CLIMATE CHANGE POLICY IN CALIFORNIA: BALANCING MARKETS VERSUS REGULATION

An emerging consensus for direct regulation and why it makes sense

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1. INTRODUCTION

1.1. Motivation

Global warming is the most challenging environmental problem ever to confront humanity. Every sector of the economy must be part of the solution because virtually every economic activity produces greenhouse gas emissions. Emissions are produced from: combustion of coal and natural gas for the generation of electricity; the use of gasoline and diesel fuels in internal combustion engines for transportation; from the direct combustion of fossil fuels and consumption of electricity in industry (petroleum refining, cement, steel, aluminum, and other manufacturing); soil disturbance, fertilizer use, and conversion of forested land to less carbon intensive uses in agriculture; timber cutting in forestry; decomposition of organic matter that produces methane gas from landfills; these are some highlights, the list goes on.

The challenge is heightened by the global scale and multi-decadal time horizon over which the optimal response would ideally be planned. Further adding to the complexity are thorny equity issues. Within industrial countries, there is justified concern about the vulnerability of low-income groups to the economic impacts of climate policy. While there is increasing reason to believe that climate progress can be affordable, and can even lead to increased economic growth and certainly improved quality of life, part of the solution is also to correct the current under pricing of the fossil fuel-based energy sources that currently dominate – internalizing the externality in economic terms. And these price corrections (increases) hit low-income households hardest because energy is a relatively larger part of their budget.

The international equity component is another challenging element of the problem of negotiating a global response. Developed countries have industrialized and achieve per capita incomes that are much higher than developing country incomes. In the process, industrialized countries have mostly (arguably entirely) used up the atmosphere's ability to absorb GHGs without climatic destabilization. Developing countries reasonably demand financial and technology transfer to assist in the attainment of a cleaner path of development.

1.2. Paper overview

With that background, we turn to our topic, climate policy in California, which has been at the forefront in the North American effort to fight global warming, and the rationale for the approach taken in California.

In 2006, California adopted the first economy-wide cap on GHG emissions in the US in the landmark Global Warming Solutions Act. California has also been a leader in bringing together western states and Canadian provinces in the Western Climate Initiative. Most recently, the state finalized its first in the world Low Carbon Fuel Standard, which will reduce the carbon intensity of the state's transportation fuels. The Low Carbon Fuel Standard is part of the state's blueprint ("Scoping Plan") for achieving the mandated emission reductions.

In addition to this recent activity, California has been a leader in energy policy for decades. In the 1970s, California developed the first appliance, lighting, and building electricity efficiency performance standards; these have become common the world over. The state was also an early adopter of a renewable electricity standard that requires a minimum amount of renewable energy be part of each utility's electricity mix.

One of the notable aspects of the California economy-wide blue print is its reliance on directly regulation. These direct regulations draw from a suite of proven policy instruments, including – performance standards, technology standards, land use standards, and targeted incentives, both carrots and sticks – to manage GHG emissions. The Scoping Plan achieves about 80% of the needed emission reductions from direct regulations. At the same time, the California plan recognizes the need to achieve an internalization of the GHG externality,that is to correct the current situation in which polluters can emit GHG emission without cost. This is the broad carbon pricing element of the approach in California, which is achieved by a broad multi-sector cap-and-trade program.

The second part of the paper explores the economic, psychological, and institutional factors that support the emerging best practice. We describe the climate change exernality in greater detail the climate change externality that is the basis for carbon pricing policies, such as carbon taxes or cap-and-trade. We explore some of the institutional challenges created by climate change policy. Next we focus on emission trading (cap-and-trade), explaining how this has worked in the US for other types of air pollution, and identify some crucial differences between them and GHGs.

We develop a thesis that, although we now have almost 40 years of experience in dealing with pollution control policy, climate change presents some unusual challenges, both conceptual and practical, for economists and policy makers alike. At the practical level, climate change poses an institutional challenge because of the breadth of its reach across the entire economy. At a conceptual level it involves a different mix of issues than has generally arisen in most existing pollution control policy, including a different balance between source-control versus end-of-pipe treatment, quite distinct long-term and short-term policy goals, and a pressing need to regulate before all the technologies exist that will be needed to meet the long-term policy goal and even, perhaps, some of the short-term policy goals. Thus, while we certainly should draw on the lessons of our past experience in dealing with pollution control, climate change policy will require a somewhat different architecture from the existing structures used for conventional air and water pollution.

We summarize lessons learned for policymakers, and suggest design requirements for effective climate change policy. A price on GHG emissions is an important step, but plays only a supporting role. The key is a robust collection of direct regulation as the foundation of the effort. We conclude that California is on the right track. Moreover, when we compare climate policy thinking in California to that in the European Union and that embodied by the new climate policy initiatives in Washington, DC, we see evidence of an emerging consensus on best practice for climate policy that involves a broad set of direct regulation in particular in key sectors like electricity generation and transportation but also across most sectors of the economy with a broad carbon pricing overlay to sweep up the last increment of economy-wide reduction needed.

2. CLIMATE CHANGE POLICY IN CALIFORNIA

On August 31, 2006, the California Legislature passed Assembly Bill (AB) 32, the California Global Warming Solutions Act; SB 1368, the Greenhouse Gas (GHG) Emissions Performance Standard; and SB 107, the Renewable Energy Act. AB 32 is a landmark in climate change policy; it places a cap on all GHG emissions in California and requires that they be reduced to their 1990 levels by 2020. This is a reduction of about 29 percent from the emissions projected to occur otherwise, and a reduction of about 15% from the 2006 level of emissions. On a per person basis, it amounts to reducing annual emissions of 14 tons per capita of CO2 equivalent down to about 10 tons per capita by 2020.

In addition, SB 1368 prohibits any retail seller of electricity in California from entering into a long-term financial commitment for baseload generation if the GHG emissions are higher than those from combined-cycle natural gas. This performance standard applies to electricity generated out-of-state as well as in-state, and to publicly owned as well as investor-owned electric utilities (IOUs). SB 107 advances from 2017 to 2010 the deadline for compliance with an earlier enacted requirement that 20 percent of the electricity sold by IOUs in California come from renewable sources.

Together with other related regulatory actions taken before then or shortly thereafter, these laws constituted the most ambitious and comprehensive effort to control GHG emissions in force in the United States. Earlier measures date back to 1988, and are summarized in Table 1;[1] the more recent measures are listed in Table 2; Table 3 provides an overview of the blueprint for AB 32 implementation that is currently being put in place through regulatory action.

TABLE 1: MAJOR CLIMATE POLICY ACTIONS IN CALIFORNIA BEFORE AB 32

1988	AB 4420 requires the California Energy Commission (CEC) to make an inventory of GHG emissions from all sources in California, conduct an assessment of the potential global warming impacts on California, and report on emission reduction strategies for California.
2000	SB 71 establishes the California Climate Action Registry.
2002	AB 1493 requires California Air Resources Board (CARB) to develop regulations to limit GHG emissions from motor vehicles sold in California.
	SB 1078 sets requirement that, by 2017, 20% of electricity sold in California come from renewable sources.
2003	CEC releases first integrated assessment of climate change impacts on California.
	California Public Utility Commission (CPUC) and CEC jointly adopt an Energy Action Plan which establishes a “loading order” for preferred options of electricity generation: first, increased conservation and energy efficiency; second, renewable energy; third, clean fossil fuel (e.g., natural gas).
2004	CARB adopts regulations requiring reduction in aggregate GHG emissions from new vehicles of 22% by 2012, and 30% by 2016.
2005	Governor Schwarzenegger issues Executive Order S-3-05 calling for GHG emissions in California to be reduced back to the 1990 level by 2020, and 80% below the 1990 level by 2050. It also directs California EPA and CEC to report biennially on climate change impacts.

