# Shockproofing Society

## How California's Global Warming Solutions Act (AB 32) Reduces the Economic Pain of Energy Price Shocks

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**Cover Image**

Image credit: Alan Crosthwaite/World of Stock.

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# EXECUTIVE SUMMARY

The price of gasoline is a telling economic weathervane. When gas is cheap, it is not given much attention. When gas prices hit record highs, however, as in 2008, the downside of America's dependence on imported energy is made painfully obvious. This report analyzes how Assembly Bill (AB) 32, California's Global Warming Solutions Act, will help protect California's economy from energy price spikes by reducing California's dependence on imported oil and natural gas.

Until now, most studies of the costs and benefits of AB 32 implementation have assumed smooth and steady increases in energy prices. Yet history shows that energy prices are subject to periodic spikes or "shocks." Prices in recent decades have been highly volatile. Since 1973, Americans have experienced six shocks when crude oil prices rose by an average of 84% in one year, and 120% in 18 months. This report is the first analysis that considers reduced exposure to energy price shocks as a benefit from implementation of measures detailed in the AB 32 Scoping Plan. We do this by estimating the avoided expenditures for energy that would result from a hypothetical crude oil and natural gas price shock in 2020.

Specifically, we asked: **if state agencies implement energy-related measures in California's Climate Change Scoping Plan, how much more money will California energy users save if crude oil and natural gas prices doubled in the year 2020 and remained at that level for one year?**

The analysis is based on two hypothetical but plausible price shock scenarios in year 2020:

- **Moderate shock scenario,** involving a year-long doubling of the U.S. Department of Energy's Annual Energy Outlook (AEO) 2020 reference crude oil and natural gas price forecasts ($114.50 per barrel (bbl) for crude oil and $7.43 per million british thermal units (MMbtu) for natural gas).
- **Large shock,** involving a year-long doubling of the AEO 2020 high price forecasts ($181.18/bbl and $7.80/MMbtu).

The value of AB32-driven reductions in fossil fuels in 2020 can be viewed two ways:

- **Importation Effect:** Reduced expenditures on oil and natural gas imports into California will be $10.0 billion in 2020 at the AEO reference price forecast, and would increase to $18.8 billion in the moderate price shock, or $29.6 billion for a large price shock.
- **Retail Effect:** Reduced expenditures for transportation and electricity fuels and industrial use of natural gas, propane, and oils will range from $4.8–$9.6 billion for the moderate and large shock scenarios, respectively.[1]

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[1] These are energy savings above and beyond those at price levels implied by the AEO reference forecast, which the California Air Resources Board (CARB) has estimated to be $7.5 billion (CARB 2010, p.55). To provide an example for context, the price of gasoline is one retail price change that we investigate. The moderate shock is a $1.09 per gallon increase in gasoline, whereas the large shock is a $2.35 per gallon increase.

## a. What California Spends on Energy Imports

California’s sizable and growing demand for natural gas, oil, and refined products (e.g. gasoline and diesel) far exceeds in-state production, leaving California increasingly dependent on oil and natural gas imports. In this report, imports refer to supplies originating outside California, which includes both neighboring states and foreign countries.

In 2006, California used the energy equivalent of 593 million barrels of oil to power its cars, trucks, planes, buildings, and industry. California’s offshore oil rigs and onshore wells produced about 265 million barrels—less than half of what was consumed. **In 2006, California therefore imported about 328 million barrels of oil for its own use. At the current price of about $75 per barrel, this is equivalent to spending $25 billion annually, or $68 million each day.** The dependence on imported natural gas is even greater: nearly nine of every ten cubic feet (87%) used in California is imported.

California’s energy imbalance is growing. California’s oil production has been on a steady decline since its peak around 450 million barrels in the mid-1980s. While Alaskan oil initially made up the difference for California-based refiners, Alaskan production has also declined rapidly, and is expected to continue to decline.

## b. Valuing AB 32 Benefits: Importation Effect

By 2020, the total oil-based energy use for transportation fuels and other oil uses is expected to be the equivalent of 614 million barrels per year (mb/y), up from 576 mb/y projected for 2012 in the absence of AB 32 implementation. Given declining in-state and Alaskan oil production, California will increase oil purchases from foreign countries and neighboring states.

The value of California energy imports in 2020 will depend on two factors: (a) prices of crude oil and natural gas, and (b) in-state fuel production. If energy prices are at the AEO-forecast reference price ($114.50 per barrel for crude oil), and California production declines at the rate experienced over 2006–2008 (-2.17% per year), **without any AB 32 measures, the oil import bill in 2020 would be $49.2 billion**.[2] Import expenditures increase substantially in the energy price shock scenarios that we investigate.

Adding natural gas to the picture reveals that California’s reliance on fossil-fuel energy imports is even more severe. Without AB 32 implementation, expenditures for natural gas imports into California will be $11.6 billion for the AEO-forecast reference price. California is likely to continue to import $60.9 billion (AEO reference price) to $94.2 billion (AEO high price) worth of crude oil and natural gas in 2020. Under worst-case conditions, with a large price shock, slowing in-state production, and steady consumer demand, **California would spend up to $182.7 billion in 2020 to import oil and gas, which equates to nearly $13,000 per household.**

The good news is that **AB 32 can reduce the amount that Californians pay for out-of-state crude oil and natural gas by $10 billion in 2020**, assuming AEO-forecast reference prices. **If California experiences price shocks in 2020, the AB 32 benefit of avoided importation expenditures would be from $18.8 billion to $29.6 billion, respectively, in the event of moderate and high price shocks.** This is based on an estimate that AB 32 measures implemented by 2020 will avoid energy demand equivalent to 75 million barrels of oil and 189 trillion BTUs (TBtus) of natural gas.

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[2] All dollar values in this report are in year 2007 dollars, indicated by “$2007” in charts and tables.

## c. Valuing AB 32 Benefits: Retail Effect

We consider what we refer to as “retail effects,” the higher expenditures for most of the primary fuels combusted in the California economy, including gasoline, jet, and diesel fuel for transportation and industrial use of natural gas, propane, and a suite of derivates of crude oil. **Under energy price shock conditions, this avoided energy demand due to AB 32 measures would save people and businesses buying gasoline, diesel, jet fuel, propane, natural gas, and industrial oil between $4.8–$9.6 billion beyond the savings already reflected in other macroeconomic studies. This range amounts to $332–$670 in savings** for the average California household in 2020 taking into account population growth.

In its updated economic analysis, CARB estimates that AB 32 would save consumers $7.5 billion in energy expenditures. These results are based on the AEO mid-range price forecast for 2020. Retail effects savings under price shock circumstances are in addition to the $7.5 billion that CARB estimated at lower energy prices. The importation effects for crude oil are extrapolated from the same gasoline and diesel consumption figures used to estimate retail effects. Similarly, the same natural gas data are used in both retail and importation effects analyses. In essence, the retail and importation effects are two different perspectives on the same energy savings. As a result, the two sets of numbers should be considered separately; they cannot be summed for a total benefit.

## d. Conclusions

We define “energy economic security” as reduced exposure to fossil fuel price spikes, and then proceed to analyze this yet-to-be quantified benefit of California’s Climate Change Scoping Plan. The macroeconomic analyses that dominate the discussion of economic impacts ignore the vulnerabilities imposed by California’s dependence on imported oil and natural gas. To begin to fill the gap in our understanding of the full benefits of AB 32, we calculate the savings that would follow under price shock conditions due to reduced reliance on fossil fuels like crude oil and natural gas. We quantify this benefit in terms of both avoided consumer spending (retail effects) and reduced dependence on imported energy (importation effects).

Our research puts the value of increased energy economic security from AB32 measure in the tens of billions of dollars. Our findings should be considered conservatively low for several reasons. We do not consider price increases in consumer goods that result from energy price shocks, nor do we analyze a shock lasting beyond one year in length, even though three of the five most recent shocks resulted in prices that were more than double the starting point after 24 months. Finally, the only costs we consider are direct costs—our analysis captures none of the indirect costs that would ripple through the economy when the next oil disaster, outbreak of war, or some other unpredictable event causes oil prices to jump.

# 1. INTRODUCTION

Policies that help California respond to global warming also will help to buffer the effects of future energy price spikes, as they will lower the state's dependence on imported energy supplies that are priced by global demand. In this report, we quantify the benefits California will gain from reduced exposure to an oil price shock in 2020 from implementation of AB 32 measures. Specifically, we've created a quantitative model[3] that builds on the existing macroeconomic forecasts by California's Air Resources Board and the U.S. Energy Information Administration and represents different views about future prices and how Californians will respond to price shocks. We analyze two perspectives when quantifying the energy economic security benefits of AB 32:

1. ***Retail effects***: The avoided payments by energy consumers, such as drivers buying gas, airlines purchasing jet fuel, and industrial facilities obtaining boiler oil.
2. ***Importation effects***: The avoided value of energy imports, which is the difference between California energy demand and in-state production.

## a. Overview of Report

This first chapter surveys the history of energy prices and describes how AB 32 will reduce energy demand in 2020. Chapters 2 and 3 provide estimation of previously unaccounted for economic energy security benefits of AB 32 from the two perspectives detailed above—retail and importation effects. The Conclusion, Chapter 4, provides context for the quantitative analysis, including the observation that this report has only illuminated direct savings to the economy; the total would be much larger when indirect effects are considered. Appendix A provides a detailed explanation of our methods. Appendix B discusses the existing literature on the economic impacts of AB 32 with a focus on a set of three recently completed macroeconomic studies. Appendix C offers some discussion on the many additional benefits that will be gained from acting swiftly and effectively to fight climate change, including a reduced likelihood of the worst effects of global warming, co-pollutant reductions, and new opportunities for innovators and entrepreneurs.

## b. Energy Price History and Future Price Shocks

Debates about when oil would reach its maximum production rates began in the 1950s, and truly entered the minds of American consumers in the early 1970s[4]. The past 40 years reveal the high volatility of crude oil and natural gas prices and a history of dramatic price increases. As shown Figure 1-A and Table 1-A, in the past 40 years Americans have experienced six significant gas price shocks following spikes in the world oil market.

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[3] Statewide Holistic Oil Cost Kalculator (SHOCK). The SHOCK model contains energy use information only for California, so we call this version SHOCK-CA.

[4] Most famous is the work of M. King Hubbert for the U.S. Geological Survey in the 1940s and 1950s. For examples, see Hubbert, 1949, or Hubbert, 1956, and anonymous opinion, "Is Oil Nearing a Production Crisis?" in *Petroleum Week*, 1956. References in this footnote from www.hubbertpeak.com/hubbert/Bibliography.htm, last visited July 14, 2010.

