26 California's energy-related greenhouse gas emissions reduction policies

David R. Heres and C.-Y. Cynthia Lin

26.1. INTRODUCTION

Global climate change is expected largely to disrupt physical and biological systems during the second half of the twenty-first century (Parry et al., 2007). Anthropogenic greenhouse gas (GHG) emissions have long been identified as the drivers of such change and, unless societies prove capable of curbing the continual rise in the concentration of those gases in the atmosphere, the costs of adaptation and of the increased risk of catastrophic events occurring will be large.[1]

In the absence of federal policies to abate GHG emissions, states and regions in the United States of America (US) started to develop GHG emissions reduction targets. One of the first North American regions to establish a reduction goal was that composed by 11 provinces and states from eastern Canada and the US in 2001.[2] Regionally, the goal was established at reducing GHG emissions to a level 10 percent below 1990 emissions by 2020 (NGE-ECP, 2001). Although several states had since set reduction goals, it was not until 2006 that California became the first subnational US entity to establish a statewide enforceable target on total GHG emissions.[3]

Signed into law in September 2006, Assembly Bill 32 (2006), the California Global Warming Solutions Act of 2006,[4] required the California Air Resources Board (CARB)[5] to define strategies to achieve statewide GHG emissions at or below the 1990 levels by 2020 and 80 percent below 1990 levels by 2050. The bill, commonly referred to as AB32, was preceded a year before by a state Executive Order mandating those reduction targets and directing the California Environmental Protection Agency to coordinate the efforts of several agencies and secretaries. A Climate Action Team (CAT), composed of representatives from 17 state agencies, worked on the proposal of GHG emissions reduction strategies. The CAT's reports (CAT, 2006, 2007) describe such measures, several of which are reflected in the final Scoping Plan (SP) adopted by the CARB (CARB, 2008). Aside from the CARB and the 12 subgroups of the CAT, the general public and stakeholders actively participated in the development of the SP through public meetings, workshops and responding to solicitation for ideas.[6]

Concerns in California regarding climate change are however not that recent and have been reflected in law since 1988, when by Assembly Bill 4420 (1988) the California Energy Commission (CEC) was directed to study the impacts of climate change on the state as well as to develop the first GHG inventory and provide policy recommendations.[7] After the establishment of a voluntary registry scheme which started operations in 2002, one of the most important milestones in California climate policy came in 2002 when the passage of Assembly Bill 1493 (2002) triggered the opposition of automakers and the subsequent involvement of the US Environmental Protection Agency (EPA).

This bill required the CARB to develop and adopt regulations to reduce GHG emissions from passenger vehicles, light-duty trucks and other non-commercial vehicles sold in California. A year after, the states of California, Oregon and Washington created the West Coast Global Warming Initiative to promote collaborative work in programs addressing climate change. In the summer of 2010, these and other state members of the Western Climate Initiative released their joint emissions-reduction strategy centred on the implementation of a regional cap-and-trade system (CTS) for GHG emissions of which the first compliance period is planned for 2012–14.[8]

Although either a statewide or a regional CTS will cover sources responsible for about 86 percent of the emissions reduction target, the economic and technology advisory committees to the CARB have recommended the implementation of complementary measures to aid in the technological and behavioral transition towards a lower-carbon economy in the state (MAC, 2007; ETAAC, 2008). This chapter describes and discusses the complementary policies pertaining to the energy sector (that is, commercial and residential natural gas use, electricity and transportation) with the highest projected GHG emissions reductions. Together, the six strategies presented in section 26.3 of this chapter (vehicle GHG standards, low carbon fuel standards, regional transportation targets, energy efficiency, renewable electricity standard, and increasing combined heat and power generation) are expected to contribute to almost 60 percent of California's 2020 reduction target.

While the description of strategies in section 26.3 of this chapter is largely based on CARB's SP, the rapid process of design and implementation of strategies that the state is experiencing resulted in changes to some of the measures considered there. Therefore, projected reductions from strategies contained in the original plan were updated whenever possible, considering the most recent modifications and estimates from CARB and other agencies involved. In section 26.4 we provide discussion regarding current debates related to specific policies, as well as their potential unintended impacts.

Among the worldwide set of subnational policies with global implications, climate policy in California stands out not only for the size of its economy (twelfth in the world in 2008) but also for its contribution to global GHG emissions (seventeenth in the world in 2000).[9] In the past, this state, which accommodates about 12 percent of the US population, has successfully experimented with environmental policies that have ultimately been adopted in the US. Furthermore, climate change impacts, some of which have been already manifesting, will spread across all the regions in the state. Some of the major threats derived from even moderate increases in temperature, precipitation and sea level rise include a higher frequency of wildfires and extreme events, water supply shifts from earlier snowpack melting, damage to infrastructure and entire coastal communities, as well as a range of impacts on the state's agriculture, public health and biodiversity (CNRA, 2009).

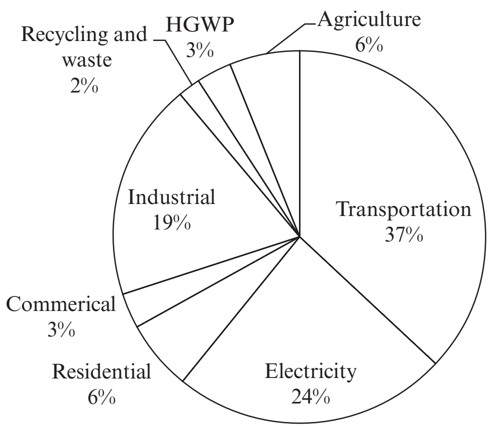
The remainder of the chapter is organized as follows: section 26.2 characterizes California's GHG inventory, highlighting the contribution of energy-related sectors, Section 26.3 presents the most important complementary measures to reduce emissions from commercial and residential natural gas use, electricity and transportation. Section 26.4 discusses some of the implications of these policies and section 26.5 concludes.

26.2. THE ROLE OF ENERGY IN THE GENERATION OF GHG EMISSIONS IN CALIFORNIA

The energy used in business establishments and houses, transportation activities, and electricity generation is globally and for most countries the largest source of GHG emissions. As shown in Figure 26.1, these activities together contributed 70 percent of the 477.74 megatonnes of carbon dioxide equivalent ($MtCO_2e$) generated within the state of California.[10] Although there exists a high dependence on private means of transportation in the US that is not only particular to California[11], the contribution from the transportation sector in the state is larger than that for the US (37 and 27 percent, respectively). This is because California's large share of hydropower and renewable resources generating electricity, together with a long tradition of energy efficiency measures, reduce the responsibility of the electricity sector in the state's GHG inventory compared to that for the nation (24 and 35 percent, respectively).

Under a business-as-usual (BAU) scenario, GHG emissions by 2020 in the state would be about 596 $MtCO_2e$. Interestingly, the two sectors with the largest shares, transportation and electricity, are also among those that would experience the largest increases in the absence of mitigation policies: 30 and 20 percent, respectively. High global warming potential (HGWP) gases, mostly used in refrigeration, are expected to increase by 300 percent under BAU. The emissions reductions of these gases are however not directly related to energy use since they result from leakage in, and disposal of, refrigeration and cooling systems.