AB 1493, enacted in 2002, is the most important of the earlier measures. It targets emissions from light duty vehicles, the largest slice of transportation sector, itself representing a preponderance of California’s emissions, about 42% in 2005. Passed in the face of strenuous industry opposition, AB 1493 directed the California Air Resources Board (CARB) to develop regulations “that achieve the maximum feasible and cost-effective reduction of GHG emissions” from motor vehicles sold in California. The Board was left to determine how to do this, subject to certain constraints including that it not ban the sale of any vehicle category or impose any new taxes, and that it provide auto makers with flexibility in complying with whatever emissions standard was devised.

[1] Terms like AB 4420 and SB 71 refer to legislation; AB stands for “Assembly Bill” and SB for “Senate Bill.” Further detail on the evolution of climate change policy in California can be found in Hanemann (2008) and Farrell and Hanemann (in press).

CARB was given two years to implement its broad mandate. CARB staff conducted an evaluation of GHG emission technologies, focusing only on technologies that were already in use in at least some vehicle models or had been demonstrated by auto companies and/or vehicle component suppliers in at least prototype form. They did *not* consider hybrid gas-electric vehicles. The emissions standards took the form of fleet average emissions per new vehicle, in grams of CO2 equivalent generated per mile driven, with a declining annual schedule for each model year between 2009 and 2016. The standards were to be introduced in two phases to allow auto makers to incorporate the changes into their normal product improvement cycle. Near-term standards (2009–2012), when fully phased in by 2012, would result in a reduction of GHG emissions of about 22 percent compared to the 2002 fleet; the mid-term standards (2013–2016) would result in a 30-percent reduction by 2016.

Despite continuing industry opposition, the CARB Board voted unanimously in September 2004 to adopt the staff recommendations and, when the legislature did not intervene to modify them, they became law in January 2006. However, they have not yet taken effect because of legal obstacles on two fronts. First, in December 2004, the automobile industry filed suit against CARB asserting that the cap on GHG emissions is akin to a fuel economy standard, which is preempted by the federal government under the 1975 Energy Policy and Conservation Act. California argued that AB 32 was designed to regulate GHGs viewed as pollutant under the 1966 Clean Air Act, rather than to regulate fuel efficiency per se. The law suit was dismissed by the California court in December 2007.[2] Second, as explained below, California is authorized under the Clean Air Act to adopt motor vehicle standards stricter than federal requirements if it receives a waiver from the U.S. EPA. Moreover, once a California waiver request is granted, other states are permitted to adopt the same rules. In December 2005, California applied to the EPA for a waiver to implement the CARB regulations. In December 2007, the EPA Administrator denied California's waiver request. In January 2008, California filed a petition with the US Court of Appeals challenging the EPA's denial; seventeen other states, representing about one half of the US auto market, moved to intervene in support of California. In April 2009, the US EPA recognized carbon dioxide as a pollutant under the Clean Air Act, further bolstering the case for California's waiver. It is widely expected that the new Obama administration will now grant California's waiver request.

[2] In September 2007, a similar suit had been rejected by a court in Vermont, where regulations patterned after those in California had been adopted in the fall of 2005.

TABLE 2 MAJOR CLIMATE POLICY ACTIONS IN CALIFORNIA

Cap of GHG Emissions AB 32 stes a cap on aggregate statewide GHG emission starting in 2012 and returning emissions to 1990 level by 2020. Blueprint ("Scoping Plan") adopted December 2008 and outlined below.
Impact research: First biennial report on impacts of climate change issued in January 2006; second to be released in Spring 2009.
Electricity
- Renewable portfolio standard Achieve 20 percent renewable energy by 2010 using tradable credits. Target now being raised to 33% by 2020. Applies to investor-owned utilities, but not municipal-owned utilities.
- California Solar Initiative, 2006. Provides for $3.2 billion in subsidies for solar electricity, especially photovoltaic. Must be 1/3 residential, with low-income set asides. SB1 extends program to municipal-owned utilities and requires developers of >50 new single-family homes to offer a solar option.
- Carbon Risk Adder, (CPUC order D 04-12-048, December 2004). To protect consumers investor-owned utilities must explicitly account for the risk of carbon regulation in the future, assuming $8/ton CO_2. No cash payments.
- GHG performance standard (CPUC decision, SB1368). Limits CO_2 emissions for baseload electricity to equal to or less than emissions from a combined cycle gas turbine plant. Applies to both municipal-owned and investor-owned utilities.
- GHG emission cap CPUC "threshold decision" in 2006 to adopt a load-based GHG cap for all electricity.
-Long Term Energy Efficiency Strategic Plan Adopted by CPUC in September 2008, requires all new residential construction in California to be zero net energy by 2020, all eligible low-income homes to be energy efficient by 2020, all new commercial construction to be zero net energy by 2030, and 50% of existing commercial buildings to be zero net energy by 2030.
Transportation
- Vehicle GHG performance standard (AB1493). Automakers must reduce vehicle GHG emissions of new cars beginning with model year 2009, leading to 30 percent reduction by model year 2016. Alternative fuel compliance path.
- Low Carbon Fuel Standard (Executive Order S-1-07, January 2007) Refiners, blenders, importers must lower GHG content of fuel by at least 10 percent by 2020. Emission reduction credits allowed.
Land Use
- Litigation. California attorney general sues San Bernardino County in April 2007 for failure under the California Environmental Quality Act to analyze GHG emissions resulting from its (land use) general plan amendment; the county settles and agrees to adopt a GHG emission reduction plan, thereby setting a precedent for local government in California. The attorney general reaches agreements with other local agencies and private entities to develop GHG mitigation plans.
- Legislation. SB 375, enacted in 2008, applies to urban areas and major rural areas and requires the regional planning organizations for those areas to align their regional transportation, housing, and land use plans so that the resulting development patterns can reduce GHG emissions by the amounts to be set by CARB.

The most important development after the enactment of AB 1493 was Governor Schwarzenegger's issuance of an Executive Order in June 2005 calling for GHG emissions in California to be reduced back to the 1990 level by 2020, and 80% below the 1990 level by 2050. AB 32 gives legislative force to the governor's 2020 target. The governor's pronouncement triggered actions by the California Public Utility Commission (CPUC), which regulates IOUs, and the California Energy Commission (CEC). There was also a further Executive Order issued by Governor Schwarzenegger in January 2007 on the Low Carbon Fuel Standard (LCFS). The LCFS was included in CARB's Scoping Plan (see Table 3 below). On April 23, 2009, CARB adopted the finalized rule for the world's first Low Carbon Fuel Standard, which calls for a 10% decrease in carbon intensity by 2020.[3]

Also affecting transportation emissions, litigation by the California Attorney General addressing consideration of greenhouse gas impacts from land use change decisions, and new legislation, notably SB 375, enacted in August 2008, which directs local planning agencies to align regional transportation, housing, and land use plans with the state's GHG reduction goals.

In this way, CARB has taken a three-pronged approach to transportation emissions: (1) vehicles, (2) fuels, and (3) development patterns. The detail is almost endless, and actually continues in transportation on to major diesel and port related rulemaking, the Zero Emission Vehicle program and etc.

The second largest source of GHG emissions in California is electricity generation.[4] In addition to regulations which directly target GHG emissions from fossil fuel-based electricity generation, the renewable portfolio standard and the solar initiative promote alternatives to fossil fuels. In the case of automobiles, while AB 1493 targets automobile manufacturers, the low-carbon fuel standard targets the oil companies and the new SB 375 begins to target vehicle miles travelled through changes in transportation and land use planning.