**Table 1-A:** Major Crude Oil Price Shocks

(Source: EIA Petroleum Price Data, Authors' Calculation)

| **Shock Year** | **Notable Events** | **Nominal Change in the Price of Crude Oil in 13th Month** | **Nominal Change in the Price of Crude Oil in 18th Month** |
|---|---|---|---|
| 1973 | OPEC oil embargo, Arab-Israeli Yom Kippur War | Not available[5] | NA |
| 1979 | Iranian Revolution, OPEC production decline | 89% | 127% |
| 1990 | Iraqi invasion of Kuwait, Gulf War | 22% | 34% |
| 1999 | Rebound from Asian Financial Crisis | 175% | 222% |
| 2003 | Oil scarcity fears, Middle East hostilities, and Price Speculation | 59% | 59% |
| 2008 | Middle East hostilities, Iraqi & North Korean nuclear scares, Hurricane Katrina | 77% | 158% |
| Average | | 84% | 120% |

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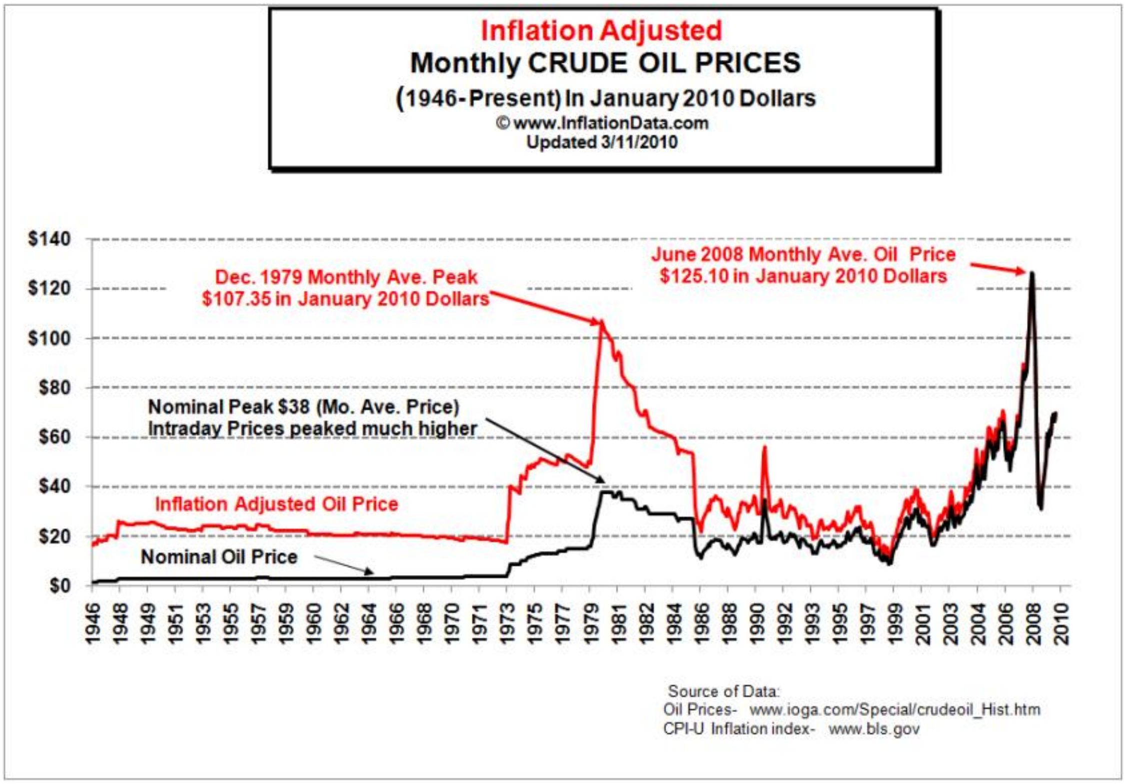
[5] We exclude the 1973 shock from the table because we have not been able to locate monthly price data, but the magnitude of the shock appears to have been about the same as the others.

**Figure 1-A:** Inflation-Adjusted and Nominal Crude Oil Prices, 1946–2010 (prices in 2010 dollars)

*The price of crude oil has risen and fallen dramatically during the past five decades.*



Source of Data:
Oil Prices- www.ioga.com/Special/crudeoil_Hist.htm
CPI-U Inflation index- www.bls.gov

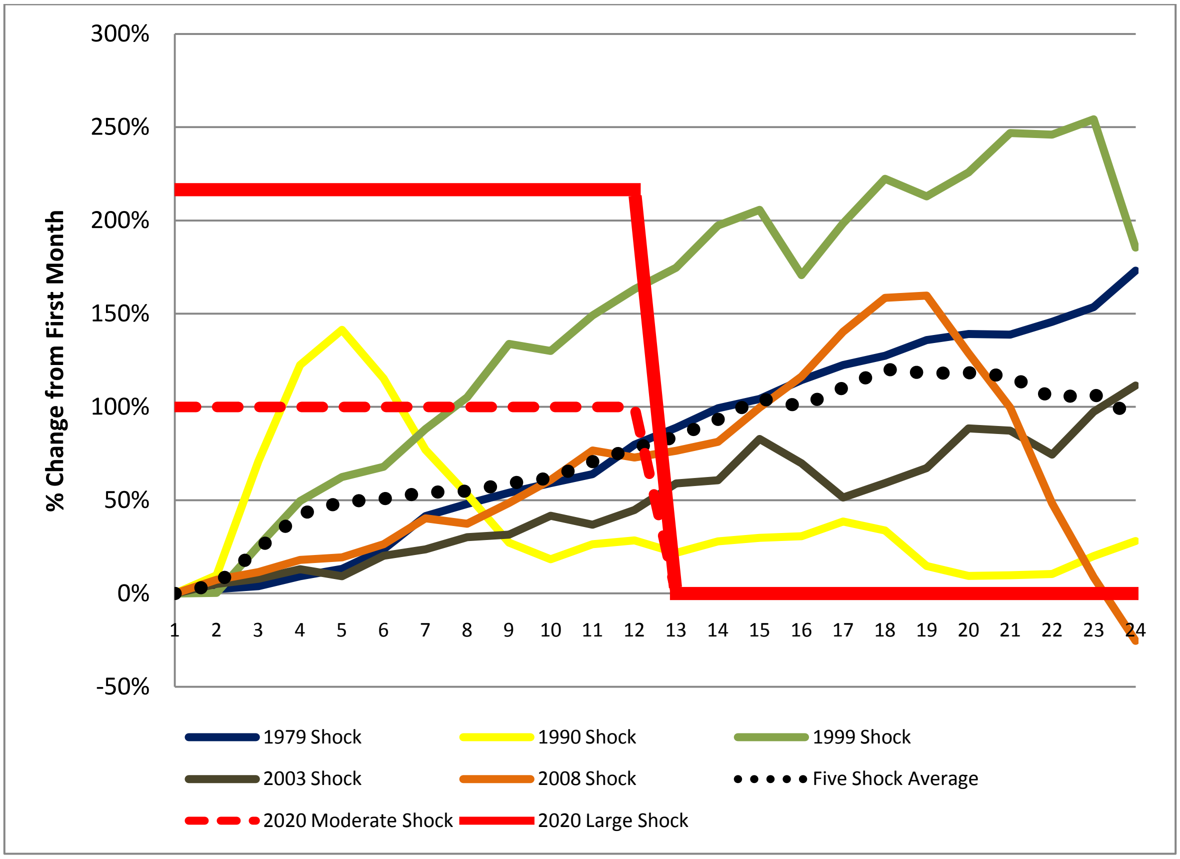
During the last five price shock events, crude oil prices increased by an average of 84% after one year and 120% after 18 months (see Table 1-A). In the face of such a precipitous rise, drivers had little opportunity to adjust behaviors.

Our hypothetical 2020 price shock scenarios are informed by our research into price shocks, but differ somewhat in magnitude and duration from the historical record. The definition of a price "shock" in our analysis is an instantaneous doubling of wholesale crude oil and whole natural gas prices on January 1, 2020 that remains at that level for a full year. As Figure 1-B indicates, our two shock scenarios involve steeper price increases, but a period of high prices that is shorter than past shocks, as we consider a simple one-year jump for analytical clarity and tractability. To better represent a 2020 shock that behaves like past shocks, our calculus should consider a doubling of prices for two years rather than one. In this respect, our hypothetical scenarios produce conservatively low results.

### **Figure 1-B:** Crude Oil Price Shocks, 1979–2009 in Inflation-Adjusted Dollars, & Hypothetical 2020 Price Shocks

*The last five price shocks were marked by steady increases in prices for a period up to 24 months, but our hypothetical shocks last exactly 12 months; our estimates are thus more conservative than may be expected in the face of an actual oil shock.*

(Source: Authors' calculations, EIA data.)



American concern about energy price shocks, dependence upon imported fossil fuel, and dwindling oil supplies has been expressed in speeches by every President since Nixon.[6] Past price shocks, as well as political rhetoric about energy independence, were—and likely will continue to be—the consequences of political tensions, including wars; and non-competitive behavior, notably collusion by oil-producing countries. New technologies, regulatory interventions, and unseen innovation will also present both new supplies and environmental and financial risks.

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[6] See EDF video: "A Plea to President Obama: 40 Years and Still No Action" at http://climateprogress.org/2010/07/09/edf-video-climate-and-clean-energy/ last visited Sept. 1, 2010.

### c. AB 32 Scoping Plan

AB 32 requires California to cap its global warming pollution emissions at 1990 levels by 2020. While a variety of existing state and federal measures will help reduce California's dependence on conventional energy supplies, they are not sufficient to bring the state's greenhouse gas emissions down to 1990 levels. The AB 32 Scoping Plan lays out measures to put the state on track to meet its economy-wide pollution-reduction commitment, including by reducing overall energy use, as shown in Figure 1-C.[7] The California Air Resources Board (CARB) is the lead agency charged with implementing the AB 32 Scoping Plan measures.