As part of CARB's obligations under AB32, the board determined the 1990 GHG statewide emissions at 427 $MtCO_2e$, therefore requiring a reduction of 169 $MtCO_2e$ (or 28 percent) with respect to the BAU scenario by 2020. The following section describes energy-related policies that will together contribute about 60 percent of the reductions required to reach the 2020 target.



Source: Data from CARB (2010a).

Figure 26.1 California GHG emissions by source category, 2008

26.3 THE OPPORTUNITY FOR ENERGY-RELATED MEASURES TO REDUCE GHG EMISSIONS IN CALIFORNIA

A CTS covering most of the GHG sources is already expected to be in operation in California by 2012. Our focus in this chapter is not on the characteristics of a potential permit market but on the complementary measures that, beyond the price signals from the carbon market, will drive technological and behavioral changes. In particular, transportation emissions are not expected to be largely abated in the absence of sectoral policies. At the current carbon content of the fuel mix used in passenger vehicles, even a high price of US$50 (USD) per tonne of carbon dioxide equivalent (CO_2e) would only translate into gasoline price increases of 18 percent over the average price of gasoline between the summers of 2005 and 2010.[12] Holding everything else constant (for example carbon content of fuels, fuel economy of cars, driving habits and population) and considering a long-run gasoline price elasticity of -0.74, transportation emissions would be only reduced by 12 percent.[13] Without any other policies, a higher price of carbon would be required to achieve considerable GHG emissions reductions in the transportation sector under a wealthier and more populous 2020 California.

The introduction of mandatory standards for vehicle fuel efficiency and fuel carbon content together with the incorporation of GHG emissions projections during the regional planning process are expected to fill the gap left by the limited response of gasoline demand to small gasoline price variations. It should be noted, however, that gasoline taxes in some European countries can be up to eight times as large as those currently in place in California.[14] Although comparable levels of taxation would imply an increase in the retail price of gasoline in California that would translate into a more visible fall in the demand for gasoline demand, the reality is that such a level of taxation on gasoline is very unlikely to be imposed anywhere in the US in the near future.[15]

The most important measures in terms of GHG reductions involving energy use are briefly described below. The mitigation strategies, intended to promote both technological changes on the supply side and behavioural changes on the demand side, are here broadly classified into transportation, and natural gas and electricity. Table 26.1, which presents the mitigation potential of each measure (with their SP identifier in parentheses) as well as its expected cost, shows that, with the exception of the Renewable Portfolio Standard, each of these measures results in net savings. Both the CARB and the CEC had stressed that the aim of increasing the share of renewable sources for electricity generation is not only to reduce GHG emissions but also to diversify energy sources; these benefits are not accounted for in the SP net cost calculation (CARB, 2008).

26.3.1 Transportation

Vehicle greenhouse gas standards (T-1)

After a four-year process characterized by automakers' opposition and the expectations about the EPA's authorization to allow California to set its own vehicle GHG standards, a waiver was finally granted in April 2009 by the EPA.[16] Under Assembly Bill 1493 (2002), the CARB was required to adopt lower vehicle GHG standards for passenger vehicles and light trucks. The standards established for new vehicles from 2009 to 2016

Table 26.1 GHG emissions mitigation strategies from California's Scoping Plan 2008

SP identifier	Strategy	Mitigation potential as a percentage of 2020 Target+	Mitigation cost in 2020 (USD per tonne of CO_2e)++
T-1	Vehicle GHG Standards	18.8	−349
T-2	Low Carbon Fuel Standards	9.5	0
T-3	Regional Transportation Targets	2.0*	−311
E-1	Energy Efficiency – Electricity	9.0	−109
CR-1	Energy Efficiency – Natural Gas	2.5	−109
E-3	Renewable Electricity Standard	7.1	197**
E-2	Increase Combined Heat and Power Generation	4.0	−196

Notes: Data from CARB (2008).
+ Shown as a percentage of the 169 $MtCO_2$e reductions required.
++ Mitigation costs were obtained from the net annualized costs and emissions reductions calculated by CARB (2008). Co-benefits and adverse impacts described in Appendixes H and J of the SP were not considered in CARB's calculations. Further details regarding the assumptions and formulae used for these estimations can be found in Appendix I of the report.
We updated mitigation potential figures to the most current estimate whenever possible (*CARB, 2010b; **CARB, 2010d).

implied an average fleet reduction of 36 percent in grams of CO_2e per mile for all new vehicles sold in California by 2016 compared to those built in 2009. These standards, also known as Pavley I, will be followed by those resulting from the final amendments to the Low-Emission Vehicles (LEV) regulations (known as Advanced Clean Cars, Pavley II, or LEV III).

The adopted regulation allows compliance flexibility by means of averaging model year fleet emissions within manufacturer, and banking and trading of credits which are in units of grams of CO_2e per mile. Borrowing from anticipated credit generation in future periods is not allowed. However, credits generated for model years 2000–2008 based on 2012 standards can be used at full value to offset shortfalls up to 2012. For future compliance periods, such credits would be only worth a fraction of their original value, ultimately expiring by 2015.

A number of states are also adopting California's standards, including neighbouring ones with the exception of Nevada. With the recently approved federal standards for model years 2012–16, equal to those from Pavley I, automakers delivering for sale in California (and in those states that adopted California standards) will in fact be subject to the federal regulation in that period but to the state regulation before and after.[17]

Overall, compared to a BAU scenario this measure is expected to remove 31.7 $MtCO_2$e from the atmosphere by 2020, 4 $MtCO_2$e of which are expected from Pavley II, representing about 19 percent of the total reduction target. According to the SP, these reductions will be achieved at a negative cost (that is, savings) of US$349 per tonne of CO_2e by 2020.

Low carbon fuel standard (T-2)

The California Low Carbon Fuel Standard (LCFS) was adopted in April 2009 and took effect in January 2010. The standard is imposed on all fuel providers requiring them to attain a decreasing level of GHG emissions per unit of fuel energy sold in California.[18] The reduction requirement increases annually, starting with 0.25 percent in 2011, rising to 5 percent in 2017 and reaching 10 percent in 2020 for both gasoline and diesel fuel substitutes.[19] Since the standard is imposed on a per-unit of fuel energy basis, specifically grams of CO_2e per megajoule (MJ), instead of in terms of an overall GHG emissions target, the overall level of emissions could be higher.[20] Importantly, life-cycle GHG emissions from extraction (cultivation in the case of biofuels) to combustion are considered, including land use conversion, as well as emissions resulting from processing and distribution of all fuels. Given other possible environmental and social impacts resulting from the production of some of the alternative fuels such as electricity and biofuels, the CARB is working with interested stakeholders to include sustainability provisions into the regulation by December 2011.

