California Leadership Strategies to Reduce Global Warming Emissions

DRAFT FOR REVIEW

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Background

Increasingly, policy makers, businesses, and the public are recognizing human-induced climate change as one of the great challenges of the 21st century. Emissions of heat-trapping gases and their resultant accumulation in the atmosphere threaten major, irreversible damage to human and natural systems. Stabilizing the climate and avoiding dangerous climatic change will require deep emissions reductions, on the order of 75%-85% in the long run.[1] By 2050, taking into account their historical contribution to the climate problem and their greater ability to finance the solutions, industrialized nations would likely need to reduce their emissions by 60%-80%.[2]

Momentum is growing globally and in the US for action on climate issues. The Kyoto Protocol will come into force in February 2005, committing most industrialized nations to binding targets through 2012 and to a long-term process aimed at far deeper reductions. Numerous states, localities, and businesses in the US have adopted their own emissions-reduction targets and actions. And the recent report of the bipartisan National Commission on Energy Policy calls for the establishment of mandatory national greenhouse gas (GHG) emissions limits.[3]

The state of California has been a historical leader on energy and environmental policy, and it is well-positioned to take a leadership role on climate. Relative to the rest of the U.S., California has lower emissions per capita and per dollar of gross state product owing to, among other issues, years of investment in renewable energy and energy efficiency. Its first-in-the-nation motor vehicle standards for greenhouse gas emissions could provide residents with billions of dollars in cost savings over the next two decades and could produce more emissions reductions than any other policy under serious consideration in the US today. However, far more actions are needed if the state is to proceed along a path consistent with climate stabilization and a vibrant, low-carbon economy.

California state agencies are actively discussing targets, timetables, and specific actions for reducing emissions of heat-trapping, or "greenhouse," gases. To inform policy development, they requested assistance to develop a preliminary assessment of future GHG emissions and opportunities to reduce them. One of the key uncertainties is how far and how fast emissions can be reduced while preserving—or perhaps even significantly enhancing—the robustness of California communities and economies. This analysis is intended to address some of this uncertainty by scoping out the potentially achievable emissions reductions from a limited number of available strategies.

From August to November 2004, we worked closely with staff members of the California Energy Commission (CEC), the Air Resources Board (ARB), the California Environmental Protection Agency, and other state agencies to review existing forecasts, identify strategies, and compile estimates of potential emissions reductions that are likely to be compatible with strong, long-term economic growth.[4] This report presents the methods, assumptions, and findings of this assessment.

Base Case Projections

California currently generates nearly 500 million metric tons of carbon-dioxide-equivalent ($MMtCO_2e$) emissions, an amount equal to 1.4% of global greenhouse gas emissions and 7% of U.S. emissions. Cars and trucks account for one-third of these emissions, and electricity use for about one-fifth. Other key emissions sources include freight and air transportation, fluorocarbons, natural gas use, land use change, farming practices, landfills, and cement production, among many others. The wide variety of emissions sources—and the potential for emissions removals by farm and forest "sinks"—present a host of challenges for policy makers and a multitude of opportunities for innovation throughout the California economy.

Under our base case projections, California GHG emissions are poised to grow to around 610 million metric tons by 2020, a 26% increase over 2000 levels and a 37% increase over 1990 levels.[5] This increase occurs even after accounting for a number of recently enacted policies, including the state's Renewable Portfolio Standard, which mandates the delivery of 20% of retail electricity from renewable resources by 2017; blending of ethanol in gasoline supplies; and the 2005 update of the state building standards. Without full implementation of these policies, the state's emissions could rise by another 18 $MMtCO_2e$ to 41% above 1990 levels by 2020. The expected rise in California emissions stands in contrast to the path of deep emissions reductions that may well be required to stabilize the climate and thereby avoid dangerous interference with human and natural systems, on the order of 75%-85% over time.

Strategies to Reduce Global Warming Emissions

California agencies, municipalities, and businesses are already pursuing, or contemplating, numerous strategies that could put the state on the path to declining emissions and a low-carbon economy. Many strategies, such as diesel anti-idling measures or an accelerated Renewable Portfolio Standard, are not directly motivated by climate concerns. Nonetheless, they could keep millions of tons of carbon dioxide (CO_2) and other greenhouse gases out of the atmosphere. Other strategies could explicitly target GHG emissions reductions, such as an electric sector or broader emission cap-and-trade system, or incentives for land managers to store carbon dioxide through tree planting and improved forest management. State agencies and others are looking at these and other options.

For this report, we identified the potential emissions impacts of a wide range of strategies. These strategies reflect opportunities for government and business as identified by state agencies or suggested by studies in other regions. While they touch on most key emission sources in the state, they are not intended as a comprehensive or ideal list of potential efforts.

Since implementation challenges vary widely, these strategies are grouped into three categories:

- *Strategies Recently Underway* have a relatively high degree of political achievability and should, with relative certainty, yield emissions reductions of roughly the magnitude estimated here. Many of these strategies, such as appliance efficiency standards, vehicle GHG standards, and diesel anti-idling measures, are already being pursued for their economic, health, and other benefits.

- *Strategies Under Consideration* are well-defined efforts that may require considerable political effort to implement or have greater uncertainties with respect to the level of emissions reductions they might produce. Many of these are new efforts that aim directly to reduce GHG emissions and position California businesses to prosper in a carbon-constrained world.
- *Long-term Strategies* are additional steps that could be taken to reduce emissions from specific sources and that would be motivated by deeper societal concerns for limiting climatic disruption. These strategies might require state-level policy mechanisms that have yet to be identified, new technologies, or federal or international action. Because they are more uncertain, the individual strategies are not listed here. Illustrative examples of such long-term strategies include improvements in light duty vehicle emissions per mile beyond what is embodied in the AB 1493 regulations (e.g., after the 2016 model year), jet fuel reduction measures, or reductions in vehicle-miles-traveled through smart growth practices.