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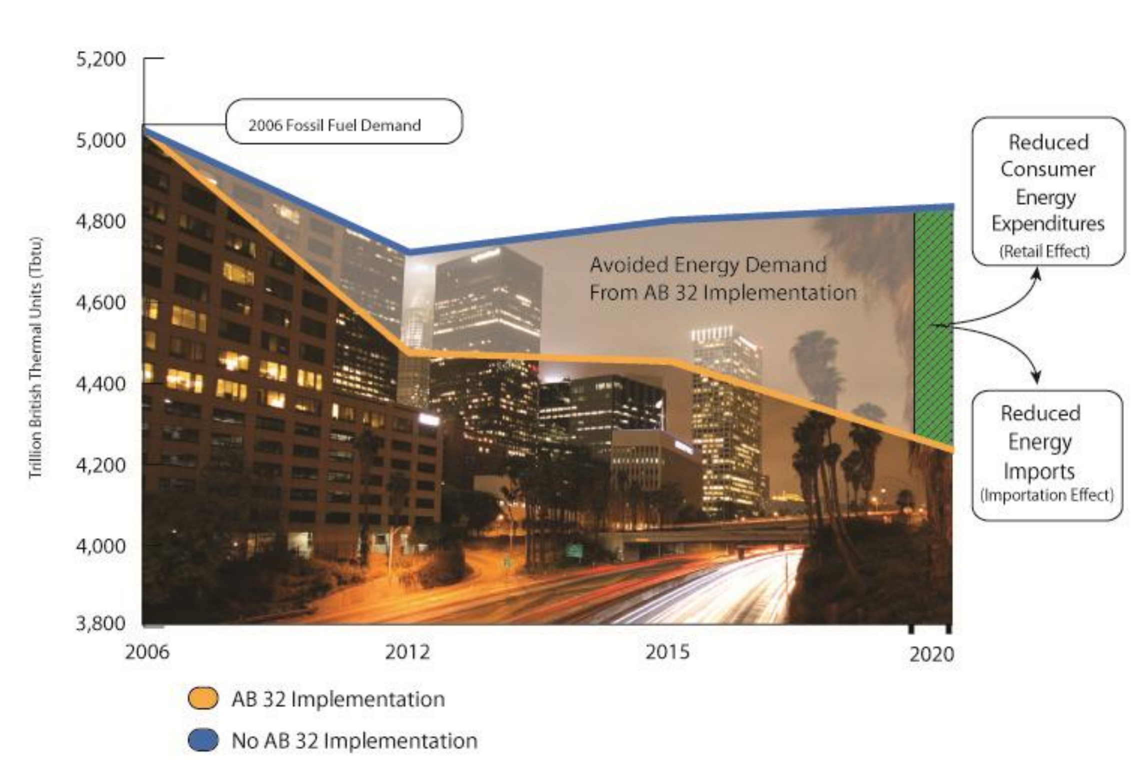
**Figure 1-C:** Reduced Fossil Energy Demand from AB 32 and Two Quantification Perspectives of this Report

*Lines show California energy demand with and without implementing AB 32 measures. This study examines the value of the difference in total energy demand in terms of expenditures for energy imports into California, and retail energy expenditures. Energy demand presented here does not include electricity imported from other states.*

(Source: CARB data, J. Kravitz)



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[7] The Scoping Plan is available at http://www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm

AB 32 policies will lead to the adoption of lower-carbon fuels, more-efficient vehicles, better-performing appliances, and high-tech homes, as well as greater use of clean, safe, domestic renewable fuels like electricity generated from the sun and wind (see Figure 1-D). As a result, California will reduce its dependence on conventional energy supplies, and thereby decrease its collective exposure to economic damage from sharp, rapid increases in global prices for conventional sources of energy.[8] We refer to this benefit of insulation from fossil-fuel price shocks as an improvement in "energy economic security." We quantify the energy economic security benefits of AB 32 by developing a hypothetical spike in oil and natural gas prices to estimate the savings to the California economy that will be realized once the AB 32 Scoping Plan measures are implemented.

By 2020, clean energy and conservation policies inspired by the need to tackle climate change will mean less overall energy demand in California.[9] For California, the AB 32 Scoping Plan lays out measures that, in addition to those already implemented at the state or federal level, cap emissions at 1990 levels. Achieving this emissions cap will translate into avoided costs for transportation fuels, as well as avoided costs for natural gas, propane, and fuels derived from petroleum.

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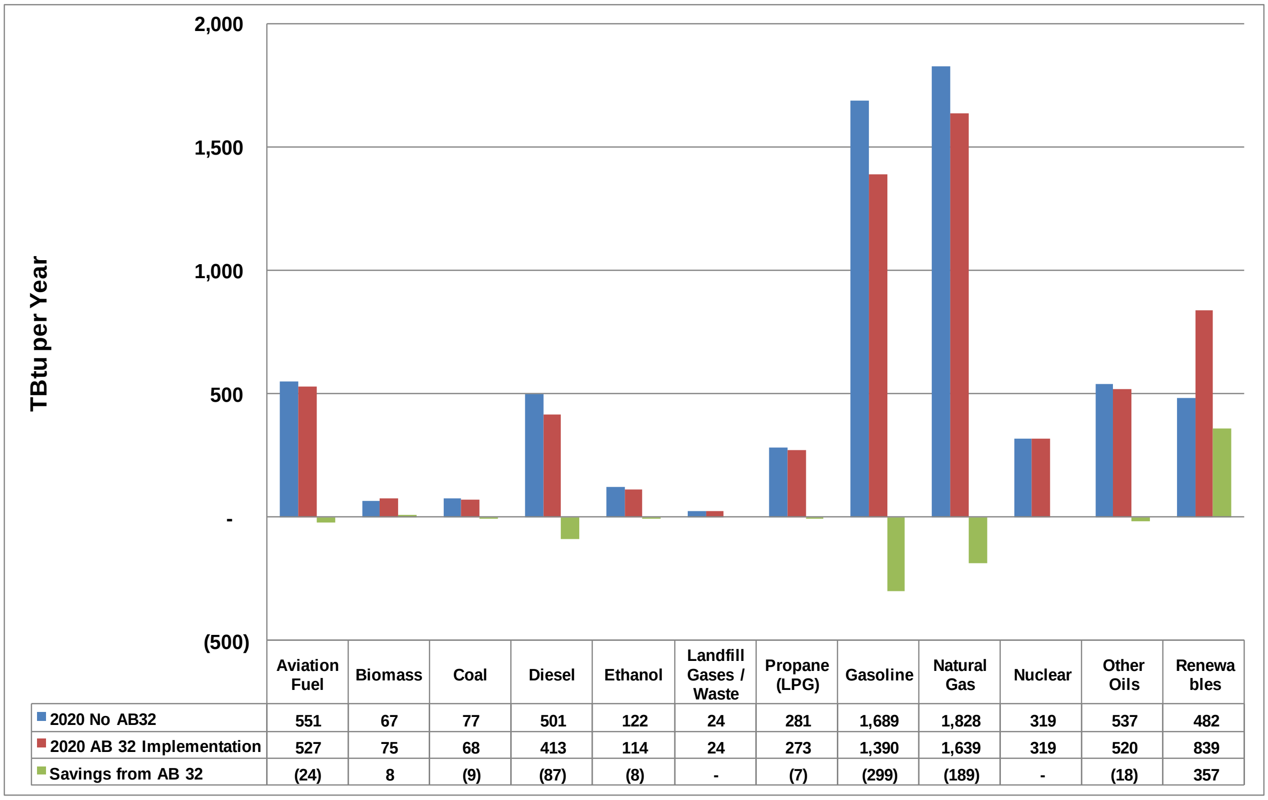
[8] A more diversified energy supply for California will hedge against conventional price shock effects, and diversification is a good risk management strategy in general. However, we recognize that increased use of renewable energy and other non-conventional approaches could themselves introduce some price risk. Solar, wind, and geothermal energy do not themselves carry a price tag. Nonetheless, the equipment needed to capture them requires imported materials.

[9] For a specific example, consider more-efficient cars on the road driving fewer miles and using less carbon intensive fuels, saving about 300 TBtu, which is 2.4 million gallons of gasoline.

## **Figure 1-D:** Statewide Energy Demand Forecast With and Without Implementation of AB 32

*AB 32 measures will reduce demand for primary fossil fuels, partly by using more renewable fuels.*

(Source: CARB, Updated Economic Impact Analysis of the Climate Change Scoping Plan)[10]



| | Aviation Fuel | Biomass | Coal | Diesel | Ethanol | Landfill Gases / Waste | Propane (LPG) | Gasoline | Natural Gas | Nuclear | Other Oils | Renewables |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 🟦 2020 No AB32 | 551 | 67 | 77 | 501 | 122 | 24 | 281 | 1,689 | 1,828 | 319 | 537 | 482 |
| 🟥 2020 AB 32 Implementation | 527 | 75 | 68 | 413 | 114 | 24 | 273 | 1,390 | 1,639 | 319 | 520 | 839 |
| 🟩 Savings from AB 32 | (24) | 8 | (9) | (87) | (8) | - | (7) | (299) | (189) | - | (18) | 357 |

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[10] These forecasts by CARB are inputs to our study and are drawn directly from CARB's Updated Economic Impact Analysis of California's Climate Change Scoping Plan (CARB 2009). Starting on page 21, CARB provides detailed a description of assumptions about what measures will be implemented due to AB 32. The case without AB 32 implementation considers the following measures to be in place:
- 20% Renewable Portfolio Standard
- Vehicle emissions performance standards established in AB 1493 ("Pavley I")
- Federal appliance standards
- Federal renewable fuels standard

CARB also presents, for both AB 32 and no-AB 32 cases, emissions and energy use by sector, and by electricity generation energy source (Table 7).

Figure 1-E shows the fossil fuel energy demand that is included in our analysis—total forecasted California demand in 2020 after the implementation of AB 32. It shows the proportion of the total demand covered by our analysis and also illustrates that, even after AB 32 reductions, California is still expected to consume large quantities of fossil fuels.