As with the case of vehicle GHG standards, the regulation allows for trading and banking of credits in order to achieve reductions at the minimum cost and provide compliance flexibility. The calculation of credits in units of $MtCO_2$e depends on the applicable standard for either gasoline or diesel as well as on the energy and carbon intensities of each alternative fuel. Adjustment factors are applied to energy generated from electricity and hydrogen because of the higher average mileage that each unit of energy from these sources delivers compared to gasoline and diesel.[21] Although credits generated within the LCFS program can be exported to other GHG emissions trading systems, buying credits generated in other programs is not allowed. This provision was made in order to attain the projected emissions reductions within the program. Borrowing from anticipated reductions in subsequent periods is not allowed; however, under certain conditions (for example no deficit reported in the previous period) fuel providers can carry over a deficit to the next compliance period without a penalty.

Gasoline and diesel consumption represented more than 99 percent of the gasoline gallon-equivalent sales for all fuels in the state in 2008. This percentage would be only slightly modified by 2020 even though the use of electricity, ethanol and natural gas to power vehicles experiences large increases under each of the scenarios considered in CEC (2010). The main obstacle for the widespread use of the different types of ethanol as primary fuel (gasoline is currently composed of 6 to 10 percent ethanol) will not be their production costs but the thousands of service stations for high-ethanol-content fuels that would need to be made available throughout the state. Despite these figures, this measure is expected to result in 16 $MtCO_2$e reductions by 2020 compared to a BAU scenario. The reductions will be mainly brought about by cellulosic and advanced renewable ethanol substituting for gasoline, and advanced renewable biodiesel substituting for diesel (CARB, 2009). According to the analysis carried out along with the SP, the costs of this measure are negligible because the costs of producing alternative fuels are projected to be competitive to those of gasoline and diesel. In section 26.4 of this chapter we explore the arguments from a study that contends that the costs of achieving these reductions are in fact large.

Regional Transportation Targets (T-3)

California's Senate Bill 375 (2008) required the CARB to set regional passenger vehicle GHG reduction goals for each of the 18 Metropolitan Planning Organizations (MPO) in the state.[22] After recommendations from the Regional Targets Advisory Committee

Table 26.2 Population, CO_2e emissions per capita and regional reduction targets in California MPOs

Region	Population in 2005 (thousands)	Passenger vehicles' CO_2e per capita in 2005 (kilograms a year)	Per capita GHG emissions target by 2020 (% change)
Southern California Association of Governments	17763	3337	−8
Bay Area Metropolitan Transportation Commission	7095	3269	−7
San Diego Association of Governments	3034	4085	−7
Sacramento Area Council of Governments	2057	3547	−7
Eight MPOs in San Joaquin Valley+	3751	2585	−5
Six smallest MPOs+	1851	2431	7

Notes:
Data from 'Proposed SB 375 Greenhouse Gas Targets: documentation of the resulting emission reductions based on MPO data', available at www.arb.ca.gov/cc/sb375/mpo.co2.reduction.calc.pdf (accessed August 2010).
+The eight MPOs in San Joaquin Valley will be complying with the targets as one entity, however the six smaller MPOs will report individually.

in September 2009, the CARB in conjunction with the MPOs agreed on establishing the targets in terms of percentage reductions on per capita GHG from passenger vehicles, instead of total GHG reductions from passenger vehicles in the region. Practical considerations were taken into account for the adoption of this metric; however it was determinant that this choice would also compensate for the different rates in population growth across the state's regions.

This strategy started out with a large reduction potential of 20 MtCO_2e in the earlier drafts (CAT, 2006, 2007), however further research found that estimate to be very optimistic and it was consequently adjusted.[23] The SP of 2008 projected 5 MtCO_2e reductions and US$1554 million in savings from this strategy by 2020. However, based on current regional targets proposed, the most recent estimate without considering the impact of LCFS and Pavley is of the order of 3.4 MtCO_2e (CARB, 2010b).

In August of 2010, the CARB (2010b) made public the proposed targets for the MPOs in the state. These were set considering the MPO's own proposal and were adopted in September of the same year. Table 26.2 summarizes baseline emission levels and 2020 targets for the MPOs. Regions generating 95 percent of the state's GHG from passenger vehicles – that is, the four largest MPOs and those in the San Joaquin Valley – would face targets of between 5 and 8 percent reductions. Some small MPOs are allowed to increase their emissions per capita, and although some of the six smallest MPOs have reduction or zero-change targets, in conjunction their emissions per capita will be larger by 2020.

From the individual plans included in CARB (2010c), the array of policies being considered by the MPOs mainly include increasing the number of high-occupancy lanes, improving the extension and service of transit, promoting new compact and mixed land use housing development in areas close to transit services, incentivizing telecommuting, extending bicycle networks, and intensifying campaigns promoting the use of alternative modes of transportation and reduced travel.

The potential reductions from this strategy are not expected to be large in the near term because a large portion of the land use patterns by 2020 will be determined by development already carried out. It is however expected that by 2035 the reduction from this strategy will be of the order of 15 $MtCO_2e$: about a fivefold increase from the 2020 projections.

26.3.2 Electricity and Natural Gas

Emissions of GHG generated in the process of production of electricity for its consumption in California account for 25 percent of the total, and are second to transportation in importance. California, however, is already the state with the lowest consumption of electricity per capita in the US.[24] While consumption per capita has increased by almost 50 percent in the US in the last 30 years, California's has practically remained steady in the same period, resulting in a per capita consumption of almost half of that in the US (CEC, 2007). Commercial and residential emissions (almost entirely the result of natural gas consumption for space and water heating and cooking) are responsible for 9 percent of the total in the state.[25]

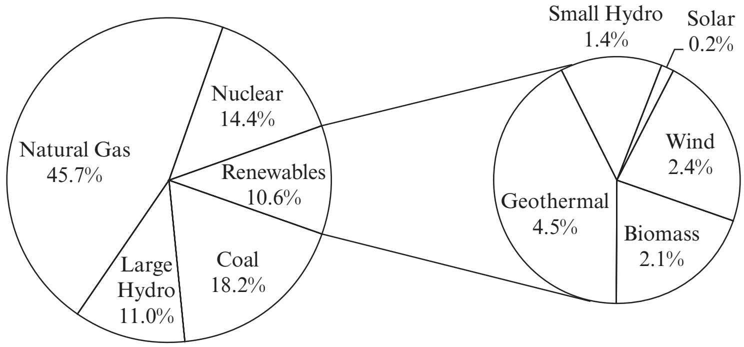
Although GHG emissions resulting from electricity generation and natural gas consumption will be covered under a CTS system as of 2012, the state has designed a set of policies that will aim directly at fostering behavioral and technological changes.[26] The main vehicle to achieve the latter will be through energy efficiency measures that require more stringent standards for appliances, and by mandating a larger share of renewable sources for electricity suppliers. Also important will be the support provided to increase combined heat and power installations. As for policies impacting the behavior of energy consumers beyond the price signals derived from the carbon market, education and real-time information about energy consumption will be central to promote conservation.