CARB was designated as the lead agency for the implementation of AB 32, and it was directed to prepare a Scoping Plan by the end of 2008 for achieving the required reductions in GHG emissions. The Scoping Plan, adopted in December 2008, recommended a combination of performance standards, energy efficiency programs and direct regulations together with a multi-sector cap and trade program. CARB estimates the baseline 1990 level of statewide emissions at 422 million metric tons of CO2 equivalent (MTCO2E), and it projects the 2020 statewide business-as-usual emissions at 596 million MTCO2E; therefore, a reduction of 174 million MTCO2E in annual emissions will be required by 2020 in order to comply with AB 32. The performance

[3] http://www.arb.ca.gov/newsrel/nr042309b.htm
http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf

[4] About half of the electricity consumed in California is imported and generated out of state. AB 32 explicitly covers electricity imports and includes them in the total GHG emissions for which California is accountable and which must be reduced by 2020.

standards, efficiency programs and other regulatory measures recommended by CARB to accomplish this emission reduction are listed in Table 3. Some of these have already been adopted by state agencies and also appear in Table 2; others are new programs.[5]

TABLE 3 GHG REDUCTION MEASURES RECOMMENDED IN CARB SCOPING PLAN

Recommended Reduction Measures	Reductions Counted Towards 2020 Target ($MMTCO_2E$)	
ESTIMATED REDUCTIONS RESULTING FROM THE COMBINATION OF CAP-AND-TRADE PROGRAM AND COMPLEMENTARY MEASURES		**146.7**
California Light-Duty Vehicle Greenhouse Gas Standards • Implement Pavley standards • Develop Pavley II light-duty vehicle standards	31.7	
Energy Efficiency • Building/appliance efficiency, new programs, etc. • Increase CHP generation by 30,000 GWh • Solar Water Heating (AB 1470 goal)	26.3	
Renewables Portfolio Standard (33% by 2020)	21.3	
Low Carbon Fuel Standard	15	
Regional Transportation-Related GHG Targets[16]	5	
Vehicle Efficiency Measures	4.5	
Goods Movement • Ship Electrification at Ports • System-Wide Efficiency Improvements	3.7	
Million Solar Roofs	2.1	
Medium/Heavy Duty Vehicles • Heavy-Duty Vehicle Greenhouse Gas Emission Reduction (Aerodynamic Efficiency) • Medium- and Heavy-Duty Vehicle Hybridization	1.4	
High Speed Rail	1.0	
Industrial Measures (for sources covered under cap-and-trade program) • Refinery Measures • Energy Efficiency & Co-Benefits Audits	0.3	
Additional Reductions Necessary to Achieve the Cap	34.4	
ESTIMATED REDUCTIONS FROM UNCAPPED SOURCES/SECTORS		**27.3**
High Global Warming Potential Gas Measures	20.2	
Sustainable Forests	5.0	
Industrial Measures (for sources not covered under cap and trade program) • Oil and Gas Extraction and Transmission	1.1	
Recycling and Waste (landfill methane capture)	1.0	
TOTAL REDUCTIONS COUNTED TOWARDS 2020 TARGET		**174**

Other Recommended Measures	Estimated 2020 Reductions ($MMTCO_2E$)
State Government Operations	1-2
Local Government Operations	TBD
Green Buildings	26
Recycling and Waste (other measures)	9
Water Sector Measures	4.8
Methane Capture at Large Dairies	1.0

[5] While CARB is the lead agency for implantation of AB 32, it itself does not have authority to implement some of the recommended measures; those must be adopted by other state agencies.

The cap and trade program would cover the electricity sector (including imported electricity), transportation fuels, natural gas and large industrial sources. Together, these sectors are projected to account for about 85% of total GHG emissions in 2020. The only economic activities not directly capped by 2020 are agriculture, forestry, and the waste sector. The cap and trade program would be introduced in two phases. Starting in the 2012 (the first compliance period), the cap and trade program would cover electricity generation and large industrial sources above 25,000 MMTCO2E. Starting in 2015 (the second compliance period), coverage would be extended to transportation fuels and industrial fuel combustion at facilities with emission less than or equal to 25,000 MMTCO2E. Firms in the capped sectors are also subject to the regulatory measures listed in Table 3 in addition to the emission cap. The total emission reduction required from the capped sectors in 2020 amounts to 146.7 million MMTCO2E. Of this, the regulatory measures listed in Table 3 account for 112.3 million MTCO2E; the remaining 34.4 million MMTCO2E of emission reduction would be achieved through the cap and trade program alone. In addition, uncapped sectors are subject to certain regulatory measures as indicated in Table 3; those measures are projected to generate an emission reduction of 27.3 million MMTCO2E. Finally, in addition to the 174 million MMTCO2E of emission reductions, the Scoping Plan recommends another 42+ million MMTCO2E of emission reduction programs aimed partly but not exclusively at the public sector, which are intended as insurance for meeting the 2020 target as well as a down payment on the additional reductions that will be required to meet the 2050 goal of reducing statewide emissions to 80% below the 1990 level by 2050.

Thus, the vast majority of reductions – about 80% – to achieve California's emission reduction mandate are expected to come from policy instruments other than carbon pricing. The California cap-and-trade program is tasked with inducing about 20% of the reductions, 34.4 MMTCO2E out of 174 total. It is notable that agriculture and forestry escape any mandates. Whatever reductions are to be achieved are to come through offsets (i.e. voluntary forestry and livestock methane projects). Some reductions are to come from changes to management practice on state forestlands.

In February 2007, California entered in to the Western Climate Initiative (WCI). What started as a memorandum of understanding amongst five governors has grown to seven states[6] and four Canadian provinces[7] covering 75% of that nation's populace. In August 2007, the WCI Partners (as they self-title) announced a regional goal of reducing economy-wide emissions to 15 percent below 2005 levels by 2020. For California, this is essentially equal to the reductions mandated by AB 32. Other jurisdictions included in the WCI have taken on commitments that are at least as steep as the roughly 30 percent reduction over business as usual that California has embraced. British Columbia has taken on a cut of about 46 percent and Arizona about 45 percent over their forecasted emissions growth for 2020 in the absence of the WCI initiative. A commitment to adopt the AB 1493 standards has been a core element of the WCI, though Ontario (home to Canadian auto manufacturing) negotiated out of this part of the pact. The WCI is developing a regional cap-and-trade program. In September 2008, the WCI partners

[6] Arizona California, New Mexico, Montana, Oregon, Utah, Washington.
[7] British Columbia, Manitoba, Ontario, Quebec.

released a framework agreement, with design elements that mostly echo that proposed for California in CARB's Scoping Plan (i.e. on the breadth of the multi-sector cap-and-trade, the timing of the expansion to transportation fuels, the point of regulation, and offsets policy). The WCI has released a workplan for the years 2009 and 2010 for completing design of this regional cap-and-trade program, and work continues.[8] Nonetheless, at this juncture, the future of the WCI is uncertain. To be translated from commitments from Governor's mansions to policy with the full force of law, additional legislative action is needed is most jurisdictions. The economic downturn is not making this easier to achieve. Even in the most progressive states, Washington and Oregon, legislative action has stalled.

3. THE CONTRAST WITH RGGI

AB 32 and the associated measures just described are one model for the control of GHG emissions. Another model is that adopted in 2005by the Regional Greenhouse Gas Initiative (RGGI) of ten northeastern and mid-Atlantic states.[9] The two models differ greatly in their coverage, motivation, and implementation.[10]

RGGI covers the emissions of carbon dioxide (CO2) from electricity generation in the member states; AB 32 covers all GHG emissions, not just emissions from electricity generation, and not just CO2 emissions. In the RGGI members, while CO2 emissions account for almost 92% of all GHG emissions, CO2 emissions from electricity account for only 24% of all CO2 emissions. In addition, the RGGI emission reduction target is less ambitious than the target set by AB 32: RGGI aims to reduce CO2 emissions from electricity generation 10% below the 2005 level by 2019 while, as noted above, AB 32 entails a 15% reduction below the 2006 level of GHG emissions by 2020.

The method of implementation and motivation are also different. RGGI focuses solely on cap and trade as the means to effect the targeted emissions reduction while, as indicated above, AB 32 involves a mix of cap and trade combined with a host of regulatory programs. With regard to motivation, RGGI was inspired by the success of the federal cap and trade program for sulfur dioxide (SO2) established under the 1990 Amendments to the Clean Air Act. RGGI was seen as a template for a potential national cap and trade program for CO2, and it was intended to be folded into such a program if and when it is created. AB 32, and AB 1493 before it, drew on California's own experience over the previous four decades in controlling emissions of air pollutants from motor vehicles through CARB and in regulating energy efficiency through CEC. As summarized in the following section, both agencies have a unique history among U.S.