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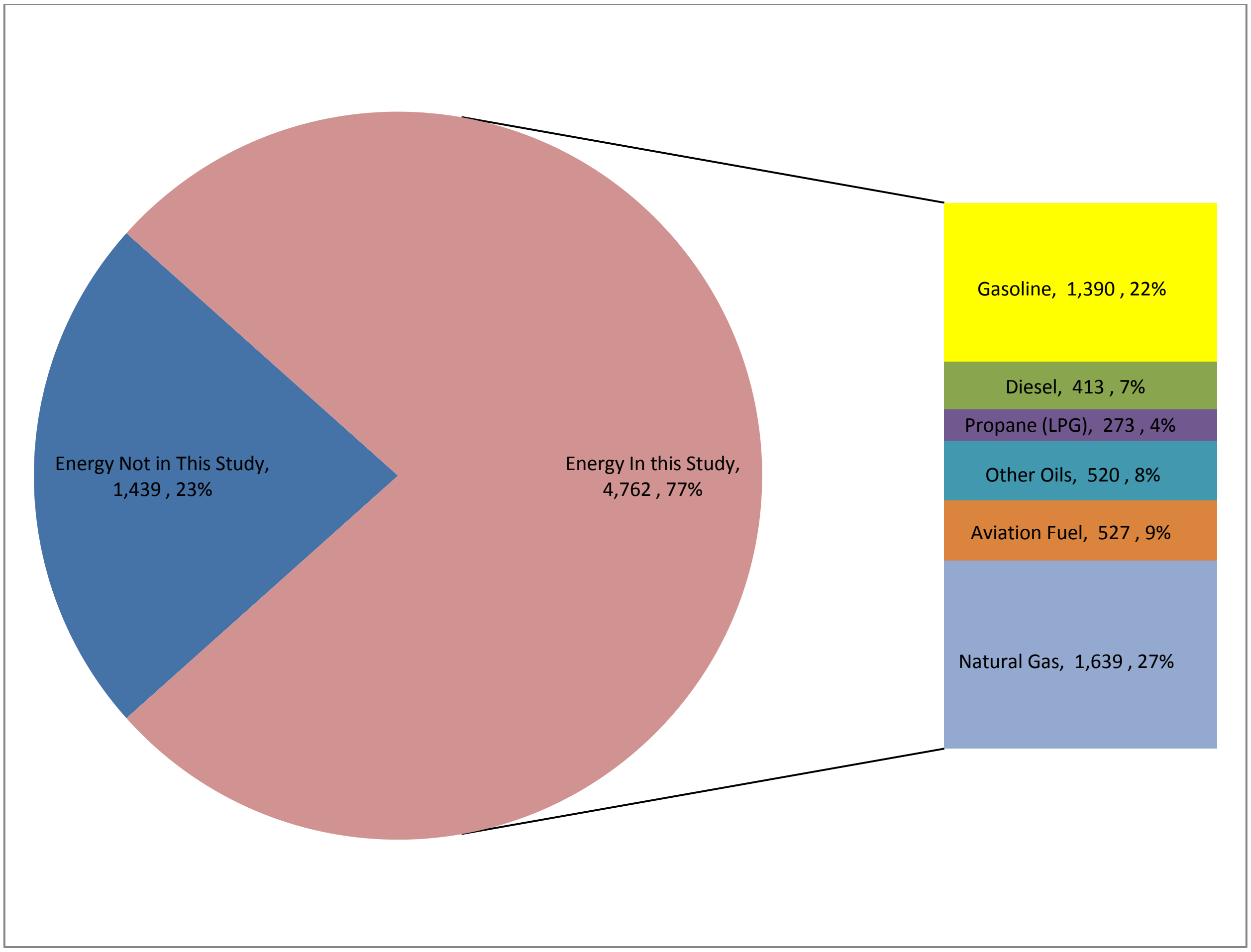
**Figure 1-E:** Total California Energy Demand in 2020 with AB 32 Implementation (TBtu, %Total)

*Even after AB 32 reductions, California will still consume large quantities of fossil fuels, but the percentage of fossil fuels will be lower with AB 32. Also, this study covers most of California primary fossil fuel use for 2020.*

(Source: CARB, Updated Economic Impact Analysis of the Climate Change Scoping Plan)



### d. Retail Effect Benefits

In Chapter 2, we focus on "Retail Effects," which are the fuel costs Californians will avoid as a result of AB 32 in the case of our oil price shock scenarios. In CARB's analysis at the AEO reference price, savings on energy will amount to $7.5 billion. We find that, in the event of fuel price spikes, the implementation of the AB 32 Scoping Plan will deliver additional savings of $4.8 billion to $9.6 billion in avoided fuel costs above and beyond the $7.5 billion estimated by CARB.

We emphasize that these are only the direct benefits, not counting ripple effects on the economy as a whole. These potential benefits, like all those characterized in this report, are direct results of AB 32 implementation (except to the extent that other state policy, or federal policy, inspires the same measures to avoid energy use and diversify energy supply).

### e. Importation Effect Benefits

In addition to a "retail effect" of consumer welfare losses due to higher energy prices, a second potential consequence of less energy use in California is reduced dependence on imported crude oil and natural gas. Currently, California imports more than half of the crude oil used, and nearly 90% of natural gas.[11] In Chapter 3, we estimate the monetary value of avoided crude oil and natural gas imports that will be avoided in 2020 after the AB 32 Scoping Plan measures have taken effect—the importation effect.

As a result of AB 32, for the year 2020, we estimate that California's importation of crude oil will fall by 18% (75 billion barrels of oil not imported) and importation of natural gas will fall by 10% (189 TBtu of natural gas not imported).The savings on oil and natural gas imports amounts to $10.0 billion (at the AEO reference price). In the moderate and large price shock scenarios, savings are nearly double: $18.8 billion and $29.6 billion, respectively. Some of these savings will translate into lower profits for energy companies and their shareholders, a consequence we do not attempt to calculate.

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[11] Sheridan, M. (2006), and CEC, (2009a, pg. 132.

## 2. RETAIL ENERGY PRICE SHOCKS

This chapter provides a *retail* perspective on the energy cost savings that AB 32 would provide in the instance of a price shock. We ask the central question: *without implementation of AB 32 measures, how much more money will California energy users pay in the year 2020 if wholesale crude oil and natural gas prices double and remain at that level for one year?* We conclude that Californians will spend \$4.8–\$9.6 billion more on energy, or between \$332–\$670 on average per California household.[12]

### a. Hypothetical Energy Price Shocks and Demand Responses

We estimate retail energy price changes in California that might follow from the doubling of crude oil and wholesale natural gas prices, which are set at the national or international level. We use statistical techniques to describe quantitatively how retail energy prices change in California when wholesale prices change. Using AEO fuel price forecasts, we use regression analysis to develop a mathematical relationship between changes in crude oil price and changes in the California retail prices for gasoline, diesel, propane, aviation fuel, and industrial oil prices. Similarly, we use the same statistical technique, regression analysis, to develop a mathematical relationship between forecast ("Henry Hub"[13]) wholesale natural gas prices and industrial retail natural gas prices. The wholesale and retail price shocks are summarized in Table 2-A. Appendix A has more detail about how wholesale price shocks are felt by retail customers in California.

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[12] Based on California Department of Finance projection of 44.1 million California residents, 14.4 million households in 2020.

[13] "Henry Hub" is the point in Louisiana's natural gas pipeline at which the New York Mercantile Exchange (NYMEX) sets prices for natural gas futures.

### **Table 2-A:** Fuel Prices: Inputs and Shock Scenario Assumptions

*This table details AEO forecasted oil and natural gas prices and associated retail energy prices in California, and price changes in the two price shock scenarios. All values are in 2007 dollars.*

(Source: SHOCK-CA)

| | **Initial AEO Forecast (price)** | **Moderate shock (change)** | **Moderate shock (price)** | **Large shock (change)** | **Large shock (price)** | **Units** |
|---|---|---|---|---|---|---|
| **Crude oil and Henry Hub natural gas prices** | | | | | | |
| Crude oil | 114.50 | 114.50 | 229.0 | 247.86 | 362.36 | $2007/ barrel |
| Natural gas | 7.43 | 7.43 | 14.86 | 7.80 | 15.23 | $2007/MMbtu |
| **California retail energy prices** | | | | | | |
| Gasoline | 3.42 | 1.09 | 4.51 | 2.35 | 5.77 | $2007/gallon |
| Diesel | 6.44 | 1.21 | 7.66 | 2.63 | 9.07 | $2007/gallon |
| Propane | 2.54 | 0.84 | 3.37 | 1.81 | 4.35 | $2007/gallon |
| Other oils | 3.40 | 1.21 | 4.61 | 2.63 | 6.02* | $2007/gallon |
| Aviation | 2.61 | 1.05 | 3.66 | 2.28 | 4.89 | $2007/gallon |
| Natural gas | 0.0125 | 0.0081 | 0.0206 | 0.0089 | 0.0214 | $2007/cubic ft |

**Numbers may not sum due to rounding errors.*

*Driver Fueling Costs During Price Shocks*

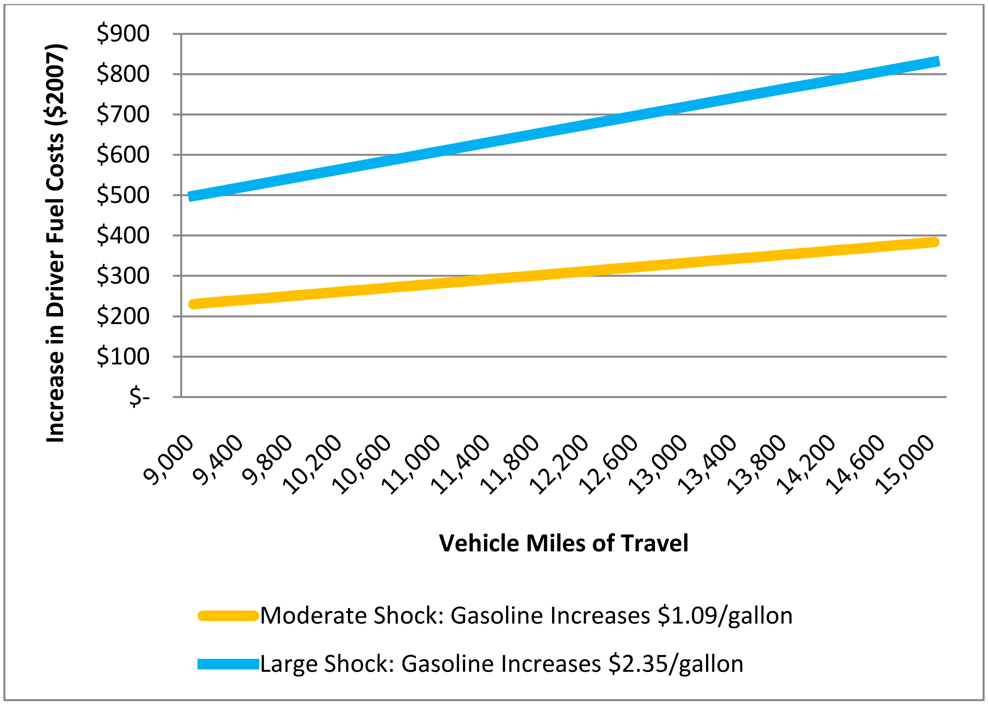
People and businesses that depend on driving are particularly vulnerable to energy price shocks. CARB estimates that AB 32 policies will save Californians nearly $2 billion per year in reduced vehicle miles of travel, and another $1.7 billion annually in reduced fuel expenditures due to vehicle greenhouse gas emissions standards. The CARB analysis assumes a steady increase in the price of fuel, without consideration of the additional economic impacts energy price shocks. Our report quantifies the additional savings to California consumers in the event of a price shock.

When a price shock hits, California drivers will spend more money at the pumps. The magnitude of extra expenditures will depend on vehicle miles driven and individual vehicle fuel efficiency. Using CARB's estimate that the fuel efficiency of the 2020 California vehicle fleet will be 42.5 miles per gallon, we estimate a cost range for the moderate and large price shocks by vehicle miles of travel (see Figure 2-A). Rather than adjusting miles driven to reflect drivers' demand elasticity, we show costs according to miles driven while holding fuel efficiency constant. The chart shows, for example, for the average driver covering 12,000 miles annually, moderate and large price shocks will translate into costs ranging from $306 to $664, respectively.[14]

**Figure 2-A:** Driver Cost Impacts from Price Shocks ($2007 billions)

*The impact of a price shock can be translated into fueling costs for drivers. For a driver that covers 12,000 miles in 2020 in a car that gets 42.5 miles per gallon, the hypothetical shocks will increase fueling costs by $306 to $664 in a moderate and large shock, respectively.*

(Source: SHOCK-CA)



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[14] Based on a California passenger vehicle fleet-wide average fuel efficiency of 42.5 mpg in 2020 (current fleet mix average is about 25 mpg).