As illustrated in Figure 1 and Table 1 below, we find that, by using a combination of these strategies, California can begin a path of declining emissions. The top line shows the emissions trajectory under base case conditions as it rises 37% from 1990 to 2020. Implementation of the strategies *Recently Underway* and *Under Consideration*—the two top slices shown—could mean state emissions would begin to decrease over the next few years. By 2010, California GHG emissions could return close to 2000 levels, and by 2020 they might drop to 8% above 1990 levels. With these strategies alone, the state could approach targets of returning GHG emissions to 2000 levels by 2010 and to 1990 levels by 2020. These targets would be "stretch goals", requiring some additional strategic efforts or helpful external factors (e.g. technological developments or federal actions) to reach these milestones..

Long-Term emission reduction strategies could provide the means to reduce 2020 emissions below 1990 levels, while paving the way for deeper emission reductions in future decades. We estimate that a set of long-term strategies could, in fact, reduce emissions to 9% percent below 1990 levels by 2020. (Analysis of long-term strategies is subject to ongoing review; descriptions of long-term strategies along with specific emission reduction estimates may be provided at a later date. Overall estimates for long-term strategies provided here are indicative, and based on preliminary analysis.[6]) This finding suggests that deeper reduction targets for 2020, such as the New England Governors/Eastern Canadian Premiers' goal of 10% below 1990 levels, might be achievable with sufficient political effort, especially if the base case projection turns out to be on the high end or if additional actions are taken at the national level.

While some strategies present net direct costs and others create net savings, overall they are likely to provide a significant economic benefit to California residents and businesses. The benefit is due to the large potential for cost-effective technology improvements that reduce electricity, natural gas, and gasoline bills. For example, the AB 1493 regulations are expected to deliver $13 billion in net present value savings to the state through 2020. Energy efficiency investments by utilities and consumers, as embodied in the California Public Utility Commission's energy savings goals, are also expected to yield billions of dollars in net present value (NPV) cost savings through 2020. Diesel anti-idling measures are projected to save

California businesses up to $575 million (NPV through 2013) as a result of fuel savings and reduced expenditure on diesel engine maintenance.[7]

This suite of strategies, while wide ranging, is far from exhaustive. Several key strategies already underway have not yet been quantified, including the green buildings initiative, hydrogen vehicles, and port and off-road equipment electrification. Other potential strategies may still be identified. Furthermore, experience suggests that emerging technologies—geological sequestration, for example—could provide emission reduction opportunities that currently cannot be foreseen.

Figure 1. GHG Emissions, 1990-2020: Impact of Strategies by Category

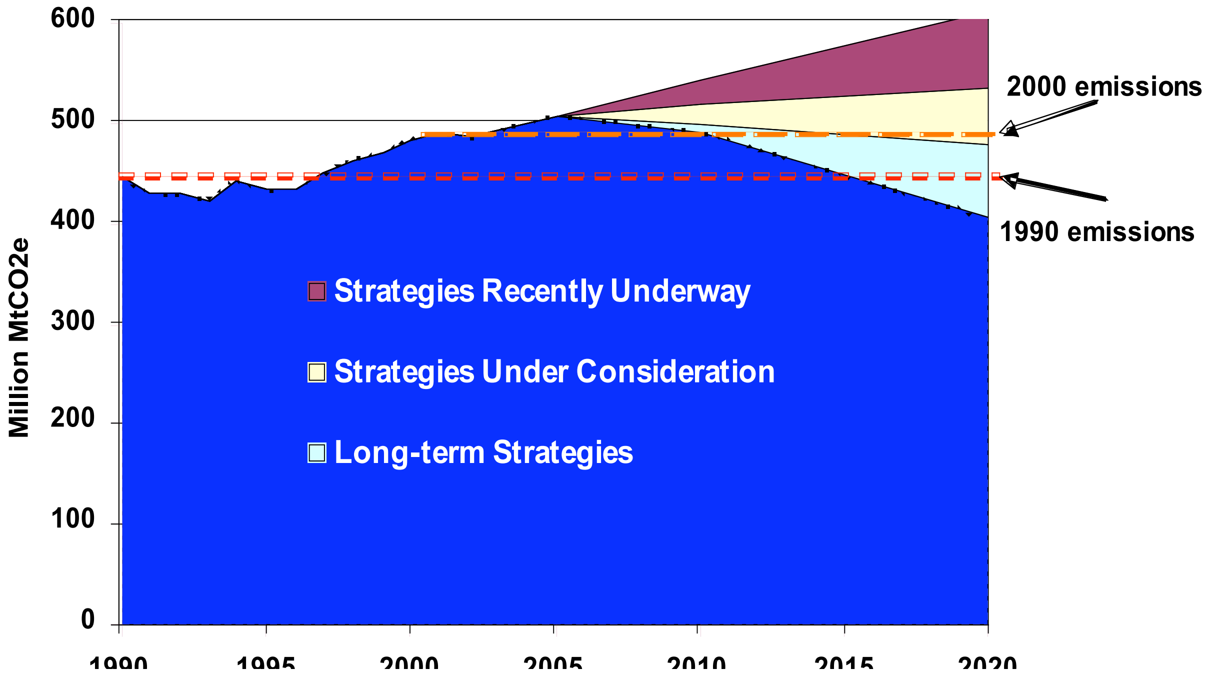

Table 1. California GHG Emissions (Including Electricity Imports)

(Million Metric Tons CO2e)	1990	2000	2010	2020
Base Case Projections	**446**	**483**	**542**	**610**
Increase relative to 1990 levels		*8%*	*22%*	*37%*
Impact of Strategies				
Strategies Recently Underway			(22)	(69)
Strategies Under Consideration			(21)	(61)
Long-term Strategies			(7)	(74)
Emissions after Strategies Underway and Under Conside	**446**	**483**	**499**	**480**
Increase relative to 1990 levels		*8%*	*12%*	*8%*
Emissions after Strategies	**446**	**483**	**492**	**406**
Increase relative to 1990 levels		*8%*	*10%*	*-9%*

Annex 1. Strategies Recently Underway

Strategies in this category have a relatively high degree of political achievability and should, with relative certainty, yield emissions reductions of roughly the magnitude estimated here. Many of these strategies, such as appliance efficiency standards, vehicle emissions standards, and diesel anti-idling measures, are already being pursued for their economic, health, and other benefits. The specific strategies and their emissions savings, as summarized in Table 2 below, include:

- **Vehicle GHG Standards (AB 1493/Pavley).** With the passage of AB 1493 in July 2002, California has moved to the forefront of improving vehicle GHG emissions. This bill requires the state to develop and adopt regulations that achieve the maximum feasible and cost-effective reduction of greenhouse gases emitted by passenger vehicles and light duty trucks. The California Air Resources Board released its analysis of proposed regulations in August 2004. The results shown here—emissions savings of 1 MMtCO2e by 2010 and 30 MMtCO2e by 2020—are drawn directly from the ARB report.[8] This report also suggests that fuel savings will more than offset the incremental costs of improved technologies, resulting in NPV savings of $13 billion through 2020.

