
| Alaska | 9% | 17% | 53% | 0% | 20% | 0% |
| **Arizona** | **35%** | **0%** | **31%** | **27%** | **6%** | **0%** |
| Arkansas | 44% | 0% | 20% | 26% | 7% | 3% |
| California | 1% | 1% | 56% | 16% | 14% | 13% |
| Colorado | 63% | 0% | 27% | 0% | 4% | 7% |
| Connecticut | 8% | 1% | 31% | 53% | 2% | 5% |
| Delaware | 59% | 5% | 33% | 0% | 0% | 3% |
| Florida | 25% | 4% | 54% | 13% | 0% | 3% |
| Georgia | 54% | 1% | 16% | 25% | 3% | 2% |
| Hawaii | 14% | 75% | 0% | 0% | 1% | 10% |
| Idaho | 1% | 0% | 13% | 0% | 80% | 7% |
| Illinois | 46% | 0% | 2% | 49% | 0% | 2% |
| Indiana | 93% | 0% | 5% | 0% | 0% | 2% |
| Iowa | 72% | 0% | 2% | 9% | 2% | 15% |
| Kansas | 69% | 0% | 6% | 19% | 0% | 6% |
| Kentucky | 93% | 2% | 1% | 0% | 4% | 0% |
| Louisiana | 25% | 2% | 50% | 18% | 1% | 3% |
| Maine | 0% | 3% | 45% | 0% | 26% | 26% |
| Maryland | 55% | 1% | 5% | 33% | 4% | 2% |
| Massachusetts | 23% | 2% | 54% | 14% | 2% | 5% |
| Michigan | 66% | 0% | 9% | 22% | 1% | 3% |
| Minnesota | 56% | 0% | 5% | 24% | 2% | 13% |
| Mississippi | 27% | 0% | 48% | 23% | 0% | 3% |
| Missouri | 81% | 0% | 4% | 12% | 3% | 1% |
| Montana | 58% | 2% | 0% | 0% | 36% | 4% |
| Nebraska | 69% | 0% | 1% | 28% | 1% | 1% |
| Nevada | 20% | 0% | 69% | 0% | 7% | 5% |

[67] It is important to note that this table illustrates the breakdown of electricity generation by state, rather than electricity consumption.

| State/District | Coal | Petroleum | Natural Gas[a] | Nuclear | Hydro[b] | Non-Hydro Renewables and Other[c] |
|---|---|---|---|---|---|---|
| New Hampshire | 14% | 1% | 26% | 44% | 8% | 6% |
| New Jersey | 8% | 0% | 34% | 56% | 0% | 2% |
| New Mexico | 73% | 0% | 22% | 0% | 1% | 4% |
| New York | 10% | 2% | 31% | 33% | 20% | 4% |
| North Carolina | 55% | 0% | 4% | 34% | 4% | 2% |
| North Dakota | 87% | 0% | 0% | 0% | 4% | 9% |
| Ohio | 84% | 1% | 3% | 11% | 0% | 0% |
| Oklahoma | 45% | 0% | 46% | 0% | 5% | 4% |
| Oregon | 6% | 0% | 28% | 0% | 58% | 8% |
| Pennsylvania | 48% | 0% | 14% | 35% | 1% | 2% |
| Rhode Island | 0% | 0% | 98% | 0% | 0% | 2% |
| South Carolina | 34% | 1% | 10% | 52% | 1% | 2% |
| South Dakota | 39% | 0% | 1% | 0% | 54% | 6% |
| Tennessee | 52% | 0% | 1% | 34% | 12% | 1% |
| Texas | 35% | 0% | 49% | 10% | 0% | 5% |
| Utah | 82% | 0% | 15% | 0% | 2% | 2% |
| Vermont | 0% | 0% | 0% | 74% | 20% | 6% |
| Virginia | 37% | 2% | 17% | 40% | 0% | 4% |
| Washington | 7% | 0% | 12% | 6% | 70% | 5% |
| Washington, D.C. | 0% | 100% | 0% | 0% | 0% | 0% |
| West Virginia | 96% | 0% | 0% | 0% | 2% | 1% |
| Wisconsin | 62% | 1% | 9% | 21% | 2% | 4% |
| Wyoming | 91% | 0% | 2% | 0% | 2% | 5% |
| **U.S. Total** | **44%** | **1%** | **24%** | **20%** | **7%** | **4%** |

Notes: (a) Includes other gases. (b) Includes pumped storage. (c) Includes solar, wind, geothermal, biomass, other wood and waste resources, and other.

Source: EIA (2010).

## Appendix 3: State Renewable Portfolio Standards and Goals

| State/District | Percent of retail sales or quantity* target | Year to accomplish the target by |
|---|---|---|
| Alabama | | |
| Alaska | | |
| **Arizona** | **15%** | **2025** |
| Arkansas | | |
| California | 33% | 2020 |
| Colorado[a] | 30% | 2020 |
| Connecticut | 23% | 2020 |
| Delaware[a] | 25% | 2026 |
| Florida | | |
| Georgia | | |
| Hawaii | 40% | 2030 |
| Idaho | | |
| Illinois | 25% | 2025 |
| Indiana[b,e] | 15% | 2025 |
| Iowa | 105 MW | N.S. |
| Kansas | 20% | 2020 |
| Kentucky | | |
| Louisiana | | |
| Maine | 30%<br>10% | 2000<br>2017[c] |
| Maryland | 20% | 2022 |
| Massachusetts | 22.1%<br>15% | 2020<br>2020[c] |
| Michigan[a] | 10% and 1,100 MW | 2015 |
| Minnesota | 25%<br>30% | 2025<br>2020[d] |
| Mississippi | | |
| Missouri | 15% | 2021 |
| Montana | 15% | 2015 |

| State/District | Percent of retail sales or quantity* target | Year to accomplish the target by |
|---|---|---|
| Nebraska | | |
| Nevada[a] | 25% | 2025 |
| New Hampshire | 23.8% | 2025 |
| New Jersey | 20.38%<br>5,316 GWh | 2021<br>2026[f] |
| New Mexico | 20% | 2020 |
| New York | 29% | 2015 |
| North Carolina | 12.5% | 2021 |
| North Dakota[b] | 10% | 2015 |
| Ohio[e] | 25% | 2025 |
| Oklahoma[b] | 15% | 2015 |
| Oregon[a] | 25% | 2025 |
| Pennsylvania[e] | 18% | 2021 |
| Rhode Island | 16% | 2020 |
| South Carolina | | |
| South Dakota[b] | 10% | 2015 |
| Tennessee | | |
| Texas | 5,880 MW | 2015 |
| Utah[b] | 20% | 2025 |
| Vermont[b,e] | 20% | 2017 |
| Virginia[b] | 15% | 2025 |
| Washington[a] | 15% | 2020 |
| Washington, D.C. | 20% | 2020 |
| West Virginia[b,e] | 25% | 2025 |
| Wisconsin | 10% | 2015 |
| Wyoming | | |

*Information as of September 2011.*

Notes: (*) In capacity (MW) or output (GWh) terms. N.S. = Not specified. (a) Extra credit for solar or distributed generation. (b) States with "Renewable Portfolio Goals," where the target is not mandated by legislation. (c) Target for new renewables. In Massachusetts, this target will escalate at 1% per annum after 2020. (d) The target for Minnesota's largest investor-owned utility, Xcel Energy. (e) Allows the use of non-renewable alternative resources to meet the target. (f) Generation target to be met solely from solar resources.

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

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