*Demand Declines in Response to Price Shocks*
In addition to energy price changes, the second key analytical component is the change in energy usage due to AB 32 implementation. California's clean and renewable energy strategies will result in lower demand for energy derived from oil and natural gas. The economics literature refers to the variable we are interested in as the "price elasticity" of demand; it can be thought of as the responsiveness in a variable (like energy demand) to changes in another variable (like energy price). More technically, price elasticity of demand is the ratio of the percentage change in demand over the percentage change in price. We searched the literature for elasticity values and have sought to capture low, middle, and high estimates. We generated results using the three values as a method of showing the sensitivity of our findings to this one influential input assumption. The specific values used in the analysis are shown in Table 2-B.

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### **Table 2-B:** Range of Elasticity Values and their Sources

*Demand for various fuel types will change differently when energy prices spike. We surveyed the research literature to identify the highest and lowest values and then used them in the moderate and large shock scenarios.*

(Sources: Vitoria Transport Policy Inst., Haigler Bailly 1999, Espey 1998, Goodwin et al 2004, and Dale et al 2009)

| **Short Term Price Elasticity of Demand** | **Low** | **Mid** | **High** |
|---|---|---|---|
| Gasoline | -0.03 | -0.15 | -0.34 |
| Diesel | -0.05 | -0.1 | -0.15 |
| Propane | -0.10 | -0.15 | -0.20 |
| Other Oils | -0.03 | -0.15 | -0.34 |
| Aviation | -0.05 | -0.1 | -0.15 |
| Natural Gas | -0.05 | -0.11 | -0.25 |

### b. Findings about Retail Effects

Our findings represent uncertainty about the value of benefits across a range of possible values. We bring together two different dimensions of uncertainty: (1) the size and duration of retail energy price increases in California, and (2) how energy users respond to the price increase by reducing their demand. This is called global sensitivity analyses, exploring the implications of different combinations of assumptions simultaneously. The lowest result follows from a doubling of the AEO reference price and a larger reduction in energy use due to the increase in energy prices (i.e. an assumption of a larger price elasticity of demand). The highest impact follows from a combination of a larger price shock and a smaller reduction in energy use due to that price increase (i.e. an assumption of a smaller price elasticity of demand).

Having explained our input assumptions (Tables 2-A and 2-B), our findings for the retail price shock impacts are summarized in Tables 2-C and 2-D.

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**Table 2-C:** AB 32 Savings from Reduced Expenditures in Price Shocks

*In a moderate price shock with high price elasticity of demand, Californians will avoid $4.8 billion in energy costs. In a large shock with low demand elasticity, the avoided energy costs will be $9.6 billion.*

(Source: SHOCK-CA)

| | **Price Elasticity of Demand ($2007 billions)** | | |
|---|---|---|---|
| **Fuel Price Scenario** | Low | Mid | High |
| Large Shock | $9.6 | $9.0 | $8.1 |
| Moderate Shock | $5.2 | $5.0 | $4.8 |

We find that AB 32 will save energy users $4.8-$9.6 billion (in $2007) if crude oil and natural gas prices doubled suddenly in 2020.

In Table 2-D, we translate the above benefits to the household level by dividing the California Department of Finance–forecasted 2020 population (44.1 million people) by forecasted households (14.4 million), which yields an average household composition of 3.07 people. These are broad-stroke numbers that do not reflect sector-specific energy demand, but are informative for comparison, and do show expenditure increases of up to $670 per home. This is the same magnitude of household costs that several studies predict of California and federal climate policies, as discussed in Appendix A.

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### **Table 2-D:** Average Household AB 32 Savings from Reduced Expenditures in Price Shocks

*The average California household will save $332 in a moderate shock with high demand response, and $670 in a large shock with low demand response.*

(Source: SHOCK-CA)

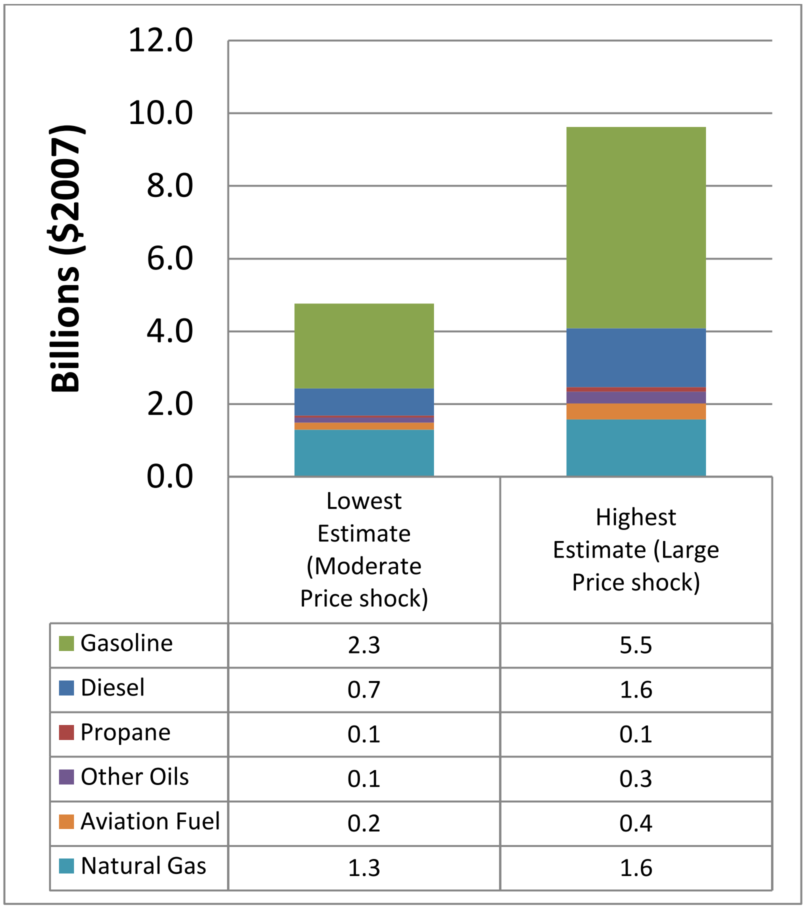
| | Price Elasticity of Demand ($2007) | | |
|---|---|---|---|
| Fuel Price Scenario | Low | Mid | High |
| Large Shock | $670 | $626 | $561 |
| Moderate Shock | $362 | $350 | $332 |

Our results indicate the largest savings will be realized by users of natural gas, gasoline, and diesel fuel. This is not surprising since these are three of the four most consumed fuels in California (see Figure 2-B). Aviation fuel is not included in the study since the aviation industry is not regulated under AB 32. Benefits from avoided natural gas use range from $1.3–$1.6 billion, whereas gasoline savings are larger, ranging from $2.3–$5.5 billion in the moderate and high-price cases. The jump in natural gas prices in the large price shock scenario is smaller because the AEO high price forecast for natural gas is not much higher than the reference price forecast, unlike the case of crude oil, where the AEO high price forecast is almost 50% higher than the reference price.

**Figure 2-B:** AB 32 Savings by Fuel Type from Reduced Expenditures in Price Shocks ($2007 billions)

*The total reduction in expenditures for moderate and large price shock in year 2020 will be reduced by AB 32 measures. These reduced expenditures can be attributed to specific fuel types.*

(Source: SHOCK-CA)



| | Lowest Estimate (Moderate Price shock) | Highest Estimate (Large Price shock) |
|---|---|---|
| Gasoline | 2.3 | 5.5 |
| Diesel | 0.7 | 1.6 |
| Propane | 0.1 | 0.1 |
| Other Oils | 0.1 | 0.3 |
| Aviation Fuel | 0.2 | 0.4 |
| Natural Gas | 1.3 | 1.6 |

### c. Conservatively Low Findings

The findings of this report should be considered conservatively low. Estimated savings are for only a one-year doubling using AEO price forecasts, which may underestimate the duration and magnitude of future price shocks. Also, the AEO high price forecast seems low in light of recent prices. Furthermore, the history of price shocks suggests that, while prices are not likely to double instantaneously (as we have assumed for analytical simplicity), they have doubled during the course of a year, and then doubled again in the second year. The 1999 price shock involved a doubling of crude oil prices within seven months, and prices continued to rise until they peaked at over 350% of the starting price after 23 months. Similarly, both the 1979 and 2003 price shocks involved prices that were still rising after 24 months.

There are some arguments to consider that are suggestive of lower net benefits than we estimate. For example, like CARB, we do not consider near-term events, such as a prolonged recession or a potential price shock event before 2020. Both would lower energy demand (with or without AB 32 implementation) and thus reduce the magnitude of benefit we calculate. Also, we do not consider a possible reversal in the trend of declining production in California due to some new technical innovation. We do not represent a sudden large increase in fossil-fuel supplies outside of California due to an unexpected engineering innovation or new discovery. We do not represent any “rebound” whereby producers respond to high energy prices by increasing production, oversupplying and thus causing energy prices to drop, briefly, below long-term average prices. Only one of six price shock events that we studied had prices at the end of 24 months that were lower than initial prices (see Figure 1-B). Also, we do not consider the effects of federal legislation. Of course, federal policy would offer energy economic security benefits.

We do not attempt to forecast the cause of the future price shock. Certainly, any of myriad events might unfold: localized refinery accidents, oil extraction disasters (like the BP oil spill in the Gulf of Mexico), international supply ripples, war in petroleum-producing nations, or collusion amongst producers. We choose not to attempt to develop a highly complicated method to predict future oil and gas prices and how these and other factors could affect future energy prices in California.

Instead of predicting future causes of price shocks, we look at historical data and see that oil price shocks have occurred. Similarly, we recognize that natural gas price dynamics are complicated, but that natural gas prices have at times moved in similar ways to crude oil prices. Our simplified approach is to explore a doubling of both crude oil and natural gas prices. We discuss the complex relationship between oil and natural gas prices further in Appendix B.