- **CPUC Energy Savings Goals.** Since the 1970s, California utilities and state agencies have been at the forefront of demand-side efficiency programs. These programs have delivered a benefit to the state economy of $875 to $1,300 per capita since 1977.[9] The California Public Utilities Commission (CPUC) recently adopted the nation's most aggressive goals for electricity and natural gas efficiency program savings for the state's three major investor-owned utilities. These goals are based on recent studies that show the potential for continued significant increases in efficiency program activity and economic savings.[10, 11] If the goals are successfully reached, energy efficiency programs would yield savings of 444 million therms of natural gas and 23 billion kWh of electricity by 2013. These energy savings would translate to GHG reductions of about 4 MMtCO2e by 2010 and 8 MMtCO2e by 2020.

- **Accelerated Renewable Portfolio Standard (RPS).** California's RPS legislation requires that 20% of electricity sales by investor-owned utilities come from qualifying renewable resources by 2017. Most of the state's publicly owned utilities have adopted plans to meet or exceed the same target. The reference case reflects current plans and trajectories to meet these renewables goals.[12] For this strategy, we considered an accelerated RPS that would aim to deliver 20% of retail electricity sales from renewables by 2010 and 33% of sales by 2020, similar to the target suggested over a year ago by Governor Schwarzenegger.[13] Our analysis suggests that this accelerated RPS could reduce California GHG emissions by 1 MMtCO2e in 2010 and by 11 MMtCO2e in 2020.[14]

- **Landfill Methane Capture.** Methane emissions can be reduced through gas capture and use (or flaring) projects at landfills not currently slated for such controls. Although many of the landfills in California have implemented methane-recovery systems, or expected to do so in the next few years, other landfills still emit a considerable volume of methane-rich landfill gas. Further landfill-gas-capture actions are possible, especially at smaller landfills. We relied on a national US EPA study to estimate achievable emissions reductions of about 30%

at costs of less than \$5.5/tCO_2e (average cost of less than \$1/tCO_2e).[15] This estimate suggests that emissions reductions of about 6 MMtCO_2e are available in 2010 and 2020.

- **Appliance Efficiency Standards.** California has already shown leadership through the state appliance efficiency standards adopted in 2002. These standards have since been emulated in nearly a dozen other states. Further efficiency standards have been proposed by the California Energy Commission (CEC) for appliances not yet covered, including consumer electronics (reducing stand-by power use), pool pumps, general-service incandescent lamps, and commercial walk-in coolers and freezers. These new appliance standards are capable of reducing GHG emissions by 3 MMtCO_2e in 2010 and 5 MMtCO_2e in 2020.[16]

- **Fuel-efficient Replacement Tires and Inflation Programs.** Low-rolling-resistance tires and the maintenance of adequate tire pressure can reduce fuel consumption by 2%. This strategy comprises a public outreach campaign to maintain that tire inflation at manufacturer-suggested levels. In addition, a new tire rating system for rolling resistance could be instituted to influence purchasing decisions toward fuel-efficient replacement tires. The emissions-savings estimates—3 MMtCO_2e in 2010 and 2020—are based on CEC and CARB estimates.[17]

- **Solar PV Buildings Initiative.** For this analysis, we considered the emissions savings from programs that would encourage the construction of 1 million new solar homes within 13 years and provide commercial installations with rebates through 2007. Estimates by CEC staff that such programs would yield more than 3,000 MW of new PV installations by 2020 enabled us to estimate GHG savings of 0.4 MMtCO_2e in 2010 and 2 MMtCO_2e in 2020.

- **Diesel Anti-idling.** Reduced idling times and the electrification of truck stops can reduce diesel use in trucks by about 4%, with major air quality benefits. These benefits inspired the recently proposed CARB measure to limit diesel-fueled commercial motor vehicle idling.[18] Based on the CARB analysis, we estimate that anti-idling measures could yield 2 MMtCO_2e in GHG benefits by 2020.[19] CARB also estimates that the proposed measures would provide savings of up to \$575 million (NPV through 2013) to California businesses as a result of fuel savings and reduced engine maintenance costs.

- **50% Statewide Recycling Goal.** Currently, the state, on average, recovers 48% of its municipal waste streams through a wide range of community-based waste-reduction and recycling programs. The state has a statutory mandate for each jurisdiction to maintain a diversion of 50% of all waste from landfilling, through greater recycling in the residential, commercial, construction, and demolition debris sectors. To increase the statewide diversion from the existing 48% to the mandated 50%, steps could include, among others, expanding collection to multifamily buildings, adding organics collection, encouraging specialized recovery of inert materials from construction and demolition, and encouraging alternative collection methods such as community drop-offs. Based on initial estimates by the California Integrated Waste Management Board, by achieving the 50% recovery goal, California could avoid GHG emissions on the order of 3 MMtCO_2e in 2010 and 2020 from these actions.[20]

- **Green Buildings Initiative and Further Building Standards.** On December 14, 2004, Governor Schwarzenegger signed S-20-04, a Green Buildings executive order that sets a goal for state buildings to be 20% more energy efficient by 2015 and encourages the private sector to also meet this goal. The order states that this goal could be reached by measures that include, but are not limited to, ensuring that all new and renovated state buildings meet the LEED Silver designation and identifying the most appropriate financing and project-delivery mechanisms to achieve these goals.[21] The energy and emissions savings of green buildings, and of further improvements to the state building standards, have not yet been estimated.