Energy efficiency: electricity and natural gas (E-1 and CR-1)

The California Long Term Energy Efficiency Strategic Plan (CPUC, 2008) provides the basis for the energy-efficiency reduction measures. The set of strategies includes building and appliance standards, as well as utility efficiency programs and provision of information technologies to help in optimizing energy use and conserving energy.[27]

The Energy Action Plan of 2003 (CEC-CPUC, 2003) has already established energy efficiency together with energy demand reductions as the primary strategy aimed to meet California's energy requirements for 2020. The California Public Utilities Commission (CPUC) and the CEC have estimated reductions of 15.2 and 4.3 $MtCO_2e$ from electricity and natural gas respectively. The CPUC and the CEC are the agencies in charge of energy policies and regulation in the state. The former regulates private utilities and providers, while the latter is authorized to regulate publicly owned utilities, as well as to adopt and update buildings and appliance standards.

The GHG emissions reductions from this strategy are based on CEC-CPUC targets of 32 000 gigawatt hours (E-1) and 800 million therms (CR-1). The reductions will be achieved through a series of codes and standards for buildings and appliances leading to



Source: Data from CEC's Energy Almanac at energyalmanac.ca.gov.

Figure 26.2 Sources of electricity generated for retail in California in 2008

'zero net energy' new residential buildings by 2020.[28] Commercial buildings should have improved their efficiency by 2020, however their goals are to be met by 2030.

To be catalogued as a zero net energy building, it must generate enough energy on-site to offset completely the energy consumed within the building in a year. This transition will be supported by intermediate standards targets, adoption of zero energy heating and cooling technologies (for example geothermal heat pumps, solar thermal water heating), integrated and passive solar designs and, importantly, by enabling the supply of energy surplus into the grid (CARB, 2008).

Although future development will have to comply with a set of standards, efforts will be strongly directed towards the energy-efficiency improvement of existing homes and establishments which comprise most of the buildings stock. CPUC's (2008) plan established a 40 percent reduction goal in energy (electricity and natural gas) consumption in existing homes by 2020. This would be achieved through a set of measures including mechanisms aimed at encouraging retrofits and providing education that will promote conservation and efficient use of energy.[29] Mandatory improvements might be imposed at the time of sale of an existing building (residential or commercial), while financing mechanisms to help cover the upfront costs of on-site renewable systems are currently being explored.

The CEC will be continuously adopting and updating standards for new types of appliances, importantly those that require plug-loads which represent a growing percentage of residential energy use. Water use efficiency, and improved compliance and enforcement are among the measures supporting the overall goal which will be achieved at net savings of over US$100 per tonne of CO_2e according to the calculations in the SP.

Renewable energy (E-3)

California's statewide GHG emissions per kilowatt hour consumed are among the lowest in the nation and more than 30 percent below the national ratio due to the high share of renewable sources and natural gas in the generation of electricity. From Figure 26.2, 10.6 percent of the electricity consumed in the state comes from renewable sources (more than one-fifth when large hydroelectric facilities are included), and the largest source of electricity is natural gas (46 percent). Even though per capita consumption of electricity is only 60 percent of that in the US, the generation capacity within the state is exceeded by the demand, and therefore California imports nearly 30 percent of its electricity needs. Because 93 percent of these imports are produced by facilities burning coal which has a carbon intensity almost twice that of natural gas, they generate more than 50 percent of the emissions assigned to this sector.

In 2006, Senate Bill 107 moved the deadline from 2017 to 2010 for private utilities to reach a 20 percent proportion of their electricity provided from renewable sources. Known as the Renewable Portfolio Standard (RPS), this legislation defines as renewable sources those electricity generation facilities that: 'use biomass, solar thermal, photovoltaic, wind, geothermal, fuel cells using renewable fuels, small hydroelectric generation of 30 megawatts or less, digester gas, municipal solid waste conversion, landfill gas, ocean wave, ocean thermal, or tidal current' (Senate Bill 107 2006). Electricity generated by large hydroelectric facilities is not considered as being produced by a renewable source due to other environmental impacts that commonly accompany them.[30] Small hydroelectric facilities and those converting biomass into electricity are required to demonstrate that other environmental impacts are negligible.

Following a recommendation included in the Energy Action Plan II (CEC-CPUC, 2005), Executive Order S-21-09 from September 2009 directed the CARB to adopt regulation that will increase the share of electricity generated from renewable sources to 33 percent by 2020. This is the most ambitious goal among the US states that have set an RPS.[31] In spite of the wide range of eligible renewable alternatives considered, wind, geothermal and solar are projected to provide 85 percent of the renewable electricity by 2020 (CARB, 2010d). This regulation, known as the Renewable Electricity Standard (RES) builds upon the Renewable Portfolio Standard and will apply to both investor-owned and publicly owned utilities.[32] In 2008, the latter type provided about 24 percent of the electricity consumed in the state, and the five (three investor-owned and two publicly owned) largest utilities provided more than 80 percent of the total electricity generated for consumption in California.

According to CARB (2010d) the RES target will translate into CO_2e reductions of 12 Mt by 2020, at a cost of US$200 per tonne.[33] The total costs of the RES are translated into monthly utility bill increases in 2020 of 3–6 percent for both residential users and small businesses. According to the economic analysis of the proposal, the cost estimate is conservative because it assumes that the cost of renewable sources remains constant. The RES will be gradually implemented in the following manner: 20 percent by 2012–14, 24 percent by 2015–17, 28 percent by 2018–19, and 33 percent by 2020 and after. Bankable and tradable renewable energy credits will provide compliance flexibility to regulated parties.

Considering the 7.9 MtCO_2e reductions that will result from the current 20 percent renewable standard, strategies enforcing renewable standards will together contribute 12 percent of the 2020 GHG emissions reduction target.

Increase combined heat and power generation (E-2)

In a CEC-commissioned study, the Electric Power Research Institute (EPRI) estimated that under a 'moderate market access' scenario for 2020, the installed capacity of combined heat and power (CHP) applications could increase by 4400 megawatts (MW).[34]

CARB's slightly smaller targeted recommendation in its SP of 2008 is based on this estimate. According to the CARB, 4000 MW of additional capacity would displace 32 000 gigawatt hours (GWh) from the grid.[35] The key change under EPRI's moderate scenario compared to current incentives is to allow energy surplus from CHP applications to be sold to the grid. However, in order to achieve the targeted increase in CHP capacity, current incentives such as payments for self-generation, access to lower gas rates and surcharge exemptions for systems meeting efficiency and environmental standards are assumed to be maintained.[36] In fact, under a scenario in which energy surplus cannot be exported but current policies are maintained, there would still be an increase in CHP capacity of about 2000 MW by 2020.

Generating electricity for its consumption, on-site CHP systems are catalogued as distributed generation systems, as opposed to centralized power generation from utilities. Along with electricity, CHP systems simultaneously produce thermal energy. The latter can be used to heat space and water, as well as to generate more electricity or to run a cooling device, therefore avoiding the consumption of fuel otherwise needed to meet those needs. Not-combined systems of power generation simply dispose of the unused energy in the form of waste heat into the atmosphere. CHP systems are best suited for applications in which the demand for electricity and heating are continuous, such as hospitals, colleges, prisons, hotels and large stores.