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[8] http://www.westernclimateinitiative.org/ewebeditpro/items/O104F21097.pdf

[9] These are Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Rhode Island, and Vermont.

[10] Since 2006, several states have adopted laws similar to AB 32. Oregon, Washington, and Hawaii have enacted the same emissions limit as AB 32, and Arizona and New Mexico are in the process of doing so. Illinois and Florida have adopted a similar emissions limit by executive order. Minnesota has enacted a law requiring a 30-percent reduction in GHG emissions from electricity, relative to 2005, by 2025.

states and, in both cases, they pioneered regulatory approaches that were later copied by the federal government and other states.

It should also be noted that, while California and RGGI share a near-term goal of reducing emissions by around 2020, California has an additional and more ambitious long-term goal of substantially decarbonizing its economy by 2050. Achieving this long-term goal requires not only immediate emissions reductions, but also an emphasis on technology development and transformation of the energy industry. In California, therefore, the challenge is to meet the 2020 target for GHG emission reduction while also laying the groundwork for a more substantial emission reduction by mid-century which almost certainly will require some different policy instruments. The instruments used to meet the 2020 target must be compatible with those needed for the 2050 target. This, too, is a factor in the difference between the relatively narrowly focused approach adopted by RGGI and the broader approach being followed in California. While RGGI was an ambitious initiative at the time it was being negotiated, the more ambitious California program reflects increased urgency due new scientific findings, increased popular support for climate action, and the leadership of Governor Schwarzenegger.

4. REGULATORY ANTECEDENTS OF CALIFORNIA'S CLIMATE POLICY

California's tradition in controlling air pollution from motor vehicles and regulating energy efficiency is a crucial factor in explaining both why there was strong public support in California for taking decisive action on climate change, first in 2002 and then in 2006, and why the policy interventions took the form that they did rather than following the RGGI model. To the extent that the emerging EU approach to climate policy may end up being closer in spirit to the California model than the RGGI model, this history is relevant for the larger context of the California-EU regulatory cooperation project

With air pollution, the story starts with the appearance of smog in Los Angeles in the early 1940s. In 1945, the city passed an ordinance setting limits on industrial smoke emissions, and an air pollution control unit was formed within the municipal Health Department. In 1947, California passed a law authorizing the creation of county-level Air Pollution Control Districts and the Los Angeles County District (LAAPCD) was formed, the first of its kind in the nation. In 1950, research by Professor A. J. Haagen-Smit at Cal Tech finally identified the problem as a photochemical reaction converting certain pollutants – primarily from refineries and motor vehicles – into smog. By 1955, after some controversy fueled by industry opponents, this finding had been confirmed and motor vehicle emissions were established as the primary factor. That year, LAAPCD formed a Motor Vehicle Pollution Control Laboratory. In 1959, California passed a law requiring the State Department of Public Health to establish air quality standards and controls for motor vehicles. In 1960, the Motor Vehicle Pollution Control Board was established to test and certify devices for installation on cars sold in California. In 1961 the Department of Public Health mandated positive crankcase ventilation on new vehicles sold in California starting in 1963, the first emission controls in the nation. In 1966, the Motor Vehicle Board adopted tailpipe emission standards for hydrocarbons and carbon monoxide, and the California Highway Patrol began random inspections of vehicle smog control devices. In 1967, a unified regulatory agency, the California Air Resources Board, was created; the Board's founding chair was Professor Haagen-Smit.

The federal government took no action on motor vehicle emissions until 1965. That year, faced with the prospect of state emissions controls in Pennsylvania and New York, in addition to California, the automobile industry agreed to support national standards for automobile emissions and Congress passed the Motor Vehicles Air Pollution Control Act which called on the Department of Health, Education and Welfare (HEW) to develop emissions standards for new vehicles, taking into consideration the technological feasibility and economic cost of compliance. In 1967, HEW responded with a proposal for a Clean Air law covering both motor vehicles and stationary source. A major issue was whether California should be allowed to impose controls more stringent than the national standard, as California's representatives urged. After a fierce battle, California got its way: the final legislation granted California alone a special waiver in deference to its "unique problems and pioneering efforts." The Administrator overseeing implementation of air pollution standards is to waive federal preemption upon application by California for such a waiver provided that the application is not arbitrary and capricious, it is at least as stringent as the national standard, and it is needed to meet California's "compelling and extraordinary conditions." The 1977 Amendments to the Clean Air Act reinforced California's independence by creating a similar waiver from federal emission standards for non-road vehicles, and by permitting California to prescribe fuel or fuel additive requirements without needing EPA approval. The 1977 Amendments also established a "piggyback" provision allowing other states, if they so chose, to adopt the California standards once these have received the formal EPA approval.

Congress' willingness to grant California this degree of latitude despite fierce industry opposition reflects its appreciation of California's role as "a kind of laboratory for innovation" in emission control technology and regulation.[11] Since 1967, California has received a waiver from the EPA, either in whole or in part, on fifty-three occasions to pioneer innovations in the regulation of emissions, including the first introduction of NOx standards for cars and light trucks (1971), heavy-duty diesel truck standards (1973), two-way catalytic converters (1975) "unleaded" gasoline (1976), low-emission vehicles (LEV) program (1994 and 1998), zero emission vehicles (1990) and evaporative emissions standards and test procedures (1999).[12] The LEV program is the primary California emissions standard adopted by other states. It originated from the 1988 California Clean Air Act (CCAA) which instructed CARB to "achieve the maximum degree of emission reduction possible from vehicular and other mobile sources." The distinctive feature of CCAA is that it set an ambitious goal and specified some broad constraints, but left wide latitude for CARB to determine how and when the goal would

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[11] The quotation is from the DC Circuit Court's ruling in Motor and Equipment Manufacturers Association, Inc. v. EPA, 627 F.2d (1979).

[12] In fact, EPA's denial in December 2007 of California's application for a waiver for AB 1493 is the first time that a waiver request has been flatly refused.

be attained. In response, CARB approved an ambitious new program in 1990 that would substantially reduce emissions from light- and medium-duty vehicles starting in model-year 1994. Rather than requiring every vehicle to meet the same emission standard, the LEV program introduced a fleet-based approach. In both the legislative language and the framing of the rule-making by CARB, AB 1493 is a direct descendant of LEV and the 1988 CCAA, and AB 32 is a direct descendant of AB 1493.

The results of CARB's efforts were impressive. While California's population grew from 21.5 million in 1975 to almost 35.5 million in 2005, and vehicle miles traveled in California grew from about 389 million miles per day in 1980 to 873 million miles per day in 2005, there have been major reductions in the statewide emission of criteria air pollutants regulated under the Clean Air Act.

The other major forerunner of AB 32 is the regulation of energy efficiency by CEC. This dates back to the early 1970s, when California's electric utilities were projecting an unending growth in demand. To meet this demand they were planning to construct a large number of new nuclear power plants. The new power plants were opposed by environmentalists who felt that the demand forecasts were overblown, conservation was deliberately being ignored, and nuclear power was both more expensive and less environmentally benign than the utilities had represented. They felt, also, that the CPUC, which focused narrowly on rate regulation, was not doing an adequate job of dealing with the larger issues of energy supply and demand in California. To remedy this, the Democrat-controlled legislature passed a bill in 1973 to create an Energy Commission that would forecast energy demand, assess efforts to reduce this demand through conservation and efficiency, and provide a consolidated approval process for the siting of new power plants. The legislation was vetoed by then Governor Reagan. Within a few months, however, the OPEC oil embargo occurred, creating an energy shortage and raising energy prices. At Governor Reagan's request, a nearly identical bill to the one he had vetoed was passed by the legislature, the Warren-Alquist Act, and this time he signed it into law in May 1974.