Table 2. Estimated GHG Savings for Strategies Recently Underway (Million Metric Tons CO_2e)

Strategy	Sector	GHG Savings (MMtCO2e) 2010	2020	Description of Strategy
Strategies Recently Underway				
Pavley Vehicle Standards (AB 1493)	Light Duty Vehicle Improvements	1	30	Emissions savings from implementation of vehicle GHG regulations are based on August 2004 ARB staff report.
CPUC Energy Savings Goals 2006-2013	Building and Facility Efficiency	4	8	The state's three large investor-owned utilities achieve the energy savings goals adopted by the California Public Utility Commission in September 2004.
Accelerated Renewable Portfolio Standard	Renewable Energy	1	11	All retail electricity providers would deliver renewable resources (or tradable credits) equivalent to 20% of sales by 2010 and 33% of sales by 2020.
Landfill Methane Capture	Non-CO2 Gases and Other Sources	6	6	Methane emissions can be reduced through gas capture and use (or flaring) projects at landfills not currently slated for such controls.
Appliance Efficiency Standards	Building and Facility Efficiency	3	5	Standards are currently proposed for a dozen or so new appliances not currently regulated.
Fuel-efficient Replacement Tires and Inflation Programs	Light Duty Vehicle Improvements	3	3	Initiatives would encourage the purchase of low-rolling resistance tires and to maintain adequate tire pressure can reduce fuel consumption by 2%.
Solar PV Buildings Initiative	Renewable Energy	0.4	2	Rebate programs would encourage the construction 1 million new solar homes in 13 years, and commercial installations (rebates through 2007).
Diesel Anti-idling	Freight Transport, Air Travel, and Off-Road	1	2	Reduced idling times and use of truck stop electrification can reduce diesel use in trucks by about 4%, with major air quality benefits.
50% Statewide Recycling Goal	Strategies Recently Underway	3	3	Achieving the state's 50% recycling goal will reduce GHG emissions associated with energy-intensive material extraction and production, as well as methane emissions from landfills.
Green Buildings Initiative	Building and Facility Efficiency	not yet estimated		The Green Buildings executive order (S-20-04) sets a goal for state buildings to be 20% more energy efficient by 2015.
Total Strategies Recently Underway		**22**	**69**	

Annex 2. Strategies Under Consideration

Strategies Under Consideration are well-defined efforts that may require considerable political effort to implement or that may have greater uncertainties with respect to the level of emissions reductions they might produce. Many of these are new efforts that aim directly to reduce GHG emissions and position California businesses to prosper in a carbon-constrained world. The specific strategies and their emissions savings, as summarized in Table 3 below, include:

- **Electric Sector Carbon Policy.** Many political and industry leaders have proposed GHG emissions cap-and-trade programs as a market mechanism to efficiently achieve the lowest-cost reductions in GHGs from power plants and major industrial emissions sources.[22] GHG trading policies can tap all options to reduce emissions: not just demand-side efficiency and renewable energy as in the strategies described previously, but also fuel switching from coal to gas, increased efficiency in fossil-fueled power generation, and ultimately, carbon capture and storage. These policies can achieve economic efficiency through emissions trading, create market signals that stimulate technology development, and position California businesses to compete more effectively in an increasingly carbon-constrained world. To generate indicative results, we estimated the impact of a carbon cap-and-trade system for the electric sector with permit prices of \$20/tCO2e.[23] Our modeling analysis suggests that, if coupled with the efficiency, renewables, and CHP strategies analyzed here, an electric-sector carbon policy could achieve a 50% reduction in electricity-related GHG emissions by 2020 relative to 2000 levels, at permit prices of \$20/tCO2e across the next 15 years. The electric sector carbon policy, as modeled here, reduces GHG emissions of 5 MMtCO2 in 2010 and 16 MMtCO2 in 2020, beyond the reductions that would result from the efficiency, renewables, and CHP strategies alone.

- **Extending CPUC Energy Savings Goals to 2020.** The current CPUC energy savings goals for investor-owned utilities run through 2013. In principle, there is no reason that similar levels of energy efficiency program activity could not continue beyond 2013 -- experience suggests that new energy savings opportunities continue to be found over time. Assuming that the CPUC energy savings goals could be extended beyond 2013 at savings levels similar to the approved goals through 2013, additional GHG reductions of 6 MMtCO2e by 2020 could be achieved.

- **Additional Energy Efficiency Programs.** While the CPUC energy savings goals are indeed ambitious, the studies underlying these goals suggest that the achievable and cost-effective potential for efficiency programs may be even greater.[24, 25] Furthermore, these goals do not currently cover public utilities and direct access electricity providers that deliver over one-third of the state's electricity.[26] We estimate that capturing these additional sources of energy savings could yield emissions reductions of 1 MMtCO2e in 2010 and 7 MMtCO2e in 2020, as well as billions in cost savings.

- **Zero Waste and High Recycling Programs.** California communities have the potential to recover well over 50% of municipal waste streams, through a variety of approaches. One such approach is the use of waste conversion technologies that can transform difficult-torecycle biomass and plastic wastes into marketable products, while also enhancing the recovery of recyclables. Based on initial estimates by the California Integrated Waste Management Board, additional zero waste and recycling programs could avoid GHG emissions on the order of 3 $MMtCO_2e$ in 2020.

- **Combined Heat and Power Initiative.** From half to two-thirds of the energy used for fuel-based electricity generation is typically lost as waste heat. Combined heat and power (CHP) systems capture this waste heat and supply it to a facility's process or building heat requirements and can thereby approximately double the overall efficiency of fuel use to around 80%. We estimate that a range of strategies to increase use of CHP could yield GHG emissions savings totaling 1 $MMtCO_2e$ in 2010 and 5 $MMtCO_2e$ in 2020.[27]

- **HFC Reduction Efforts.** Hydrofluorocarbons, or HFCs, the predominant substitute for ozone-depleting substances in cooling and refrigeration equipment, may represent the GHG emissions source with the most rapid rate of growth in California. We derived estimates of achievable emissions-reductions opportunities and their costs from a national US Environmental Protection Agency report.[28] We adjusted to California conditions by accounting for the industries in California and avoiding double-counting with other strategies in our analysis, and estimated potential emissions reductions of 18%, relative to the base case, at costs up to $7/$tCO_2e$. This set of measures would reduce GHG emissions by about 3 $MMtCO_2e$ in 2010 and 5 $MMtCO_2e$ in 2020.