According to EPRI's study, 776 sites with an accumulated capacity of 9130 MW were in operation in 2005, of which about 90 percent of the systems had capacities above 20 MW. It is important to note that most of the current and projected incentives are directed towards installations smaller than 20 MW in which the expansion potential is larger.

Under the Waste Heat and Carbon Emissions Reduction Act (Assembly Bill 1613 2007), the CPUC is authorized to require investor-owned utilities to purchase excess electricity from customers with CHP systems.[37] The Act also made provisions for the adoption of feed-in tariffs and to establish a pilot program in which utilities would finance upfront costs of customers installing CHP systems.[38]

Publicly owned utilities are also required by this Act to establish a program that allows their customers to install CHP systems and creates a market for the excess electricity generated. Such electricity would be purchased at a rate determined by the governing boards of the publicly owned utility instead of the rate determined by the CPUC for investor-owned utilities.

In December 2009, the CPUC ordered electric corporations to adopt contracts for electricity purchases from small (up to 5 MW) and medium (up to 20 MW) eligible customers with CHP systems. The decision also established that the costs of a combined cycle gas turbine will serve as the basis of the rate at which the electricity will be paid.[39]

Although CHP applications can be fueled by renewable sources, 84 percent of installed CHP systems in 2005 depended on natural gas to produce energy. The CARB assumes that natural gas is used to run all of the added CHP capacity in its GHG emissions reductions calculations. The combustion of natural gas to produce electricity generates on-site emissions of pollutants other than carbon dioxide. Emissions of the latter are considered in the calculations of the net GHG change with and without this strategy, while installations must comply with existing regulations for other pollutants and environmental standards. The added installation target would deliver reductions of 6.7 $MtCO_2e$ at almost US$200 savings per tonne.

26.4 DISCUSSION

Even though the six mitigation strategies overviewed in this chapter will reduce California's GHG emissions, not all of them can guarantee that those emissions will not be generated elsewhere as a response to the state's policies. For instance, leakage of GHG emissions can occur under the Low Carbon Fuel Standards, the Renewable Portfolio Standards and the Vehicle GHG Standards programs. In particular, under the LCFS, fuel exporters outside California might divert their high-carbon-content fuels to other regions and the low-carbon ones to California, with a negligible change in global emissions from this regulation. Automakers and electricity producers exporting to California might react in comparable ways. Responses from different industries can take another dimension by relocating in states with laxer regulations. This type of response would not only leave global GHG emissions unchanged, but could inflict further negative impacts on the state's economy.[40] Leakage is minimized and ultimately resolved when more states and countries adopt California's or comparable regulations.

Another concern that is relevant to all of the measures described in this chapter is how environmental and economic impacts will be spatially and socially distributed among Californians. Importantly, most of these programs already have provisions addressing environmental justice,[41] while others are working on its incorporation.[42] These issues become particularly important in the case of siting renewable energy generation facilities such as landfill gas, and wind and solar farms which can involve considerable environmental and aesthetic impacts. As mentioned earlier, large hydroelectric facilities are not considered under the CEC's eligible renewable sources due to the wide range of environmental damage they can entail.

While concerns about leakage of GHG emissions and environmental justice permeate through most of regional mitigation policies, other unintended impacts are specifically related to some of the measures. The higher fuel economy under the vehicle GHG standards program could derive into a more intensive use of cars due to reduced total costs per mile. The magnitudes of this rebound effect calculated by Van Dender and Small (2005) were however taken into account in the estimation of the GHG emissions reductions. On the other hand, this policy has been criticized for its lack of stringency in light of required GHG emissions reductions to stabilize the climate (Johnson, 2007). However, this critique and that regarding the low cost-effectiveness and inefficiency of the LCFS in Holland et al. (2009), are less sustained when these policies are viewed as part of a policy package that includes a CTS covering transportation emissions, and when their individual goals other than GHG reductions are taken into account.

A contrasting finding in Holland et al. (2009) is that the LCFS program will result in costs ranging from 263 to 903 per tonne of CO_2e compared to the negligible cost that the CARB placed on this strategy. It is important to stress that both the LCFS and the RES programs, which could deliver reductions at a cost, have objectives beyond GHG emissions reductions such as diversifying energy sources for security reasons. An investigation on the benefits obtained as a result of meeting these other objectives would be necessary in a complete assessment of the economic efficiency of the policies.

In fact, assuming that achieving the GHG reduction target is the only objective, complementary policies are redundant in the presence of a CTS that covers most of the emissions. For instance, since the global warming impact of 1 tonne of CO_2e is the same regardless of its source, policies aimed at reducing GHG emissions within the transportation sector will not be economically efficient unless other ancillary benefits or policy objectives are relevant, or the overall GHG emissions cap is set at a level higher than that yielding the social optimum.

Regardless of their economic efficiency and cost-effectiveness it is undeniable that the complementary policies will facilitate the transition towards a lower carbon economy in California. Based on their own and other studies' elasticity estimates, Heres and Niemeier (2011) argue that separate increases in the range of 20–25 percent in the price of gasoline or in residential density could deliver the same GHG emissions reductions in the state. Modifying the type of housing development might seem technically more difficult than imposing a tax on gasoline; however the latter option is commonly perceived to involve a large political burden. Bundling the two policies will result in larger reductions; however efficiency gains would depend on the stringency of each policy alone and the full set of objectives. The potential synergies that could develop between an RPS and energy efficiency measures also justify the coordination of policies. In Mahone et al. (2009) the level of investments on energy efficiency that are cost-effective increases in the presence of a higher RPS because the latter increases electricity prices.

Some strategies that would deliver emissions reductions to individuals and businesses at apparently negative costs have not been widely adopted due to other factors beyond cost and savings calculations at private discount rates. As Jaffe et al. (2004) point out, although the diffusion of new technologies is always gradual, the rate of adoption might still be suboptimal. For instance, a potential energy efficiency gap – that is, a slower than optimal substitution of energy-inefficient appliances and systems for high-energy-efficiency ones – can also be hindered by market and non-market failures. Examples of the former are the public-good attributes of information, and principal–agent situations that can arise when the owner of a building chooses the investments in energy efficiency (Jaffe et al., 2004). An important non-market failure in this context would be the uncertainties regarding future benefits from an investment in energy efficiency occurring today. The presence of some of these barriers to adoption calls for policy interventions, such as the implementation of financing mechanisms and measures to provide better access to information, aimed at remedying the efficiency gap. A study prepared for the CEC (EPRI, 2005) found some of these barriers to be highly relevant in the context of the expansion of CHP systems, especially short payback periods demanded by users, which could be the result of uncertainties regarding future energy prices and systems costs.