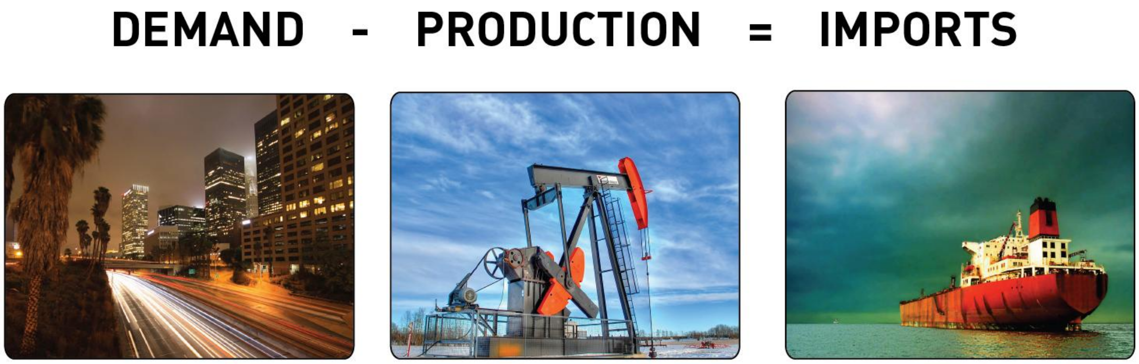
We do not attempt to predict the likelihood of either price spike, nor do we suggest that the price range we use represents a statistical confidence interval. Critical reviewers might argue the likelihood of a sudden price doubling is lower when reference prices are high. At first brush, this observation suggests that the high end of our estimated range is less likely than the low end. However, the AEO price ranges are not ascribed with probabilities, so there is no reason to assume that (a) the mid price is a median, or (b) the uncertainty is best described as a normal distribution. When considering growing energy demand in other very large nations, notably China and India, lack of recent discoveries of major new conventional fuel reserves, and the ongoing prospect of production and refining interruptions due to bad weather or political conflict, we believe that the realized crude oil price in 2020 is more likely to be akin to the AEO high price forecast than the AEO reference price forecast, a disputable but non-resolvable viewpoint that suggests the higher avoided costs estimates are more likely.

## 3. IMPORTATION EFFECTS

California is endowed with vast and unique natural resources, including some of the most significant energy resources in the country. Yet they are not enough to meet the state's enormous demand, leaving California dependent on both oil and natural gas imports. In 2006, California used the energy equivalent of 593 million barrels of oil to power its cars, trucks, buildings, planes, and industry,[15] but the offshore oil rigs and onshore wells only produced about 265 million barrels—less than half of what was consumed.[16] The dependence on imported natural gas is even greater: around 87% of the natural gas used in California is imported.[17]

In this chapter, we examine the impact AB 32 will have on California's dependence on imported energy, using the equation shown in Figure 3-A.

**Figure 3-A:** California Energy Balance



(Source: J. Kravitz, images from Flickr Creative Commons)

This chapter calculates the amount less that California will pay for imported fuel as a result of AB 32, based upon predicted shifts in demand and in-state fuel production.

Using the AEO moderate price forecast, we find that the AB 32 Scoping Plan measures implemented by 2020 will enable California to avoid spending an estimated $10 billion on oil and gas imports to make up the difference between demand and supply. More significantly, under moderate and large price shock scenarios, the value of avoided oil and gas imports increases to $18.8 billion and $29.6 billion, respectively. During a price shock without AB 32 measures, the state's import bill could be well over $112 billion if the AEO forecasted reference price doubles during the shock. In the high price shock scenario, California would spend $182.7 billion to import energy in 2020, or nearly $13,000 per household on average. With AB 32, California would spend

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[15] For consistency with AB 32 Scoping Plan projections, this chapter uses the 2006 energy data from the AB 32 Scoping Plan to represent current conditions. We sum the primary energy use for gasoline, diesel, aviation fuel, propane, and other oil uses, (expressed in BTUs) and convert it to oil barrel BTU equivalency, to represent California oil-based energy demand. In this analysis, propane is assumed to be entirely sourced from oil products.

[16] EIA, Petroleum Production data, 1981-2010 (figure includes state and federal off-shore production)

[17] CEC, 2009a, IEPR, page 131

$153 billion to import energy in the high price shock situation—a savings of nearly $30 billion compared to the scenario without AB 32 implementation.

We emphasize that these estimates of the economic value of avoided oil and natural gas imports are based on the same energy savings estimated by CARB due to AB 32 measures and used in Chapter 2. This chapter offers a different perspective on the same benefits investigated in Chapter 2.

### a. Oil Import Exposure

Crude oil imports come to California from two sources: Alaska, via pipeline, and overseas, by tankers bringing oil to refineries near ports. The California oil picture is somewhat complicated by the fact that these refineries process more oil than California uses. Neighboring states that lack a coastline depend on California refineries for gasoline, diesel, and jet fuel. California is the sole supplier of refined crude oil and gas products, such as gasoline and diesel fuel, for Nevada, and a major supplier to Arizona via dedicated pipelines; some refined products also go to Oregon. California also imports some finished products to make up the exact mix of diesel, jet fuel, and gasoline blend stocks in different regions of California.[18] These exchanges with neighboring states do not mask the fact that California uses far more crude oil than it produces.

California’s energy imbalance is growing—the gap between in-state demand and in-state supply is growing. As shown in Figure 3-B, California's oil production has been on a steady decline since its peak around 450 million barrels in the mid 1980s.[19] While Alaskan oil initially made up the difference for California-based refiners, Alaskan production has fallen even further, and these trends are expected to continue. In all likelihood, barring any significant new domestic discoveries of oil, future California imports will come increasingly from foreign countries.

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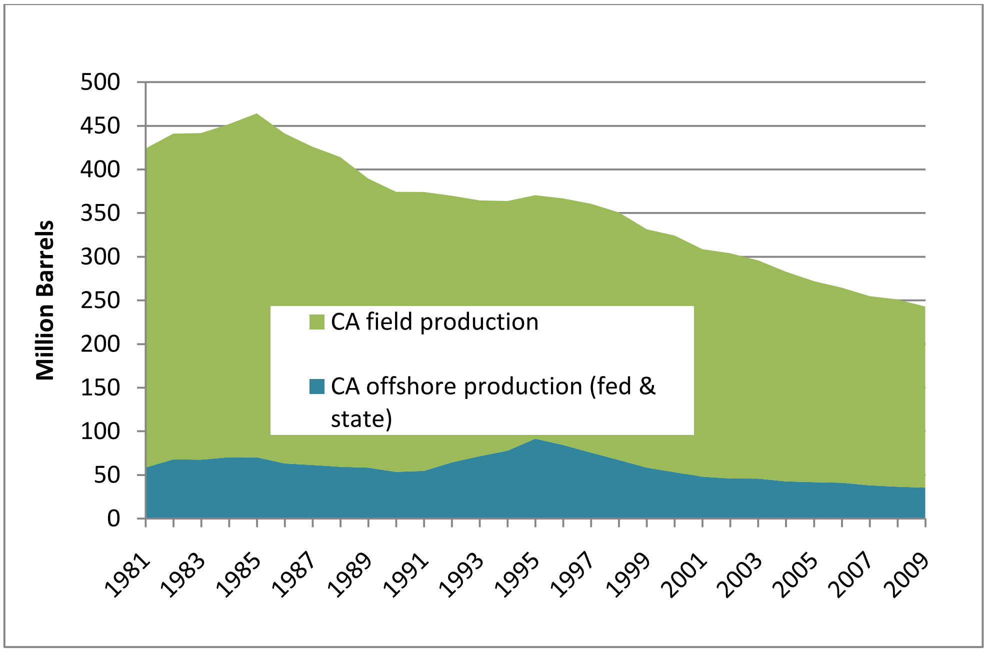
[18] CEC, 2009b, p.145

[19] Note these EIA figures include production from both state and federal waters, and there is some discrepancy with IEPR 2009 figures, which graphically show a peak of 400, and refer to a peak of 426 mb/year (CEC, 2009b, IEPR transportation supplement, page 122).

**Figure 3-B:** California Petroleum Production, 1981–2009

*California's in-state oil production has been in decline since the mid-1980s.*

(Source: EIA, Petroleum Production data, 1981-2010)



Apart from AB 32, California already has standards in place to reduce oil use, such as programs to require cleaner vehicles, and to develop alternative fuels and alternative-fueled vehicles. Consequently, the demand for gasoline, diesel, propane, and jet fuel is expected to rise at a lower rate than in past decades. Nevertheless, continued population growth will mean California's oil demand also will continue to grow, especially if AB 32 implementation is abandoned. By 2020, the total oil-based energy use for aviation fuels (mostly jet fuel), diesel, gasoline, propane, and other oil uses is expected to be the equivalent of 614 mb/y, up from 576 mb/y projected for 2012 in the absence of AB 32 implementation.[20] Given declining in-state oil production, net imports of oil into California will continue to rise.

It might be argued that reducing the importation of fuel could also be accomplished through greater in-state oil production. There are two reasons why we do not consider this scenario seriously. First, the California Energy Commission (CEC) concludes in the 2009 Integrated Energy Policy Report (IEPR) that any significant increase in California's offshore oil production is at least a decade away, putting it out of the range of our current analysis.[21] More importantly, although increasing supply would reduce the importation effect, it would not reduce the retail effect, since California consumers would still pay the high prices from an oil shock regardless of the source of the oil. Only a reduction in oil demand can reduce our exposure to oil price shocks. Switching to local supplies does not provide protection.

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[20] CARB, 2010, Primary energy use, Case1 (reference case).

[21] CEC, 2009b, p.147

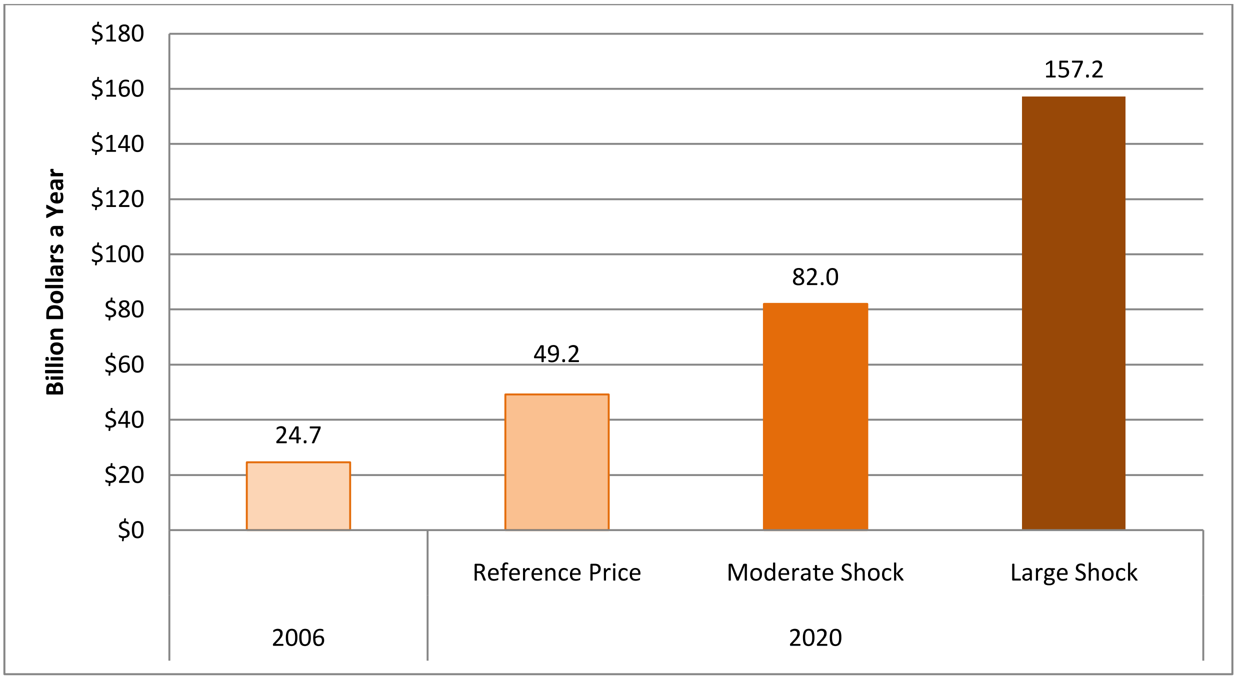
The amount that California pays to import its oil is significant. In 2006, California imported about 329 million barrels of oil to balance energy demand with the shortfall in its own production.[22] At the current price of about $75 per barrel, this is equivalent to spending about $25 billion on imported fuel in a single year.[23]