- **Biodiesel Blend.** Biodiesel is a renewable diesel fuel substitute that can be produced from naturally-derived oils and fats. Accounting for the energy used to grow feedstocks and manufacture it, biodiesel offers a net life-cycle GHG emissions reduction of about 78% relative to diesel (on a Btu basis).[29] For this analysis, we considered biodiesel blending at a rate of 2% in all on-road diesel by 2010 and a rate of 20% by 2020, which would require major increases in available supply, and a successful use of various oil-seed feedstocks. Low blends of biodiesel can be used in typical internal combustion diesel engines without any modifications.

- **Industrial Carbon Policy.** California's industrial sector emits about two-thirds of its fossil fuel CO_2 emissions on-site.[30] Studies suggest that many industries have significant opportunities for cost-effective fuel savings, and where management has made energy and emissions reductions a clear goal, manufacturers have been able to make major strides.[31] An ACEEE study showed that industries nationally could save money while reducing oil use by 14%, gas use by 11%, and coal use by 29% over 15 years, through a range of initiatives to motivate and assist industries to exploit energy efficiency opportunities.[32] There are several options for tapping the potential for reducing direct fuel use and other GHG emissions in industry: inclusion in a cap-and-trade system, negotiated emissions-reduction agreements, or other incentives and measures. For this analysis, we considered the cost-effective industrial fuel-use reductions as identified in the ACEEE study noted above,[33] on the assumption that an industrial carbon-emissions policy, such as a cap-and-trade system, could be designed to capture them.

- **Semiconductor Industry Targets.** The Semiconductor Industry Association has committed to a voluntary goal of reducing its perfluorocarbon emissions to 10% below 1995 levels.[34] According to rough data available on these emissions levels, we estimate that maintaining the SIA goal through 2020 would reduce emissions by 2 MMtCO_2e by 2010. We assume this cap on emission will be maintained to 2020. This leads to emissions reductions, relative to the base case, of 2 MMtCO_2e in 2010 and the same reduction level in 2020.

- **Afforestation of Rangelands**. A Winrock/CEC study closely examined the suitability of different California lands for reestablishing forests.[35] The study found that the conversion of California rangelands into forests could sequester over 5 billion metric tons of CO_2 over an 80-year horizon, at prices up to \$5.5/tCO_2. This measure uses the assumption that about half the identified potential activities costing less than \$2.7/tCO_2e could be implemented; afforestation activities would take place on about 100,000 acres statewide. The resulting emissions removals total 2 MMtCO_2e in 2020.

- **Manure Management.** Methane emissions, along with noxious odors, can be reduced through the use of biogas digesters, which can also produce energy for heating or electricity applications, and can produce valuable soil amendments that increase soil fertility and productivity.[36] Over two dozen dairy farms have applied for digester support under a CEC matching-grant program; the potential is far greater. Absent California-specific analysis of manure management,[37] we rely on a US EPA study[38] that indicates the potential for a 15% reduction at a net economic benefit, a 20% reduction in emissions at marginal costs of \$5.5/tCO_2e (average costs of \$0.3/tCO_2e). We used the EPA analysis to estimate a potential for 1.3 MMtCO_2e in emissions reductions in 2010 and 2020.

- **Conservation Tillage/Cover Crops:** Low and no-till cultivation not only limits soil erosion and cuts tillage costs but can also increase carbon storage in soils and yield near-term sequestration benefits. In other regions of the US, conservation tillage has proven profitable for farmers. According to a draft analysis by Winrock for the CEC, the most likely crops for which conservation tillage could be most readily applied are tomatoes, cotton, beans, and corn: crops grown extensively in the Central Valley, as reflected in the estimate sequestration by county shown.[39] We reduced the Winrock estimates by 50% to develop an illustrative estimate of 2 MMtCO_2e in annual emission reductions in 2010 and 2020.

- **10% Ethanol Blending in Gasoline.** The ethanol content of gasoline can be increased from its current 5.7% to 10% without any engine problems. Precise GHG benefits and local air emissions impacts are uncertain. We use an estimate of 27% life-cycle GHG emissions reductions relative to gasoline (on a Btu basis).[40] Cellulosic ethanol—manufactured from agricultural residues, forest and mill wastes, or short-rotation woody crops—offers significantly greater life-cycle GHG emissions savings, on the order of 79% relative to gasoline, depending on the feedstock.[41] However, processes to produce cellulosic ethanol are still under development; thus we assume that cellulosic ethanol enters the fuel market only in 2011, climbing to 20% of the ethanol market by 2020.

- **Reducing Methane Leaks and Venting in Oil and Gas Systems.** Producing, processing, transporting, and distributing oil and natural gas can lead to the leakage and venting of methane.[42] The US EPA, working with the natural gas industry, has identified opportunities to reduce these methane emissions, 33% of which can be reduced with net cost savings.[43] Applying these estimates to California suggests that emissions reductions of 1 MMtCO2e are possible in 2010 and 2020, at a net economic benefit.

- **Blended Cement.** The use of clinker—a key binding component in cement that releases CO_2 in its manufacture—can be reduced through substitution of fly ash and other substances. So-called "blended cement" can face market barriers because it takes longer to set; however, it often yields a stronger and otherwise superior product. As an illustrative calculation, we considered the option of increasing the use of blended cement or otherwise reducing the clinker fraction in cement by 5%, on average, statewide, by 2020. This would reduce GHG emissions by 0.1 MMtCO2e in 2010 and 0.3 MMtCO2e in 2020.[44]

- **Longer-rotation Forestry.** Extending the average harvest cycle by five years or more can increase average carbon storage, increase overall wood product yield, and provide ancillary environmental benefits. However, the cost of carbon sequestration from changing forest-management practices is relatively high. The Winrock /CEC analysis referred to above suggests that a cumulative 3.5 MMtCO2e could be sequestered through extended rotations on 310,000 acres at costs of up to $14/tCO2e. Assuming that half of this amount could be readily achieved, the net removals in 2020 come to about 0.2 MMtCO2e.

- **Transport Refrigeration Units, Off-road Electrification, Port Electrification (Ship to Shore).** There are opportunities to reduce diesel and gasoline use in dozens of applications, with resulting local air pollution benefits. A briefing by the California Electric Transportation Coalition suggests the potential to reduce fuel use by 100 to 200 million gallons per year from a variety of off-road electrification technologies.[45] This would translate to about 1 to 2 MMtCO2e in emissions reductions; however, since the electricity requirements are unclear, we were unable to calculate the net savings and thus did not include an estimated reduction in the overall results.