A crucial hurdle to be cleaned in order to increase the amount of electricity consumed on-site from renewable sources and CHP systems is to allow their electricity surpluses to be exported. In several countries this has been accompanied not only by electricity purchases quotas that utilities have to meet from specific sources (that is, RPS) but importantly with a feed-in-tariff (FIT) by which a price per kilowatt hour of electricity is guaranteed to the seller, therefore resolving part of the uncertainties. The larger costs of electricity generation from most renewable sources have been covered in the past through direct subsidies to the utilities purchasing the electricity, or more commonly by authorizing increases in the price per kilowatt hour delivered to end users. The purpose of the FIT in California, less ambitious than some of the European FITs which were designed as substitutes for enforced RPSs, is to facilitate sales of surplus electricity generated by small renewable energy projects (less than 3 MW). Because the California's FIT is based on the cost per kilowatt hour of a combined cycle natural gas turbine power plant and an overall cap on utilities' required purchases has been set, this particular program does not transfer public funds to any of the parties and should not imply large changes to the retail price of electricity. This program alone might fall short of providing incentives to spread the exploitation of renewable sources to produce electricity that some European countries have experienced. However, California's hybrid approach combining an RPS and an FIT will ensure that the target of 33 percent electricity from renewable sources is met.

26.5 CONCLUDING REMARKS

By passing AB32 in 2006, California became the first subnational US entity to establish a state-wide enforceable target on total GHG emissions. AB32 required the CARB to define strategies to achieve statewide GHG emissions at or below the 1990 levels by 2020, and 80 percent below 1990 levels by 2050 (Assembly Bill 32 2006). Among the worldwide set of subnational policies with global implications, climate policy in California stands out for the size of its economy (twelfth in the world in 2008) and its contribution to global GHG emissions (seventeenth in the world in 2000).

Although either a state-wide or a regional CTS will cover sources responsible for about 86 percent of the AB32 emissions reduction target, the economic and technology advisory committees to the CARB have recommended the implementation of complementary measures to aid in the technological and behavioral transition towards a lower carbon economy in the state (MAC, 2007; ETAAC, 2008). The six energy-related complementary policies presented in this chapter (vehicle GHG standards, low carbon fuel standards, regional transportation targets, energy efficiency, renewable electricity standard, and increasing combined heat and power generation) are expected to contribute to almost 60 percent of California's 2020 reduction target. With the exception of the Renewable Electricity Standard, each of these measures results in net savings.

There are some concerns related to the six mitigation strategies reviewed in this chapter, however. First, until other states and countries adopt similar policies, leakage of GHG emissions can occur. Second, there are potential distributional impacts and environmental justice concerns. Third, the vehicle GHG standards program may lead to a rebound effect. Fourth, the LCFS may not be cost-effective or efficient. Fifth, complementary policies are redundant in the presence of a CTS that covers most of the emissions. It should be noted that these concerns have been, or are expected to be, addressed by the authorities in charge of developing the final regulations. Despite their potential drawbacks, the six mitigation strategies reviewed in this chapter will reduce California's GHG emissions and will facilitate the transition towards a lower carbon economy in California.

NOTES

1. Although their present value calculation is subject to controversy, future economic costs of inaction could be undeniably large. The core of the debate among economists is not about whether or not we should impose restrictions on the emissions of GHG but rather about the timing and magnitudes of such restraints. Heal (2009) provides a review of the main positions in the field.
2. The Canadian provinces of Newfoundland and Labrador, Nova Scotia, Prince Edward Island, New

Brunswick and Quebec, and the states of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.

3. The Pew Center on Global Climate Change maintains an updated description of regional efforts and rulemaking in the US (www.pewclimate.org/states-regions, accessed August 2010).
4. Hanemann (2008) provides a compelling recount of the events leading to the passage of this legislation in California. He explores the political and legal circumstances reigning during the few years prior to the law enactment but the narration is also enriched by tracing back the seeds to the ahead-of-federal regulations on air pollution in the middle of the twentieth century and the creation of a unique state Energy Commission in 1974. The interested reader will find further interesting details about the different segments and characters along the road to the passage of AB32 in Hanemann (2007).
5. Part of the California Environmental Protection Agency, CARB's mission is: 'to promote and protect public health, welfare and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state' (www.arb.ca.gov/html/mission.htm accessed August 2010). Under AB32, aside from developing the scoping plan with reduction strategies to become operative by January 2012, the board is also responsible for setting the 1990 statewide GHG emissions reference level, adopting regulation requiring the mandatory reporting of GHG emissions sources, ensuring that early actions receive appropriate credit, convening an environmental justice advisory committee, and appointing an economic and technology advancement advisory committee (CARB, 2008).
6. CAT's subgroups are the economic sector-specific subgroups for agriculture, cement, energy, forest, green buildings, land use, recycling and waste management, state fleet, and water energy; the other three are multisector subgroups for economics, research and state operations.
7. The first California GHG inventory was published in 1990 and reported only carbon dioxide emissions from 1988. It was not until 1997 that emissions of methane and nitrous dioxide were included, and in 2002 emissions of gases with a high global warming potential were also incorporated. The CEC was in charge of developing the inventory until 2007 when this responsibility was transferred to the CARB.
8. Other partners are the states of Arizona, Montana, New Mexico and Utah, and the Canadian provinces of British Columbia, Manitoba, Ontario and Quebec. Five other US states, three Canadian provinces and six Mexican bordering states participate as observers.
9. Gross domestic product by state and country obtained from the US Department of Commerce Bureau of Economic Analysis at www.bea.gov/regional and from the World Bank database at data.worldbank.org. GHG emissions for California are from CARB (2010a). The earliest year for data on all GHG emissions by country from the World Resources Institute (cait.wri.org) is 2000. Websites were accessed in August 2010.
10. Tonnes (t) and metric tons are unit measures representing 1000 kilograms. Therefore a megatonne (Mt) is equal to both 1 million tonnes and to 1 million metric tons (MMT). The latter is the terminology used in the US inventories, while tonnes is the standard elsewhere, particularly in the reports published by the Intergovernmental Panel on Climate Change (IPCC). We follow IPCC's terminology throughout this chapter.
11. According to data from the Federal Highway Administration of the US Department of Transportation, vehicle miles travelled almost tripled between 1970 and 2007 in both California and the rest of the US ('Highway statistics summary to 1975' and 'Selected highway statistics and charts 2007' available at www.fhwa.dot.gov, accessed August 2010). However, since population growth in California has been larger compared to that in the other 50 states together during the same period ('Population estimates' from the US Census Bureau at www.census.gov, accessed August 2010), the increase in vehicle miles travelled per capita has been more rapid in the rest of the country than in California (87 and 55 percent, respectively). The high reliance on private means of transportation is also reflected in the small share of all person-trips that were made by public transportation – about 4 percent – in both the nation and California (calculated from preliminary data from the '2009 National Household Travel Survey' available at nhts.ornl.gov, accessed August 2010).
12. This example borrows from Sperling and Yeh (2009). Considering that 1 tonne is equal to 2204.6 pounds and that each gallon of gasoline produces 19.4 pounds of CO_2e (from current EPA emission factors), a CO_2e price of US$50 per tonne translates into 44 cents per gallon. The average of weekly prices for regular gasoline from August 2005 to August 2010 in California is US$2.40 per gallon (based on data from the CEC's 'Energy almanac' at energyalmanac.ca.gov).
13. This is the average of the mean values for long-run elasticities from the literature review in Lin and Prince (2009). It should be noted that this is probably a conservative assumption since these elasticities were estimated with long time series and there is evidence of a downward shift in the magnitudes of at least short-run elasticities (Hughes et al., 2008).
14. From data for August 2010 from the International Energy Agency, the gasoline taxes are between 113 and 179 per cent of the pre-tax price for France, Germany, Italy, Spain and the United Kingdom (www.

iea.org). This percentage is only 17 per cent in the US and 21 per cent in California (the latter is calculated from August 2010 prices and taxation levels in energyalmanac.ca.gov). Importantly, since the pre-tax prices are very similar among these regions, the retail prices in the above European countries are about twice as high as those in the US, California inclusive.