The resulting CEC has four main mandates:[13] (1) Facility siting and environmental protection: CEC has exclusive power to certify thermal power plants of 50 MWh or larger to meet statewide energy needs; (2) Energy forecasting and planning: CEC is required to forecast future statewide energy needs, evaluate supply options for meeting those needs, and more generally develop and implement an energy policy for California; (3) Energy efficiency and conservation: CEC is empowered to establish building and appliance efficiency standards, and is required to promote conservation through research and public education programs and grant and loan programs; and (4) Technology development: CEC funds research, development and demonstration programs for

[13] The CEC's authority covers not just investor-owned but also municipal utilities within California.

technologies using renewable, alternative, and cleaner energy, including transportation fuels.[14]

A parallel development, stimulated by the same forces that had led to the formation of the CEC, was the rise of energy efficiency as a subject of academic and scientific study. In 1971, UC Berkeley had created an interdisciplinary graduate program, the Energy and Resources Group (ERG). Two years later, the oil embargo stimulated a number of physicists to start thinking about the physics of energy use and energy efficiency. The American Physical Society sponsored a study of energy efficiency for the summer of 1974, which led to the production of a landmark text, *Efficient Use of Energy* (1975). Several of the authors were at Berkeley, in the Physics Department, ERG, or the adjacent Lawrence Berkeley National Laboratory (LBNL); one of leaders, Art Rosenfeld, was a physics professor at Berkeley working in the particle physics program at LBNL. He decided to sponsor a summer study in 1975 at the Berkeley School of Architecture on energy-efficient buildings covering lighting, windows, and heating, ventilation and air-conditioning equipment.[15] Meanwhile, one of CEC's first actions in 1975 was to draft building energy-efficiency performance standards; however, the draft regulations were based on crude and oversimplified model of heat flow within a building. The two groups decided to join forces. Rosenfeld and his colleagues used their research to develop an improved software program which CEC took as the basis for reformulating what became known as "Title 24" building standards issued in 1977. This established a symbiotic relationship between CEC and the research community which has flourished for 30 years. CEC funds research by academic scientists and engineers which establishes a rigorous foundation for energy efficiency regulations that CEC subsequently promulgates.
In the case of appliances, how CEC came to issue the first energy efficiency standards is described by Rosenfeld (1999): "In 1976 Governor Jerry Brown was looking for a way to disapprove Sundesert, the only still pending application for a 1-GW nuclear power plant. The Title 24 standard for buildings was an accepted idea, but somehow standards for appliances seemed more like a federal responsibility, so appliance standards were still controversial. David Goldstein and I [Rosenfeld] then discovered that there was absolutely no correlation between refrigerator retail price and efficiency, although we controlled for every feature we could imagine. … I pointed out to Governor Brown that California refrigerators were already using the output of 5 Sundeserts, and that even minimal standards would avoid the need for 1.5 Sundeserts, at no additional cost. Brown promptly called Energy Commissioner Gene Varanini, who corroborated our claim. After that, standards for new refrigerators and freezers were developed quickly and put into effect in 1977." Over the next seven years, CEC followed up with appliance efficiency

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[14] A somewhat similar agency was created in New York in 1975: the New York State Energy Research and Development Authority (NYSERDA) has mandates corresponding to the CEC's mandates (3) and (4), but not to (1) or (2).

[15] This account is based on Rosenfeld (1999). What became the Center for Building Science and the Energy & Environment Division at LBL, and the UC California Institute for Energy Efficiency, are outgrowths of this research effort. Rosenfeld co-founded the California Institute for Energy Efficiency and also the American Council for an Energy Efficient Economy, and he founded and directed the Center for Building Science until 1994. In 2000 he was appointed one of the five California Energy Commissioners by Governor Davis, and his appointment was renewed for another five years by Governor Schwarzenegger in 2005.

standards for fluorescent lamp ballasts, various air conditioning products, heat pumps, furnaces, boilers, wall heaters, and showerheads, and faucets.

Throughout this period, the federal government was relatively inactive with regard to appliance standards.[16] The initial federal response to the oil embargo had been to call for voluntary targets for appliance efficiency. This was soon overtaken by the mandatory appliance efficiency standards being imposed by California, New York and some other states. The Carter Administration subsequently proposed mandatory federal standards and Congress ultimately agreed; the 1978 National Energy Conservation and Policy Act directed the US Department of Energy (DOE) to formulate mandatory efficiency standards for appliances. However, this was opposed by the Reagan Administration which instead proposed a “no standard” standard. The Reagan standard was overturned by the federal courts in 1985. By 1986, six states had adopted standards on one or more products and appliance manufacturers were coming around to the notion that a pre-emptive federal standard would better serve their interests than the expanding patchwork of individual state standards. A compromise was reached, embodied in the 1987 National Appliance Energy Conservation Act (NAECA), whereby Congress would adopt specific standards on many major appliances, with the provision that these federal standards would then preempt any state standards. However, the states are left free to adopt efficiency standards for products *not* covered by federal standards. Subsequent moves by states to adopt standards for products not covered by NAECA led to the passage of federal legislation in 1988 establishing efficiency standards for fluorescent lamp ballasts, and in 1992 to standards on a variety of lamps, electric motors, and commercial heating and cooling products.

The 1988 federal standard for fluorescent lamp ballasts merely replicated the standard that California had set in 1978, and something similar was true of most of the other federal appliance efficiency standards. Under NAECA, DOE is required to periodically review and revise its efficiency standards, but this has generally occurred at a rather sluggish pace. Meanwhile, states including California have continued to innovate with efficiency standards for products not subject to DOE standards. In December 2004, for example, CEC set new energy efficiency standards for 17 different products ranging from light bulbs to swimming pool pumps to small power supplies for electronics; it is estimated that the new standards will save approximately 100 MW of new generating capacity in California every year.[17]

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[16] The account that follows is drawn from Nadel (2002).

[17] CEC press release, 12/15/04. In addition, CEC had issued new building efficiency standards in 2001 and 2003, and other appliance efficiency standards in 2002. The following is an example of how things work. DOE issues energy efficiency standards for consumer products, but not for commercial products, and not water efficiency standards. In 2001, DOE issued new energy efficiency standards for residential clothes washers. In 2002, CEC adopted more stringent energy *and water* efficiency standards for *commercial* clothes washers (not federally regulated). Later that year, the legislature passed AB 1561 requiring CEC to establish water efficiency standards for residential clothes washers at least equal to those for commercial clothes washers. CEC adopted the water efficiency standards for residential clothes washers in September 2004.

Another important state actor contributing to California's record on energy conservation is the CPUC which itself "got religion" with respect to energy conservation. In the 1970s it started approving the use of ratepayer funds for energy efficiency activities and energetically pushed the IOUs in California to administer a variety of energy efficiency programs. A major innovation by CPUC was the adoption of rate decoupling for regulated natural gas utilities in 1978 and electric utilities in 1982. Rate decoupling ensures that utilities receive their expected annual revenue even if energy efficiency programs reduce their sales. This has since been adopted by a dozen other states for natural gas and about half a dozen states for electricity.

The IOUs' energy conservation programs have grown in scale over time. Starting in the early 1990s, they began to be integrated into the Biennial Resource Planning process conducted jointly by CPUC and CEC. The Energy Action Plan jointly adopted by CPUC and CEC in 2003 elevated conservation and energy efficiency to the first priority in the loading order to be followed by California's electric utilities. CPUC recently took the next step and adopted a Long Term Energy Efficiency Strategic Plan which sets a roadmap for future energy efficiency in California requiring that all new residential construction in California be zero net energy by 2020, all new commercial construction be zero net energy by 2030, and 50% of existing commercial buildings be zero net energy by 2030.

The activism by CEC, CPUC and California's electric utilities with respect to energy efficiency has had a significant impact on electricity use in California over the past three decades. Electricity use per capita in California has stayed roughly constant since 1975. By contrast, it has increased by about 50% nationally over this period. In other western states, it has increased by about two thirds over the period.