- **Hydrogen Vehicles.** Hydrogen fuel-cell vehicles may offer major emissions savings after 2020, especially if hydrogen is produced from low-GHG sources. The GHG benefits of hydrogen will depend greatly on the feedstocks and processes ultimately used to make it (from renewables to coal, with or without carbon capture and storage), deliver it (electricity and gas networks and/or a new hydrogen delivery infrastructure), and use it (direct use of hydrogen or on-board re-forming of fossil fuels). Since the focus of this analysis is on the period up to 2020, and most hydrogen analysts view a major hydrogen transition in the longer term, we did not analyze a hydrogen scenario specifically.

Table 3. Estimated GHG Savings for Strategies Under Consideration (Million Metric Tons CO_2e)

Strategy	Sector	GHG Savings (MMtCO2e) 2010	GHG Savings (MMtCO2e) 2020	Description of Strategy
Strategies Under Consideration				
Electricity Sector Carbon Policy	Electricity/Industry Carbon Policy	5	16	The state would implement a carbon cap and trade system or other market mechanism to encourage low-carbon electricity. Results shown for regional cap & trade with permit price of $20/tCO2. Switching all of CA coal sources, including out-of-state, to natural gas would save 30-40 MMtCO2e.
CPUC Energy Savings Goals extended to 2020	Building and Facility Efficiency	0	6	CPUC Energy Savings Goals are extended beyond 2013, assuming similar annual savings targets.
Zero waste/high recycling Strategies	Non-CO2 Gases and Other Sources	0	3	Efforts to exceed the 50% goal could include the use of conversion technologies that transform biomass and plastic wastes into marketable products.
Additional Efficiency Programs	Building and Facility Efficiency	1	7	Additional programs and incentives capture achievable cost-effective gas and electric efficiency savings beyond CPUC goals, including additional efforts by public utilities and direct access providers.
Combined Heat and Power Initiative	Building and Facility Efficiency	1	5	Barrier removal and incentive programs can increase the penetration of CHP (cogeneration) systems in industrial and commercial sectors.
HFC Reduction Strategies	Non-CO2 Gases and Other Sources	3	5	Savings are possible through a variety of incremental measures, such as leakage reduction or use of alternate HFCs.
Biodiesel blend	Alternative Vehicle Fuels	0.4	5	Biodiesel would be blended at a rate 2% in all on-road diesel by 2010 and a rate of 20% by 2020, which would require major increases in available supply, and successful use of various oil seed feedstocks.
Industrial Carbon Policy	Electricity/Industry Carbon Policy	2	4	Cost-effective reductions in fossil fuel use can be achieved via carbon emission standards, voluntary commitments, or point source carbon cap & trade.
Semi-conductor industry targets (PFC emissions)	Non-CO2 Gases and Other Sources	2	2	This reduction level is consistent with the stated goal of Semiconductor Industry Association to reduce emissions 10% below 1995 levels by 2010.

Strategy	Sector	GHG Savings (MMtCO2e) 2010	2020	Description of Strategy
Strategies Under Consideration				
Afforestation of rangelands (Tier 1)	Farms and Forests	0	2	Conversion of rangelands typically used for grazing into forests could theoretically sequester up to 5 billion metric tons of CO2 over an 80 year time horizon.
Manure Management	Farms and Forests	1	1	Methane emissions, along with noxious odors, can be reduced through the use of biogas digesters, which can also produce energy for heating or electricity applications.
Conservation tillage/cover crops	Farms and Forests	2	2	Agricultural management practices, selectively applied, can increase carbon stored in soils, while improving soil quality and fertility and reducing erosion.
10% Ethanol Blending in Gasoline	Alternative Vehicle Fuels	1	1	The ethanol content of gasoline can be increased from its current rate of 5.7% to 10%. Precise GHG benefits and local air emission impacts are uncertain.
Reduced Venting and Leaks in Oil and Gas Systems	Non-CO2 Gases and Other Sources	1	1	Strategies can reduce methane lost to the atmosphere in oil and gas production, processing, transmission, and distribution.
Increased Use of Blended Cement	Non-CO2 Gases and Other Sources	0.1	0.3	Decreased use of clinker via substitutes (e.g. fly ash) or other means can reduce direct CO2 emissions from cement use as well as the energy used to produce cement.
Increase riparian buffer zones	Farms and Forests	0	0.2	Extending buffer (no-cut) zones around riparian areas can increase carbon storage while providing improved habitat.
Longer rotation forestry	Farms and Forests	0	0.2	Extending the average harvest cycle by five years or more can increase average carbon storage, increase overall wood product yield, and provide ancillary environmental benefits.
Green Buildings Initiative	Building and Facility Efficiency	not yet estimated		Incentives or further building standards can encourage designs with significantly lower energy use and other sustainability benefits. Long-term savings potential could be significant.
Hydrogen Vehicles	Alternative Vehicle Fuels	not yet estimated		Hydrogen fuel cell vehicles may offer major emissions savings after 2020, especially if hydrogen is produced from low-GHG sources.
Transport refrigeration units, Off-road electrification, Port electrification (ship to shore)	Freight Transport, Air Travel, and Off-Road	not yet estimated		Dozens of opportunities from lawn mowers to ships, with significant local air pollution benefits.
Total Strategies Under Consideration		**21**	**61**	

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ADDENDUM

Approach to Estimating Emissions and Emissions Reductions

We prepared this analysis in close consultation with California agencies, in particular the staffs of the Energy Commission (CEC) and Air Resources Board (ARB). Wherever possible, we identified strategies and drew estimates of emissions, emissions savings, costs, and other variables from agency reports and suggestions. Where state level estimates were unavailable, we looked to local (e.g., solid waste management), regional (e.g., electric sector carbon policy), or national sources (e.g., non-CO_2 emissions strategies). We presented initial findings to CEC and ARB staff in meetings held in September and October 2004. This report reflects a number of their inputs and improvements.