15. See Parry and Small (2005) for some conjectures regarding the political factors behind a presumably lower than optimal gasoline tax in the US (higher than optimal in the United Kingdom).
16. California had set standards for motor vehicles prior to the passage of the Federal Clean Air Act of 1970. On this basis, a provision was included in the Act allowing California to set its own stricter than federal emission standards for motor vehicles as long as it meets a set of conditions followed by a waiver granted by the federal government. Once granted, other states are free to abide by Californian or the federal standards. AB32 also considered the development of a 'feebate' program that would achieve the same reductions as this measure in the event of a final rejection of the waiver request. A feebate program would have provided rebates for high fuel-efficiency vehicles and imposed fees on low fuel-efficiency vehicles.
17. Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 75 Fed. Reg. 25324 (2010) (to be codified at 49 CFR Parts 531, 533, 536, 537 and 538).
18. The point of regulation is where finished gasoline is first manufactured or imported. This could be refineries, blenders or importers, but sometimes also wholesalers further downstream. In the latter case the wholesaler would have to report the GHG associated with the ethanol used for blending.
19. Final Regulation Order, Low Carbon Fuel Standard (2010), Title 17, California Code of Regulations, sections 95480–95490.
20. For instance, a provider could be selling fuels in 2020 representing a total carbon content larger than that in 2010 but that is lower in a per-unit of fuel energy basis.
21. For example, the carbon intensity of electricity considering an electricity mix of natural gas and renewable energy sources is larger than that for gasoline (104.71 and 95.86 grams of CO_2e per MJ, respectively). However, once adjusting and according to the average carbon intensity targets, carbon intensity of fuels and the formulae for credit generation in the Final Regulation Order, only 62 MJ from electricity would be necessary to offset 1000 MJ from gasoline by 2020.
22. MPOs are composed of representatives from local government and federal and state transportation authorities. They receive funding from the federal government and are in charge of the design of long-term planning policies.
23. Actions expected from this strategy appeared originally in CAT (2006) under the strategies 'Measures to Improve Transportation Energy Efficiency' and 'Smart Land Use and Intelligent Transportation', with combined reductions of 27 $MtCO_2e$ by 2020. CAT (2007) modified the title of the former to 'Transportation Efficiency' and adjusted the estimate of the latter, resulting in combined reductions of 19 $MtCO_2e$ by 2020.
24. In 2008 California consumed 7.1 thousand kilowatt hours per capita. This number was 12.3 for the US and 31.3 in Wyoming, the state with the largest consumption of electricity per capita in 2008. Electricity sales in kilowatt hours by state are available at the Energy Information Agency (www.eia.gov, accessed August 2010). Population estimates by state for 2008 are available at US Census (www.census.gov, accessed August 2010).
25. Emissions from electricity consumed in homes and businesses are included in 'electricity' emissions. When assigned to commercial and residential, the combined share of these sectors rises to 22 percent. Note that California only produces a small fraction of the natural gas consumed within the state (13 percent), however all of the emissions resulting from consumption are considered as produced within the state.
26. Natural gas GHG emissions will not be incorporated in the first compliance period of the CTS (2012–14) but are expected to be covered in subsequent phases.
27. The groups of strategies can be consulted in detail in CPUC (2008). The Scoping Plan (CARB, 2008) distinguishes 12 strategies that will maximize energy efficiency.
28. By law such standards must be cost-effective. That is, the efficiency savings must be larger than the installation, maintenance and operation costs.
29. Advanced metering infrastructure is currently being deployed in California by some of the largest electricity utilities as part of the energy conservation measures promoted in the state. Also known as smart metering, the purpose of this system is to provide real-time information about electricity consumption and prices through displays installed in homes and businesses.
30. Among these impacts are changes in stream flows and reservoir surface area, groundwater recharge, water temperature, turbidity and oxygen content. Biological impacts, damage to historic sites, changes in visual quality, loss of scenic resources and increased erosion are also important ('Hydroelectric power in California', www.energy.ca.gov, accessed August 2010).
31. Summary map of 'RPS policies from the Database of State Incentives for Renewables and Energy Efficiency' at www.dsireusa.org.
32. Investor-owned and publicly owned utilities provide together almost 95 percent of the electricity con-

sumed in the state. Other type of electricity providers such as joint utility agencies, rural electric cooperatives and self-generators will also be subject to the standard. Any type of provider whose retail sales fall under 200 000 megawatt hours will be exempted from the requirement. The latter group delivers less than 1 percent of total retail sales in the state.

33. This estimate does not include the benefits from energy sources diversification. Environmental impacts from construction and operation of transmission lines and localized air impacts are also not included. The latter will nevertheless be subject to existing legislation.
34. Assessment of California CHP market and policy options for increased penetration', EPRI, Palo Alto, CA, California Energy Commission, Sacramento, CA, April 2005.
35. CARB's calculations assume a utilization factor of 85 per cent; that is, the electricity generator is operating $0.85 \times 365 \times 24 = 7446$ hours a year. This number of hours multiplied by the generation capacity of 4000 MW results in 29 784 000 MW hours or about 30 000 GWh. Further assuming a 7 percent loss along the transmission lines from centralized power generation, these additional on-site CHP applications would displace 32 000 GWh from other sources.
36. 'Departing load cost responsibility surcharges' apply to customers of electric utilities that discontinue or reduce their purchases because part of their electricity needs are generated on-site. The purpose of these surcharges is to retain contributions towards the funding of social and energy efficiency programs and previous investments without shifting costs to other customers. Small CHP applications meeting energy efficiency and environmental standards can currently apply to be exempted from these surcharges.
37. An eligible customer must comply with certain criteria such as time of installation and capacity of the CHP system. The latter is also required to meet interconnection specifications and to comply with efficiency and GHG standards.
38. The eligibility criteria under the so-called 'pay-as-you-save' pilot program was amended by Assembly Bill 2791 (2008). It was previously directed solely to non-profit organizations but it now includes government facilities.
39. In January 2010 the three largest investor-owned utilities filed a joint motion to stay (denied in June 2010) the 'Decision adopting policies and procedures for purchase of excess electricity under Assembly Bill 1613' (D.09-12-042). The decision and rest of rule-making catalogued under 08-06-024 are available at http://docs.cpuc.ca.gov/Published/proceedings/R0806024.htm. This document provides an interesting example of the obstacles encountered in the implementation process of a state-wide policy that would differently affect the parties involved.
40. On grounds of the negative impacts to California's economy, Proposition 23 to be voted in November 2010 calls for a 'temporary' suspension of AB32 until the state-wide unemployment rate falls below 5.5 percent for four consecutive quarters. Based on monthly statistics, Elkind et al. (2010) find that the unemployment rate has been above 5.5 percent for almost 80 percent of the time since 1976. The passage of the proposition would practically suspend permanently the CTS and some of the complementary measures reviewed in this chapter. In particular, the LCFS, increasing CHP and RES programs, would not be implemented, while the regional transportation targets could be affected (Elkind et al., 2010).
41. Environmental justice refers to: 'the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies' (US Environmental Protection Agency at www.epa.gov/environmentaljustice/, accessed August 2010).
42. Appendix J in CARB (2008) identifies potential adverse environmental impacts and provides general recommendations that would support the environmental justice requirements of the strategies in the SP. The regulatory design for strategies such as LCFS and RES was especially recommended to address a large number of potential impacts.