In summary, for several decades California has charted a distinctive course in regulating motor vehicle emissions and promoting energy efficiency. These efforts had three distinctive features which have set the tone for California's more recent efforts on GHG emissions. First, California was acting unilaterally to solve what were seen as important issues for California, regardless of their wider national or international significance. Second, the approach adopted was one of science-based regulation. Both CEC and CARB actively sponsor peer-reviewed research and this has provided a firm foundation for their regulatory actions. Third, the emphasis so far has *not* been on market based incentives; nevertheless the approach adopted is widely believed to have served California well.

5. THE CLIMATE CHANGE EXTERNALITY

Climate change is an example – perhaps the most far-reaching example – of an economic externality: a person decides to engage in an action involving, say, the combustion of fossil fuels based on a calculation of the benefits and costs of this action to himself, but disregards the adverse consequences ultimately imposed on others because of the increased accumulation of greenhouse gasses (GHGs) in the atmosphere.[18] Because the actor does not bear all of the (ultimate) costs, too much of the action is likely to be undertaken from the larger viewpoint of society. Therefore, some correction is called for in order to protect the public interest. This conceptualization of an externality and the problem it creates for the unimpaired functioning of a free market has been known to economists since Pigou (1912) first identified it. Pigou also identified the two main remedies: direct regulation by the government to limit the level of the externality-causing action, or the imposition of a corrective tax on the action by the government equal to the amount of the divergence between the social and private cost associated with the action; the tax would serve to internalize the externality and harmonize the private actor's interest with that of society.

An alternative remedy was famously proposed by Coase (1960): the government should promote bargaining among the affected individuals by ensuring that property rights are clearly defined and reducing transaction costs. In this case, given the global spatial scale and the intergenerational nature of climate change impacts, the Coasian bargaining solution is not likely to be a realistic option. However, another alternative, emissions trading in a cap-and-trade system, first suggested by Crocker and Wolozin (1966) and Dales (1968), which shares some similarity with Coase's idea, *is* likely to provide a realistic option for dealing with the externality associated with GHG emissions, as explained further below.

Thus, the economic concepts needed to deal with climate change were well understood by economists by about 1970. Moreover, since about that time, environmental issues began to assume a prominent place on the political agenda in the United States and other industrial nations, and the institutions of modern pollution control policy became established then. In the US, for example, the federal Environmental Protection Agency (EPA) was established in 1970, the Clean Air Act was passed in 1970, and the Clean Water Act was passed in 1972.

[18] To be sure, the interaction between the actor and the victim of his unintended consequences is less direct with greenhouse gas emissions than with, say, the emission of a toxic pollutant which is immediately harmful on inhalation. But, conceptually, the economic externality is the same.

6. Institutional Challenges

Greenhouse gas emissions involve a variety of pollutants: 84.3 % of GHG emissions in the US are emissions of carbon dioxide (CO2), 8% are emissions from methane (CH4), 5.8% are emissions from nitrous oxide (N2O) and the remainder come from various other gasses. Most of the CO2 emissions come from the combustion of fossil fuels, but about 3% of total emissions represent CO2 from sources other than fossil fuels. In terms of the sources of GHG emissions, California has a somewhat different pattern than the US as a whole. For the US overall, 33% of GHG emissions come from the generation of electricity; 27% come from transportation; 19% come from industrial sources; 8% come from agriculture and forestry; 7% come from the commercial sector; and 6% come from the residential sector. The major trend over time is an increase in the relative share from transportation. This is illustrated by the data for California which, in several ways, represents the future economic structure and life-style of many developed countries. 41% of the GHG emissions in California come from transportation, while only 20% come from electricity generation; 23% come from the industrial sector; 8% come from agriculture; 5% come from the residential sector; and 3% come from the commercial sector.

Because of the dispersion of emission, no single state or federal agency seems fully adequate for the task of managing GHG emissions across the breadth of the economy. In California, for example, the agency that, until recently was most heavily involved in monitoring statewide GHG emissions, the California Energy Commission, itself has no regulatory authority of any sort over these emissions. The regulatory agencies include the California Air Board, which since 2002 has been involved in managing GHG emissions from motor vehicles, and the California Public Utility Commission which has regulates investor-owned electric and gas utilities and has been involved since 2005 in enforcing a renewable portfolio standard and setting a carbon adder for new generating facilities and a GHG emissions cap, all for investor-owned utilities. As noted above, 23% of California's GHG emissions come from industrial facilities including petroleum refining and cement production, over which no existing agency has specific regulatory oversight. The remaining emissions come mainly from agriculture and waste facilities (landfills); these come under purview of California Department of Agriculture and the California Waste Management Board, but neither agency has any regulatory experience relating to GHGs.

In California, there has been political disagreement regarding which agency should have primary authority for implementing the new state law, passed in August 2006, which requires that, by 2020, total emissions of GHGs from all sources in California must be reduced to their level in 1990. One side (mainly the Democrats who control the legislature) prefers the California Air Resources Board; another (mainly the Republican Governor) prefers the California EPA, and agency more directly under the Governor's direct control, but one that has no existing in-house economic expertise (unlike the Air Resources Board or the Public Utility Commission). Looking beyond the specific political issues peculiar to California politics, the larger issue is likely to be a dilemma everywhere – whether to transform an existing environmental agency into a climate change agency, or to turn to other agencies with more direct experience in energy regulation.

7. EMISSIONS TRADING AND ITS PROPER ROLE IN CLIMATE POLICY

There is a growing recognition of the need to take some action to reduce GHG emissions; the question is: what type of action? Moreover, there is a growing awareness in the policy community of the potential role for emissions markets; the question is: how large is this role? We start with the second question and then proceed to a consideration of the first.

The idea of emissions trading – also referred to as a cap-and-trade system -- was first suggested by Crocker and Wolozin (1966) and Dales (1968). In this mechanism there is a cap on emissions – both a cap on overall emissions of all firms, and caps on the emissions of individual firms. But, firms are permitted to buy and sell emission permits, thus allowing their individual discharges to become different from the cap they were originally assigned. The aggregate level of emissions by all firms, however, always stays within the aggregate cap set by the government. The system therefore combines the features of a limit on the total quantity of emissions together with those of a price mechanism (emissions tax) which leaves individual firms free to determine their preferred level of emissions subject to the market incentive of a price associated with increased emissions. It has the efficiency property that it achieves the aggregate level of emissions set by the government at the lowest current aggregate cost.

It took more than 20 years before this system actually became a major component of US pollution control policy. This came about with the 1990 Amendments to the Clean Air Act, of which Title IV established a market for tradable sulfur dioxide (SO2) emissions by individual electric power plants. The policy objective was to reduce emissions by these plants from a level of about 19 millions tons of SO2 per year in 1980 to 9 millions by 2000. To achieve this goal, the 1990 Amendments created a cap on SO2 emissions which applied first to the largest and dirtiest electricity generating plants starting in 1995 (Phase I) and then, starting in 2000, to virtually all fossil-fueled plants (Phase II).

The SO2 trading program worked remarkably smoothly. It achieved what was a 50% reduction in emissions over 6 years, between 1995 and 2000, at less than half the cost than had been predicted when the legislation was being contemplated. A similar success was attained starting in 2004 with emissions trading for NOx emissions in 19 eastern states and the District of Columbia during the summer season. The NOx trading scheme has reduced emissions by 62%, from 1.5 million tons to 0.56 million tons, again at a much lower cost than had been anticipated before the program began.

The success of the SO2 trading program was highly influential in determining the inclusion of the Clean Development Mechanism in the design of the Kyoto Protocol and in the formation of the European Union Emission Trading System which commenced operation in 2005. It also served as the template for the Regional Greenhouse Gas

Initiative (RGGI) initiated in 2006 by nine states in the northeastern US which is intended to reduce CO_2 emissions by electric power plants in these states by 10% relative to their 2005 level by 2019. It is also widely regarded as a template for a national US policy to control GHG emissions.