By 2020, California's oil import bill will be greater still, as illustrated in Figure 3-C. The value of energy imports depends on two factors: (a) the price for energy (crude oil and wholesale natural gas), and (b) in-state fuel production. If oil prices are at the AEO forecast reference price ($114.50 per barrel), and California oil production declines at the rate experienced over 2006–2008 (2.17% per year), without any AB 32 measures the import bill would be $49.2 billion in 2020.[24]

**Figure 3-C:** Value of oil imports in 2020, under AEO reference price and shock scenarios ($2007 dollars)

*A year 2020 price shock would lead to significant increases in how much Californians pay for imported oil.*

(Source: SHOCK-CA)



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[22] As stated above, this import figure, based on primary energy usage, is an estimate of California imports. Actual physical imports are greater, to meet the needs for neighboring states.

[23] We note that a portion of this value may return to California in the form of profits for California-headquartered oil companies, namely Chevron. These are not included in the above figures.

[24] We do not present data for 2020 projection under AEO high price scenarios as there would be no corresponding results for Chapter 2 and this could induce confusion. However, note that with prices at the AEO-forecast high price ($181.18 per barrel) and California production declining at the higher rate (3.23%) seen over the 1998-2008 period, the import bill would be $82.0 billion in 2020.

Predictably, this already sizable number becomes even larger in the price-shock scenarios analyzed. If California were to experience a price shock in which the world oil price were to double for one year, California would, in the absence of the AB 32 Scoping Plan measures, spend between $86.1 billion and $157.2 billion in 2020 for its oil shortfall. In the same way we factor in the price elasticity of demand in Chapter 2, these figures take into account the reduced consumption that would be expected in response to the price shock. Clearly, under both anticipated and unanticipated price shock situations, California will be paying an enormous amount of money for oil imports in 2020.

### b. Natural Gas Import Exposure

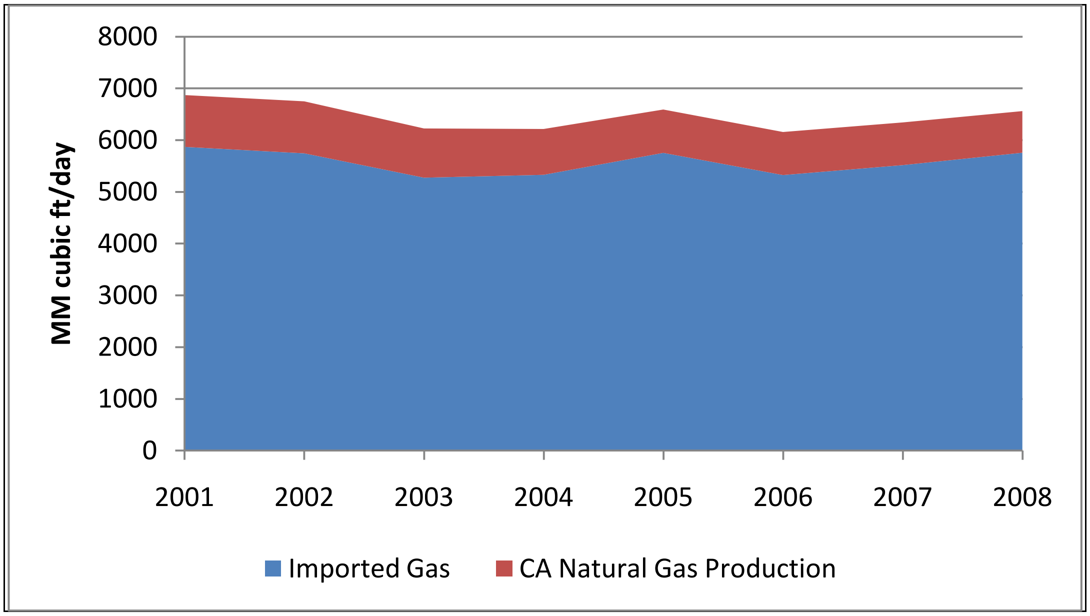
California meets its natural gas needs partly through local production, but the vast majority of natural gas (nearly 90%) comes from outside the state, delivered through pipelines from the Southwest, the Rocky Mountains, and Canada.[25] Natural gas imports during the past decade are shown in Figure 3-D.

While overall U.S. natural gas production has risen in recent years, California's production has been declining slowly, resulting in an increasing reliance on imported natural gas and exposure to natural gas price shocks. The CEC projects this downward trend in production to continue through 2020, from 825 MMcf/d in 2006 to 700 MMcf/d by 2020.[26] Figure 3-E shows the recent and forecasted decline in in-state production of natural gas.

**Figure 3-D:** California's Natural Gas Imports

*Most of the natural gas California uses is imported from neighboring states.*

(Source EIA Natural Gas Summary)



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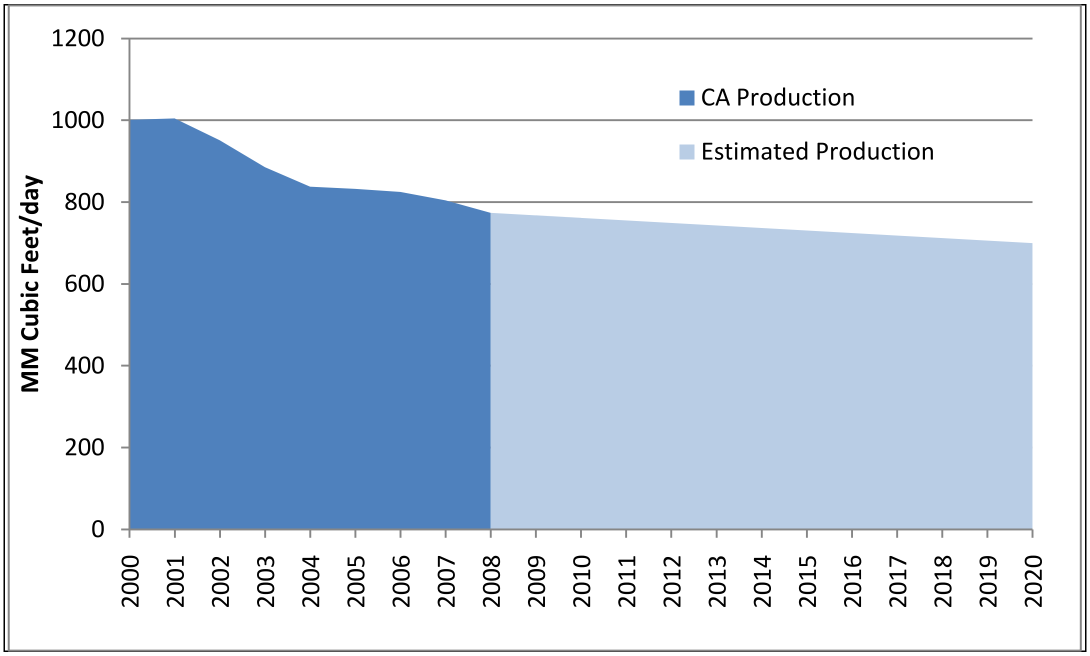
[25] CEC, 2009a, IEPR, p.132.

[26] CEC, 2009a, IEPR, p.132

**Figure 3-E:** California's Natural Gas Production

*California's natural gas production has declined and is forecasted to continue its decline.*

(Source EIA Natural Gas Summary)



While in-state production of natural gas continues to decline, demand is expected to rise through 2020. The result, as with oil, is a widening gap between supply and demand, and increased dependence on imported natural gas. Current California imports are close to 6,000 MMcf/d. At current prices of natural gas, this represents an annual payment to other states and countries of about $9.7 billion.[27]

Looking to the year 2020, we estimate the gas import bill without implementation of the AB 32 Scoping Plan measures. As in the scenarios for oil, we use AEO forecasts for natural gas, which are $7.43 per MMbtu for the reference price and $7.80 per MMbtu for the high price.[28] The 2020 natural gas demand is based on the Scoping Plan analysis.[29]

As in the oil case, we develop a bounded estimate by considering ranges for both natural gas price and in-state production. To develop a range estimate of California's expected in-state natural gas production, we use the IEPR projection of 700 MMcf/d of California production by 2020 for both scenarios. As in the oil analysis, the price shock scenarios use the lower and upper ranges of price

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[27] Import estimate based on EIA 2008 data, showing 6,711 MMcf/d usage, and 774 MMcf/d CA production, for a net import of 5,937 MMcf/d. Price used is current Henry Hub price of $4.30 per MMBtu.

[28] Please see Appendix A for a discussion on these forecasts.

[29] Note that the Scoping Plan natural gas demand projection, though directionally similar, do not exactly match the EIA data used in Figure 4-C. For the purposes of the current analysis, however, all 2020 natural gas calculations are based on the energy demand reported in the Scoping Plan.

elasticity to reflect the possible range of consumer demand response to a doubling of natural gas prices.

As shown in Figure 3-F, growing dependence on imported natural gas will mean California is significantly exposed to price shock risks. The possibility of paying up to $27 billion for natural gas imports is very real. This natural gas import bill adds to the previous discussion of a potential oil import bill of up to $157.2 billion during a price shock.