REFERENCES

Assembly Bill 32 (2006), Chapter 488, California Statutes of 2006 (codified at Cal. Health and Safety Code §§ 38500-38599).

Assembly Bill 1493 (2002), Chapter 200, California Statutes of 2002 (codified at Cal. Health and Safety Code §§ 42823, 43018.5).

Assembly Bill 1613 (2007), Chapter 713, California Statutes of 2007 (codified at Cal. Pub. Util. Code §§ 2840-2845).

Assembly Bill 2791 (2008), Chapter 253, California Statutes of 2008 (codified at Cal. Pub. Util. Code § 2842.4).

Assembly Bill 4420 (1988), Chapter 1506, California Statutes of 1988.

CARB (2008), 'Climate change scoping plan: a framework for change', California Air Resources Board.

CARB (2009), 'Proposed regulation to implement the Low Carbon Fuel Standard. Volume I. Staff Report: initial statement of reasons', California Air Resources Board.
CARB (2010a), 'California greenhouse gas inventory for 2000–2008', California Air Resources Board.
CARB (2010b), 'Proposed regional greenhouse gas emission reduction targets for automobiles and light trucks pursuant to Senate Bill 375', California Air Resources Board.
CARB (2010c), 'Draft regional greenhouse gas emission reduction targets for automobiles and light trucks pursuant to Senate Bill 375', California Air Resources Board.
CARB (2010d), 'Proposed regulation for a California renewable electricity standard', California Air Resources Board.
CAT (2006), 'Climate Action Team report to Governor Schwarzenegger and the legislature', Climate Action Team.
CAT (2007), 'Climate Action Team proposed early actions to mitigate climate change in California', Climate Action Team.
CEC (2007), '2007 Integrated Energy Policy report: final report', California Energy Commission.
CEC (2010), 'Transportation energy forecasts and analyses for the 2009 Integrated Energy Policy report: final report', California Energy Commission.
CEC-CPUC (2003), 'Energy Action Plan I', California Energy Commission and California Public Utilities Commission.
CEC-CPUC (2005), 'Energy Action Plan II', California Energy Commission and California Public Utilities Commission.
CNRA (2009), '2009 California climate adaptation strategy', California Natural Resources Agency.
CPUC (2008), 'California long-term energy efficiency strategic plan: achieving maximum energy savings in California for 2009 and beyond', California Public Utilities Commission.
Elkind, E., D. Farber, R. Frank, M. Hanemann, D. Kammen, A. Kanterbacher and S. Weissman (2010), 'California at the crossroads: Proposition 23, AB 32, and climate change', Center for Law, Energy and the Environment, University of California, Berkeley, CA.
EPRI (2005), 'Assessment of California CHP market and policy options for increased penetration', Consultant Report Prepared for the California Energy Commission, Electric Power Research Institute.
ETAAC (2008), 'Recommendations of the Economic and Technology Advancement Advisory Committee. Final report. A report to the California Air Resources Board', Economic and Technology Advancement Advisory Committee.
Hanemann, M. (2007), 'How California came to pass AB 32, the Global Warming Solutions Act of 2006', Working Paper, Department of Agricultural and Resource Economics, University of California, Berkeley, CA.
Hanemann, M. (2008), 'California's new greenhouse gas laws', *Review of Environmental Economics and Policy*, **2** (1), 114–29.
Heal, G. (2009), 'Climate economics: a meta-review and some suggestions for future research', *Review of Environmental Economics and Policy*, **3** (1), 4–21.
Heres, D.R. and D. Niemeier (2011), 'CO_2 emissions: are land-use changes enough for California to reduce VMT? Specification of a two-part model with instrumental variables', *Transportation Research Part B*, **45**, 150–61.
Hughes, J., C. Knittel and D. Sperling (2008), 'Evidence of a shift in the short-run price elasticity of gasoline demand', *Energy Journal*, **29** (1), 93–114.
Holland, P., J. Hughes and C. Knittel (2009), 'Greenhouse gas reductions under low carbon fuel standards?' *American Economic Journal: Economic Policy*, **1**, 106–46.
Jaffe, A., R. Newell and R. Stavins (2004), 'Economics of energy efficiency', in C. Cleveland (ed.), *Encyclopedia of Energy Vol. 2*, Oxford: Elsevier, pp. 79–90.
Johnson, K.C. (2007), 'California's greenhouse gas law, Assembly Bill 1493: deficiencies, alternatives, and implications for regulatory climate policy', *Energy Policy*, **35**, 362–72.
Lin, C.-Y.C. and L. Prince (2009), 'The optimal gas tax for California', *Energy Policy*, **37**, 5173–83.
MAC (2007), 'Recommendations for designing a greenhouse gas cap-and-trade system for California: recommendations of the Market Advisory Committee to the California Air Resources Board', Market Advisory Committee.
Mahone, A., C.K. Woo, J. Williams and I. Horowitz (2009), 'Renewable portfolio standards and cost-effective energy-efficiency investment', *Energy Policy*, **37**, 744–77.
NEG-ECP (2001), 'Climate Change Action Plan 2001', New England Governors – Eastern Canadian Premiers.
Parry, I.W.H. and K. Small (2005), 'Does Britain or the United States have the right gasoline tax?' *American Economic Review*, **95** (4), 1276–89.
Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (eds) (2007), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge: Cambridge University Press.

Senate Bill 107 (2006), Chapter 464, California Statutes of 2006 (codified in scattered sections of Cal. Pub. Res. Code and Cal. Pub. Util. Code).
Senate Bill 375 (2008), Chapter 728, California Statutes of 2008 (codified in scattered sections of Cal. Gov. Code and at Cal. Pub. Res. Code §§ 21155, 21159.28).
Sperling, D. and S. Yeh (2009), 'Low carbon fuel standards', *Issues in Science and Technology*, Winter, 57–66.
Van Dender, K. and K. Small (2005), 'A study to evaluate the effect of reduced greenhouse gas emissions on vehicle miles traveled', Final Report ARB Contract Number 02-336.