Given the conceptual advantages of emission trading as seen from the perspective of economic theory and the practical success with emission trading in dealing with SO_2 and NO_x since 1995, how can there be any doubting its role as a centerpiece of GHG control policy? To answer this question, one needs to understand (1) how the reduction in SO_2 and NO_x emissions was accomplished, and (ii) the physical and engineering differences between SO_2 and NO_x as pollutants versus GHGs.

With SO_2, several strategies were used to bring about the reduction in emissions:

- Existing power plants
  - Modify combustion by switching from high- to low-sulfur coal.
  - Install a scrubber to remove emissions post- combustion
  - Change dispatch order to favor lower-emission plants
- New power plants
  - Fired by natural gas rather than oil or coal.

Analogous strategies – a mix of modification of combustion and post-combustion removal of pollutant from the effluent stream – were used in the case of NO_x.

These strategies are noteworthy for what was *not* done. Conservation and demand management played *no* role in attaining the emission reduction. Switching from fossil fuel to renewables (wind, solar, geothermal, etc) played *no* role in attaining the emission reduction. And, technological innovation played *no* role in attaining the emission reduction. For both SO_2 and NO_x, the post-combustion removal of pollutants relied on very well-understood and mature technologies (flue gas scrubbers, etc) that had been in use for over 20 years. Using natural gas instead of coal or oil was an even more mature technology. And, while there were some initial concerns about problems with slag if low-sulfur coal was used, these were quickly worked out by experimenting with the operation of the combustion process: no significant modification of equipment or investment in any new technology was required.

Indeed, it can be said that the cap-and-trade system worked extremely well because of the simplicity of required responses by plant owners and operators, and because no technological innovation was required, with attendant cost and performance uncertainties.

This does not bode well for GHG emission reduction. CO_2 is fundamentally different than SO_2. For CO_2 there is no good analog for the strategies used to reduce SO_2: Fuel switching is not such a major option because there is no low-CO_2 coal (co-firing with biomass can be done, but on a limited scale and the logistics are complicated).

Moreover, there is no post-combustion scrubber. Carbon capture and sequestration cannot be retrofitted to an existing power plant -- it requires a new plant.

Consequently, unlike with SO_2 and NO_x, the only significant way to reduce CO_2 emissions from *existing* coal-fired plants is to use them less. Hence, for CO_2 reduction the policy objective focuses more on *new* power plants and aims to influence their design rather than their operation. In particular, it is essential to ensure that, if new coal-fired plants are built, (1) they attain higher thermal efficiency than what is conventional now through technologies such as supercritical combustion or IGCC, and (2) they are designed from the beginning to be able to accommodate carbon capture and sequestration (CCS) once that technology has been refined and becomes available. Otherwise, what is needed in the electricity sector is an emphasis on (1) conservation and energy efficiency, and (2) the use of renewables to generate electricity

In short, with SO_2 and NO_x, the policy approach was to reduce emissions by modifying the functioning of the *existing* coal-fired fleet, and emission trading by power plant owners quickly attained this objective. The same strategy is unlikely to work for CO_2 because the existing power plants cannot do much to reduce their emissions. Compared to SO_2, dealing with CO_2 emissions calls for an entirely different strategy for electricity generation. The generating technologies that matter are *not* mature, namely: high thermal efficiency coal combustion, carbon capture and sequestration, and renewable energy technologies such as solar, wind, wave, and geothermal.

Furthermore, while a strategy targeted narrowly at power plant owners worked very well for SO_2 and NO_x, it cannot be similarly effective for CO_2. This is because, while electricity generation accounted for about two thirds of all SO_2 and NO_x emissions, it accounts for a much smaller fraction of CO_2 emissions – as noted earlier, it accounts for only one third of these emissions nationally in the US, and only one fifth in California. An emission control strategy targeted at electric power plants alone will be grossly inadequate.

The need to control a much broader swathe of the economy drastically changes the regulatory problem. In the US, emission trading worked quickly and effectively for SO_2 and NO_x because of the simplicity of dealing with a small number of actors – the owners and operators of power plants – who constituted a narrow, and relatively homogeneous, section of the economy. This is not going to be possible for CO_2 or other GHGs.

However, there is a lesson to be learned from the success of emission trading for SO_2 and NO_x that is applicable to GHGs. The cap in these trading systems is equivalent to a *performance* standard, as opposed to an input standard or a technology standard, which is the type of regulation that had been applied previously in air and water control policies in the US. However, a performance standard is economically more efficient than those types of standards – in fact, it is superior to *any* other type of standard. Therefore, the lesson for CO_2 regulation is that, however this is done, it should involve a performance standard focused on emissions rather than one based on technology.

8. TOWARDS A DESIGN FOR CLIMATE CHANGE POLICY

It is useful to restate the key policy objectives. The objectives underlying climate policy are importantly different than those that applied to air and water pollution when the modern legislation was being adopted in the early 1970s. With climate change, the scale of the emission reduction that is seen as being ultimately needed is significantly larger than was the case for air and water pollution – the figure being mentioned for developed countries is an ultimate reduction in GHG emissions of 60-80% *below* the level in 1990. Not only is the emission reduction much larger than with air and water pollution, but its implication is more dramatic – nothing less than a transformation requiring a substantial decarbonization of the economy. Whereas air and water pollution control may have required some new technologies for end-of-pipe-treatment, climate change requires new technologies for source reduction, a more profound and radical prospect.

Because of the ambitious objective for climate policy, it is essential to employ a phased approach to emission reduction. The initial goal for the EU, for example, was to reduce emissions to about 5% below the level in 1990, to be followed now by a reduction of 20-30% below the 1990 level by 2020, and be followed by further reduction(s) thereafter to attain the mid-century target. In California, which passed legislation last year, the first goal is to reduce emissions back to the 1990 level by 2020, and then, by mid-century, to reduce emissions 80% below the 1990 level (see Hanemann, 2008).

While there have been phased emission reductions in some other pollution control policies, the phasing for GHG reduction is far more substantial. Not only is the emission reduction more severe, but also the ultimate trajectory for emission reduction is still not determined and the policy instruments which will be required for later phases are not all yet known. Compared to conventional air and water pollution policy, GHG emission reduction is a more uncertain journey towards a more distant goal.

This has important implications for the design of emission reduction policy. It calls for the use of a variety of policy instruments, rather than a single instrument, to attain goals set for different points in time. For example, while existing technologies can go some way to reducing emissions, as indicated above new technologies for energy use and generation, and carbon capture and sequestration, will be required to meet the mid-century goal of a substantial decarbonization of the economy. Consequently, a policy that promotes the use of existing technology to reduce emissions, but not the development and adoption of new technologies, will not be sufficient to meet the goals for emission reduction later in the century.

This is relevant for several aspects of the current debate on the role of cap and trade as a tool for climate policy. One aspect is the admissibility of offsets: should emission reductions in other jurisdictions – for example, emission reductions secured in developing countries through the Clean Development Mechanism – count towards meeting one's quota under a cap and trade system? In the EU Emission Trading System, CDM offsets are expected to be included in the second phase, starting in 2008. In California, the question now being discussed is whether emission reductions in other US states or in other developed countries (e.g., the EU) should be permitted as offsets. The argument in favor of permitting these offsets is that this makes it possible to achieve a given level of emission reduction at the lowest possible cost. The argument against is that it does nothing in the long run to help decarbonize the California economy: paying to get a new Chinese factory to adopt a 1980s vintage production technology instead of a 1940s vintage technology lowers emissions in China but does nothing to move California towards a new 21st century low-carbon technology.