In most cases, we followed the same approach to emissions accounting used by the CEC in its state emissions inventory.[46] We look more closely at the emissions associated with electricity generated out of the state to meet California's demands. We include these out-of-state emissions in this analysis for three reasons. First, California's electricity demand is responsible for such emissions. Second, they are significant, equal to about one-tenth of the state's emissions. And finally, the state can take several actions—increasing efficiency, using renewable energy, and implementing carbon policies—that might reduce those emissions. California stakeholders should closely consider the question of whether and how to count GHG emissions from imported electricity in setting and tracking an emissions target. A number of other accounting questions also need to be resolved, such as the treatment of transportation fuels used out of state and for international travel.

There are important interactions among strategies that make assigning precise emissions reductions to individual strategies rather difficult. Efficiency, renewable, and combined heat and power (CHP) resources, for example, all reduce the need for conventional fossil-fuel-based electricity generation. Our analytical approach considers the combined impact of these policies on the need for such electricity generation; we then allocate a portion of the overall emissions reductions to the individual strategies. For other fuels, we evaluate the strategies in sequential order. Therefore, strategies lower down the list, such as alternative vehicle fuels, yield fewer emissions reductions than they would if they were evaluated first. Similarly, several of these policies, such as the utility carbon policy, the Renewable Portfolio Standards, and alternative vehicle fuel strategies, would produce significantly greater emissions reductions than shown here were they considered in the absence of other strategies (e.g., efficiency programs and vehicle standards) that eliminate some of the emissions they would otherwise address.

ENDNOTES

[1] According to the New England Governors and Eastern Canadian Premiers' *Climate Change Action Plan 2001*, "over the long term, anthropogenic GHG emissions must be reduced to levels that no longer pose a dangerous threat to the climate. The best science available at present indicates that attaining this goal will require reductions in GHG emissions of approximately 75–85% below current levels." http://www.negc.org/documents/NEG-ECP%20CCAP.PDF.

[2] Two studies on climate change commissioned by the German Bundestag indicate that a GHG emissions reduction of 80 % by 2050 is needed to stabilize the climate. www.bmu.de/files/broschuere_climatechange_policy.pdf. Based on its assessment of the science, the UK has committed to a target of reducing its GHG emissions to 60% below 1990 levels by 2050, and has acknowledged that even deeper cuts may be needed. http://www.dti.gov.uk/energy/whitepaper/ourenergyfuture.pdf. The Oregon Governor's Advisory Group on Global Warming Oregon recently adopted a 2050 goal of achieving a "climate stabilization" level at least 75% below 1990 levels. http://www.energy.state.or.us/climate/Warming/Report/GWPlan.pdf.

[3] www.energycommission.org.

[4] In June and July 2005, we received further input from various agencies, including the California Waste Management Board, and the California Public Utilities Commission, and others. .

[5] Relying heavily on the CEC's most recent projections of electricity and fuel use, we developed a base case projection of energy use and emissions through 2020. This base case assumes a continuation of current trends and reflects the implementation of a number of recently enacted policies. These policies include energy-savings targets based on a September 2004 California Public Utilities Commission (CPUC) decision, the current state Renewable Portfolio Standard (under which renewable resources provide 20% of California's electricity by 2017), 5.7% ethanol blending in gasoline supplies (as of 2003), and the 2005 Building Standards. (We do not include policies that have not yet been fully adopted, such as the vehicle GHG standards.) Therefore, it is important to recognize that the base case itself already embodies several powerful emissions-reducing strategies, and their full implementation will be essential to achieving overall reductions in state emissions.

[6] Our December 2004 draft analysis originally included a more detailed assessment of individual long-term strategies and their emissions reduction potential. This analysis was prepared for internal use by CalEPA, who determined that the long term strategies require further consideration by the Climate Change Action Team. Given a variety of perspectives about which individual strategies to pursue, and the associated emission reduction they might yield, CalEPA requested that the individual long-term reductions strategies not be presented in this report.

[7] Adoption of the Proposed Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling, Staff Report, ARB, July 22, 2004. http://www.arb.ca.gov/regact/idling/idling.htm

[8] California Environmental Protection Agency Air Resources Board, 2004. *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles,* August 6. http://www.arb.ca.gov/regact/grnhsgas/isor.pdf.

[9] Bernstein, M., et al., 2000. *The Public Benefit of California's Investment in Energy Efficiency*, prepared for the CEC, Rand report MR-1212.0-CEC, http://www.rand.org/publications/MR/MR1212.0/.

[10] *California Statewide Commercial Sector Natural Gas Energy Efficiency Potential Study*, Fred Coito and Mike Rufo, Kema-Xenergy, for PG&E, July 2003. *California Statewide Residential Sector Energy Efficiency Potential Study*, Fred Coito and Mike Rufo, Kema-Xenergy, for PG&E, April 2003. *California Statewide Commercial Sector Energy Efficiency Potential Study*, Fred Coito and Mike Rufo, Kema-Xenergy, for PG&E, July 9, 2002. *California Industrial Market Characterization Study*, Xenergy, for PG&E, December 2001.

[11] CPUC Decision 04-09-060.

[12] The reference case renewables trajectory is drawn from Appendix A of the CEC Draft White Paper, "Accelerated Renewable Energy Development", June 30, 2004. The scenario used (Scenario 7) includes known growth and procurement plans for renewable resources, and a minimum of 1% per year increase in the renewables sales fraction, as needed to get to 20% by 2017.

[13] Governor Arnold Schwarzenegger's Action Plan for California's Environment, Final Draft, November 9, 2003.

[14] The relatively low level of savings in 2010 reflects the expectation that California utilities will be close to providing 20% of sales from renewables even in the reference case. See endnote 12.