Another issue is which type of policy instrument -- emission trading or some alternative -- is likely to be most effective mechanism at promoting technological innovation. There is now quite a large theoretical economics literature, and a small empirical literature, on the effect of environmental regulation on technological innovation (for summaries, see Requate, 2005 and Jaffe, Newell and Stavins, 2003). Different theoretical analyses reach different conclusions depending on the assumptions made about the structure of the model, but a common finding is that an emissions tax does better than emission trading at promoting innovation, and emission trading does better than a standard regulating emissions. With a standard, for example, there may be deliberate or unintended technology lock-in, and once a firm is in compliance with the standard it gains no economic benefit from further innovation that would reduce its emissions below the standard. With an emissions tax or an emissions market, by contrast, the firm does stand to gain from additional innovation because this reduces the amount of emissions tax payment or allows the firm to sell unneeded emission permits for profit. Compared to an emission tax, with an emissions market there is some degree of price uncertainty that could discourage a risk-averse firm from investment in innovation; there can also be market power in an emissions market that reduces the degree of innovation relative to an emissions tax. Besides market power, the ranking of policy instruments is confounded by whether one assumes that the regulator modifies the instrument (lowers the emissions limit or cap, or raises the emissions tax) in response to technological innovation.

However, most of the existing theoretical literature makes one or both of two key assumptions that are, in fact, inappropriate for climate change. First, a large portion of the theoretical literature models a polluting firm as choosing between two given abatement technologies, one an existing technology and the other a new technology that has a fixed cost of adoption but offers some cost advantage once adopted. However, in the terminology of innovation, this is not invention but *diffusion*. The distinction, due originally to Schumpeter, is important and bears emphasizing. Schumpeter identified three stages in the process of technological change: invention, innovation and diffusion. Invention is the first development of a scientifically or technically new product or process, which may involve both basic and applied research; innovation is accomplished when the new product or process is commercialized, that is made available on the market; diffusion is when the product or process comes to be widely used through adoption by many firms or individuals. It should be clear that, in the case of climate change, invention and innovation are the core issue – the development and commercialization of technologies that do not exist yet or, at best, are still highly experimental (e.g., carbon capture and sequestration).

Also, it is the diffusion stage which provides the setting for a large portion of the empirical evidence on the relationship between environmental regulation and technological change. This diffusion stage is also what shows up in most of the empirical analysis of this relationship. One piece of evidence is the experience with SO2 and NOx trading: as noted above, what happened was not invention or innovation leading to the commercialization of new technologies but simply the diffusion of existing, mature ones. The same seems true of emission trading in 1982-87 in connection with the US phase down of lead in petroleum refining. The technology used, isomerization, was a mature one by the late 1970s, as indicated by the fact that the cost of isomerization equipment, which had fallen by about 40% in real terms between 1968 and 1975, stayed almost constant between 1980 and 1995 (Kerr and Newell, 2003); thus, there was neither invention nor innovation. Indeed, in the case of SO2 and NOx control technologies, Taylor (2007) shows that rate of patent issuance dropped off sharply once emission trading began.

Secondly, even where the theoretical literature explicitly considers invention (modeled as a choice of how much to invest annually in R&D),[19] it is generally assumed that the firm which does the invention is the same as the firm which causes pollution and invests in abatement. In fact, however, this is generally false: the vast majority of the inventers are not the polluters but rather machinery suppliers and other outside sources. Lanjouw and Mody (1996) estimate that machinery suppliers were the source of about 80% of the patents for the control of industrial air pollution, water pollution, oil spills, and the exploitation of non-fossil fuel energy sources. Taylor (2007) shows that electric utilities and oil companies accounted for only about 18% of the patents for SO2 control, while 82% of the patents are held by research institutions and, especially, other entities; with NOx control, oil companies, transportation companies and utilities account for only about 13% of the patents, while 87% of the patents are held by other entities.

The fact that different parties engage in invention, innovation and pollution abatement has an important implication for public policy because it creates the possibility of a type of market failure in a competitive market economy known as a *coordination problem*. There are multiple actors along the way from basic research to applied research, to pilot scale testing, to commercial scale testing, to marketing, to adoption and, for a new product or process to become successfully adopted, they need to coordinate their individual decisions in various ways. This is especially important if the product or process is costly and capital intensive to develop, commercialize, and adopt. The different agents' expectations must be in harmony for there to be a smooth progression from invention to diffusion. The polluting firm must be reasonably confident it can recoup the investment if it invests in an expensive new production process that lowers GHG emissions (e.g., carbon capture and sequestration). The equipment supplier,

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[19] The characterization of invention as a continuously increasing function of R&D expenditure via a conventional production function itself likely to be highly misleading for the technologies involved in decarbonization and carbon sequestration.

likewise, must be reasonably confident that there will be an industrial market before he invests in commercializing this product. And the venture capitalist must be reasonably confident that the product will be marketable if it is successfully commercialized before he finances the research and development effort. The coordination problem arises because each of the various actors does not know, or at least cannot be sure, of the others' expectations and intentions. Given the large time lag and uncertainty that will probably arise in getting from initial research to widespread adoption, the coordination problem is likely to be especially severe for many carbon control technologies. In this particular case, consequently, the price signal generated by a functioning carbon emission market is unlikely, by itself, to provide adequate coordination among the parties that need to be involved. Additional policy instruments will be required.

What are examples of such policies? In the literature on technological change, it is common to classify innovation promoting policies as either supply push or demand pull. Examples of supply push policies are research and development grants, subsidies, and tax breaks. Examples of demand pull policies are product subsidies, loan guarantees, regulations (for example, emission standards), and commitments by public agencies to purchase a substantial quantity of the product. Some combination of such policies will certainly be required.

9. CONCLUSION

Critical to effective climate policies will be the extent to which they induce (1) technological innovation, and (2) behavioral change by virtually every economic agent. More so than for any the pollutants dealt with in the past, the sources of GHG emissions extend across the entire economy. The diversity of sources, and their heterogeneity with regard to capital intensity, time lags for capital turnover, and economic and institutional structure mean that policymakers should employ a variety of policy strategies. The overall portfolio has to be effective for multiple sectors – not just electricity or heavy industry alone. Some sectors – for example, oil refining, cement production, several other heavy industries, and landfills -- will lend themselves well to an emission trading system because there is a good record of emissions and a limited number of entities to monitor. To deal with other sectors – transportation and agriculture may be important examples – emission regulation involving performance standards are likely to be more effective.

The required changes are more profound than can be achieved through an emission trading system alone, although emission trading certainly needs to be part of the portfolio of policy instruments. An over-reliance on carbon pricing could in fact increase costs because of an implicit overestimation in the effectiveness of price changes in driving behavioral change. Put differently, regulations help overcome market failures other than the GHG emission externality, and in this way can enable the capture of low cost reductions, in particular energy efficiency, which carbon pricing alone would miss. In addition to the need for a strong regulatory component, climate policy needs to be seen as a phased sequence of policies that play out over time, not as one policy set at a single point in time.

Our survey of policy developments in California finds a package of policies going forward that is very much in line with our thinking about an optimal package of policies, an extensive set of direct regulatory policy instruments with a broad carbon pricing element. Moreover, a similar approach is being taken the EU. It is heartening that we see the same best practices principle in the Waxman-Markey draft legislation that is currently the main subject on Capitol Hill. There are separate sub titles for clean energy and energy efficiency and one sub title for the cap-and-trade in their bill. It seems that Californians in position of power in Washington (Waxman, Boxer, Pelosi, Steve Chu, Nancy Sutley, Van Jones) are carrying the State's message to the federal level.

One interesting point of further commonality between CA and the EU is also in evidence in their willingness to commit unilaterally to relatively strong 2020 reductions, 20% below 1990 levels. While concerns are raised about potential competitiveness challenges about unilateral action and much attention is rightly focused on international cooperation – harmonized action is preferable – we also see an appetite for significant unilateral action. The reality is that much is being done by Chinese authorities too, in terms of policies to advance efficiency and renewable energy. These policies make sense as welfare enhancing measures even in the absence of global cooperation. Partly this is due to the multiple benefits of climate policies, in particular improved energy security, energy savings from efficiency investments, and collateral environmental benefits. Also, there is a sense that clean technology will be an important global market, and smart domestic policies will propel domestic firms to success in this marketplace. And of course, there is the intention of inspiring global cooperation.