[15] Emissions reductions are based on Table 6, US EPA, 2001*b. Addendum to the U.S. Methane Emissions 1990-2020: 2001 Update for Inventories, Projections, and Opportunities for Reductions*. http://www.epa.gov/methane/projections.html.
[16] Electricity and gas savings are based on CEC, 2004. *Update of Appliance Efficiency Regulations,* November. http://www.energy.ca.gov/reports/2004-11-30_400-04-007F.PDF. CEC, 2004. *Appliance Standards 2004 with Lifecycle Costs,* September. Our estimates assume the appliance standards are in force on January 1, 2006, and are set at the highest tier identified in the report for each appliance. .
[17] See Appendix C of CEC/ARB, 2003.
[18] Adoption of the Proposed Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling, Staff Report, ARB, July 22, 2004. http://www.arb.ca.gov/regact/idling/idling.htm.
[19] This figure is net of added electricity use at truck stops.
[20] Some of these reductions will occur outside California. These estimates include emissions reductions associated with changes in industrial production when using recycled rather than virgin input. For example, using recycled aluminum cans rather than virgin ore reduces energy for production by 95%, leading to overall emissions reductions of about 14 MtCO2e per million tons of cans recycled.
[21] http://www.dot.ca.gov/hq/energy/ExecOrderS-20-04.htm. *LEED* refers to the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) green building rating system.
[22] For example, see the Climate Stewardship Act, or the recommendations of the National Commission on Energy Policy (http://www.energycommission.org). Nine Northeastern states, through the Regional Greenhouse Gas Initiative, are already moving to design and implement a regional cap-and-trade system, initially for electricity sources.
[23] Tellus, 2004. Specifically, we modeled a scenario in which permit prices reach $20/tCO2e in 2020 across the Western Electricity Coordinating Council (WECC) region. This approximates the impact of a California cap that covers CO_2 from imported electricity as well as from in-state electricity generation, a so-called "load-based cap." The WECC stretches from the West Coast to parts of Montana, Wyoming, Colorado, and New Mexico.
[24] *California Statewide Commercial Sector Natural Gas Energy Efficiency Potential Study*, Fred Coito and Mike Rufo, Kema-Xenergy, for PG&E, July 2003. *California Statewide Residential Sector Energy Efficiency Potential Study*, Fred Coito and Mike Rufo, Kema-Xenergy, for PG&E, April 2003. *California Statewide Commercial Sector Energy Efficiency Potential Study*, Fred Coito and Mike Rufo, Kema-Xenergy, for PG&E, July 9, 2002. *California Industrial Market Characterization Study*, Xenergy, for PG&E, December 2001.
[25] CPUC Decision 04-09-060.
[26] Estimates of additional achievable electricity savings were drawn from a CEC scenario in which state per capita electric use decreases by 0.3% per year. Messenger, M. 2003. *Discussion of Proposed Energy Savings Goals For Energy Efficiency Programs In California*, Energy Efficiency and Demand Analysis Division California Energy Commission. Estimates of additional natural gas savings were based on discussions with CEC staff, and assume that 20% of the maximum achievable cost-effective savings (beyond the energy savings goals) could be achievable.
[27] To get a rough sense of overall achievable CHP potential, we looked at the market for California CHP identified in a US Department of Energy market potential study, Onsite Sycom Energy Corporation, *The Market and Technical Potential for Combined Heat and Power in the Industrial Sector*, and *The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector*, both prepared for the USDOE EIA, January 2000. We applied judgment to limit the total potentials achievable by 2020 to a fraction of that indicated in the studies (1,900 MW industrial and 700 MW commercial).
[28] US Environmental Protection Agency, 2001a*. US High GWP Emissions 1990-2010: Inventories, Projections and Opportunities for Reductions.* http://www.epa.gov/highgwp/projections.html.
[29] Actual savings will be highly dependent on the biodiesel feedstock use—waste oil, soybeans, brassica crops, or others. Sheehan, J., et al., 1998. *An Overview of Biodiesel and Petroleum Diesel Life Cycles*, A joint study by the U.S. Department of Energy, National Renewable Energy Laboratory, and the U.S. Department of Agriculture, Office of Energy. May 1998. http://www.afdc.doe.gov/pdfs/3812.pdf.
[30] In addition, cement production emits significant quantities of CO_2 from the processing of limestone.
[31] For example, Lafarge, the world's largest cement manufacturer, has committed to reduce greenhouse gas emissions 10% below 1990 levels by 2010. Polaroid has made the commitment to reduce CO2 emissions 25% below 1994 levels by the year 2010.
[32] American Council for an Energy-Efficient Economy (ACEEE) study, *Smart Energy Policies: Savings Money and Reducing Pollutant Emissions through Greater Energy Efficiency* (Nadel and Geller, 2001).

[33] These reductions addressed only coal and oil use, since natural gas efficiency gains are fully addressed through the CPUC goals and additional savings described in the previous section.
[34] http://www.epa.gov/highgwp/semiconductor-pfc/mou_files/mou.pdf.
[35] Brown, S., et al., 2004. *Carbon Supply Curves for Forest, Range, and Agricultural Lands of California,* Winrock International for the CEC Public Interest Energy Research Program.
[36] http://www.suscon.org/dairies/methanedigesters.asp.
[37] Analysis of this and other non-CO_2 emissions-reduction options is currently under way at the CEC.
[38] US Environmental Protection Agency, 1999.
[39] Brown, S., et al., 2004. *Carbon Supply Curves for Forest, Range, and Agricultural Lands of California,* Winrock International for the CEC Public Interest Energy Research Program.
[40] Wang, M., Saricks, C., and Santini, D., 1999. *Effects of Fuel Ethanol Use on Fuel-Cycle Energy and Greenhouse Gas Emissions,* Argonne National Laboratory, ANL/ESD-38.
[41] Wang, M., Saricks, C., and Santini, D., 1999. *Effects of Fuel Ethanol Use on Fuel-Cycle Energy and Greenhouse Gas Emissions,* Argonne National Laboratory, ANL/ESD-38
[42] In 2000, California oil and gas systems are estimated to have emitted 2.2 MMtCO_2e, and these emission levels are projected to remain fairly constant through 2020, according to draft non-CO_2-emission projections under preparation by ICF for the California Energy Commission.
[43] US Environmental Protection Agency, 1999. *Report on U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions* (EPA 430-R-99-013).
[44] For every tCO_2e from clinker reduced, another tCO_2e from energy requirements is reduced, based on EPA figures.
[45] California Electric Transportation Coalition, 2004. "Briefing on Electric Transportation Technologies: Zero Emissions, Reduced Energy and Operating Costs, Increased Flexibility for California Business," PowerPoint presentation, August.
[46] California Energy Commission, 2002. Inventory *of California Greenhouse Gas Emissions and Sinks: 1990-1999.* http://www.energy.ca.gov/reports/600-02-001F, Report #600-02-001F.