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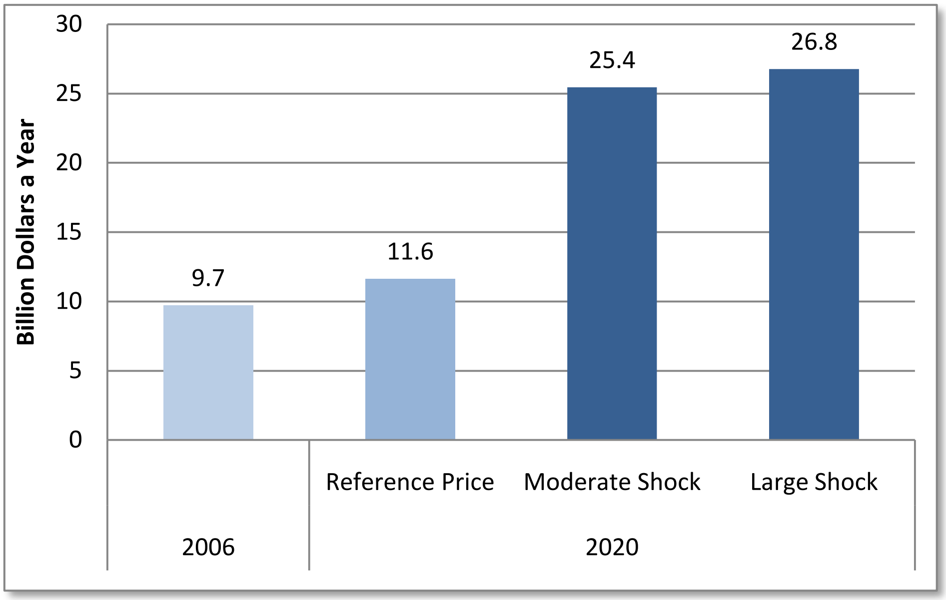
**Figure 3-F:** Value of Natural Gas Imports in 2020, Under Price Shock Scenarios

*Californians will pay significantly more for natural gas in the face of an oil shock in 2020.*

(Source: SHOCK-CA)



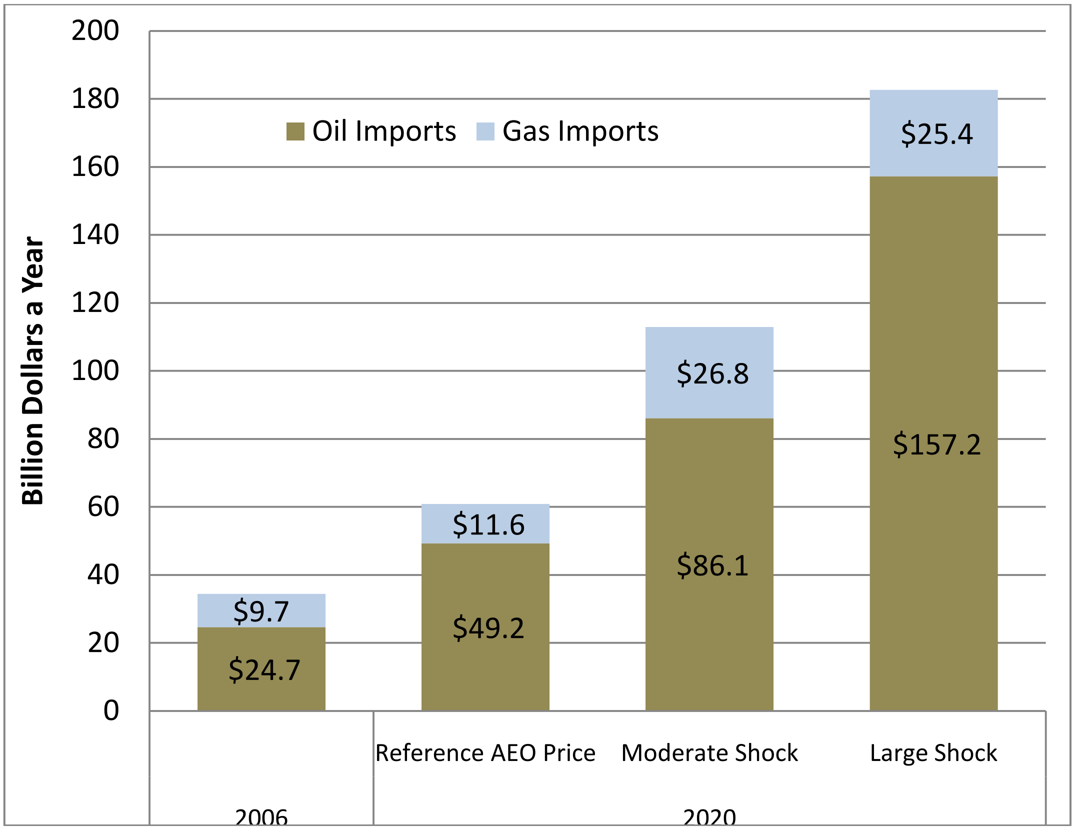
### c. Import Savings from AB 32

As shown above, California is reliant on both oil and natural gas imports. Figure 3-G shows the combined exposure to fossil-fuel import prices. California currently pays around $34 billion annually for fossil-fuel imports, and by 2020 this will grow to $60.9 billion in an AEO reference price scenario. During a price shock, absent AB 32 measures, California's import bill could be up to $168 billion in one year.

**Figure 3-G:** Total Expenditure on Oil & Natural Gas Imports, Without AB 32 ($2007)

*Without AB 32, a sharp increase in prices for natural gas and oil in 2020 would mean Californians could pay up to $182 billion to import energy from outside the state.*

(Source: SHOCK-CA)



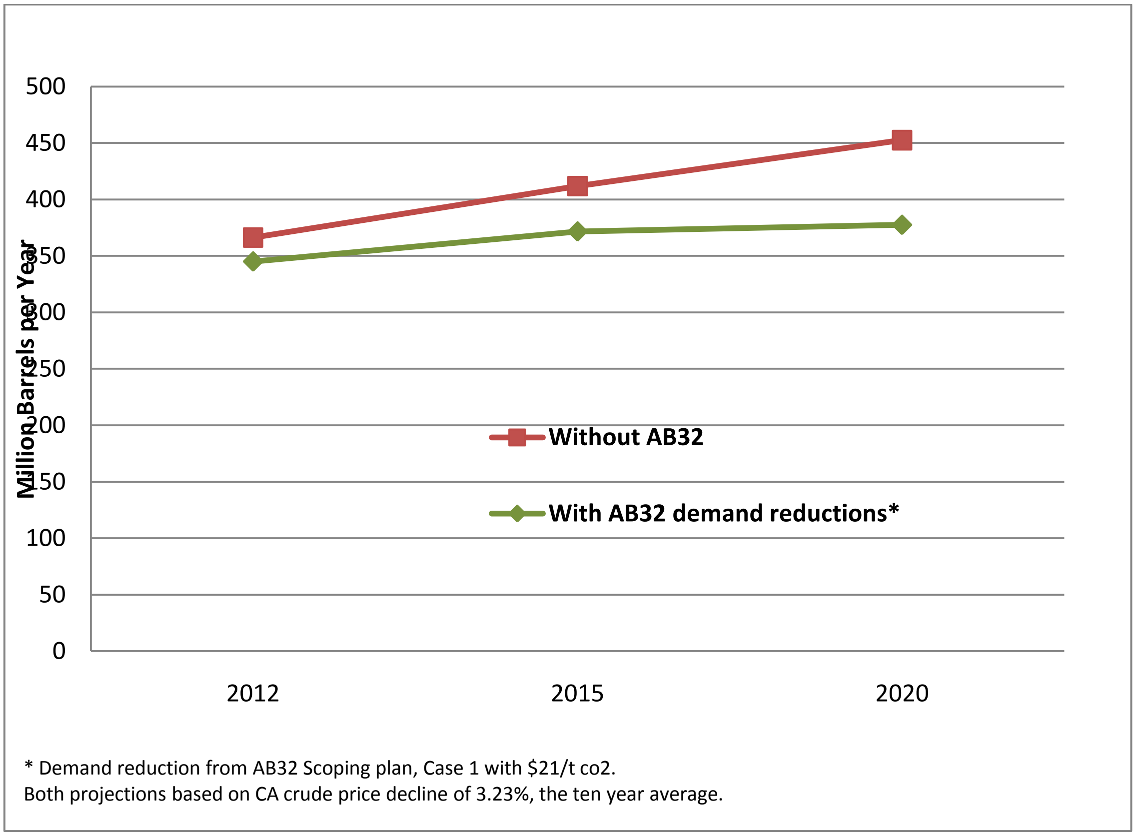
By reducing energy demand, the AB 32 Scoping Plan measures can lessen California's dependence on imported fuels, and thereby reduce the adverse impacts of oil and natural gas price shocks.

In terms of oil, AB 32 measures would help reduce California's net oil imports by reducing demand for oil products. The modeling conducted for AB 32 indicates that AB 32 measures will stabilize oil-based demand after 2015. Figure 3-H shows the results of the Energy 2020 modeling conducted for AB 32[30] combined with the California oil production forecasts from the CEC's 2009 IEPR. Without the AB 32 measures, demand for oil continues to rise, and if California's in-state oil production continues to decline at rates similar to the last 10 years, the shortfall by 2020 will be as high as 453 million barrels and growing. However, by reducing oil demand through the AB 32 measures, imports will stabilize at 378 million barrels by 2020. In short, efforts to fight climate change through AB 32 implementation will reduce oil imports by about 75 billion barrels of oil per year by 2020. For natural gas, the results are similar. The implementation of the AB 32 Scoping Plan reduces the projected demand for natural gas in 2020 from 1,828 TBtu per year to 1,639 TBtu per year, an approximately 10% reduction.

**Figure 3-H:** California Net Oil Imports (to meet California demand for refined products)

*Adopting AB 32 will lead to reduced total demand for oil in California and the benefits will increase over time.*

(Source: SHOCK-CA)



* Demand reduction from AB32 Scoping plan, Case 1 with $21/t co2.
Both projections based on CA crude price decline of 3.23%, the ten year average.

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[30] This modeling work by CARB is discussed in the context of similar analyses in Appendix B and provides the input data for Chapters 2 and 3. See CARB's website at http://www.arb.ca.gov/cc/scopingplan/economics-sp/models/models.htm (last visited June 7, 2010).

### d. Import Savings from AB 32 in Price Shocks

The savings from AB 32 are significant in and of themselves. But even more significant, as has been highlighted by the analysis of this report, is how AB 32, by decreasing California's reliance on fossil fuels, lowers the risks of significant economic impacts from fossil fuel price shocks.

Expenditures on imported oil and natural gas with and without AB 32 are summarized in Figure 3-I. Reduced demand for energy as a benefit of AB 32 measures would lower California's import bill by $10 billion in the AEO 2020 reference forecasts. In our moderate and large price shock scenarios, in which both oil and natural gas prices double for one year, California would avoid $18.8 billion and $29.7 billion in energy imports, respectively, by implementing the AB 32 Scoping Plan measures.

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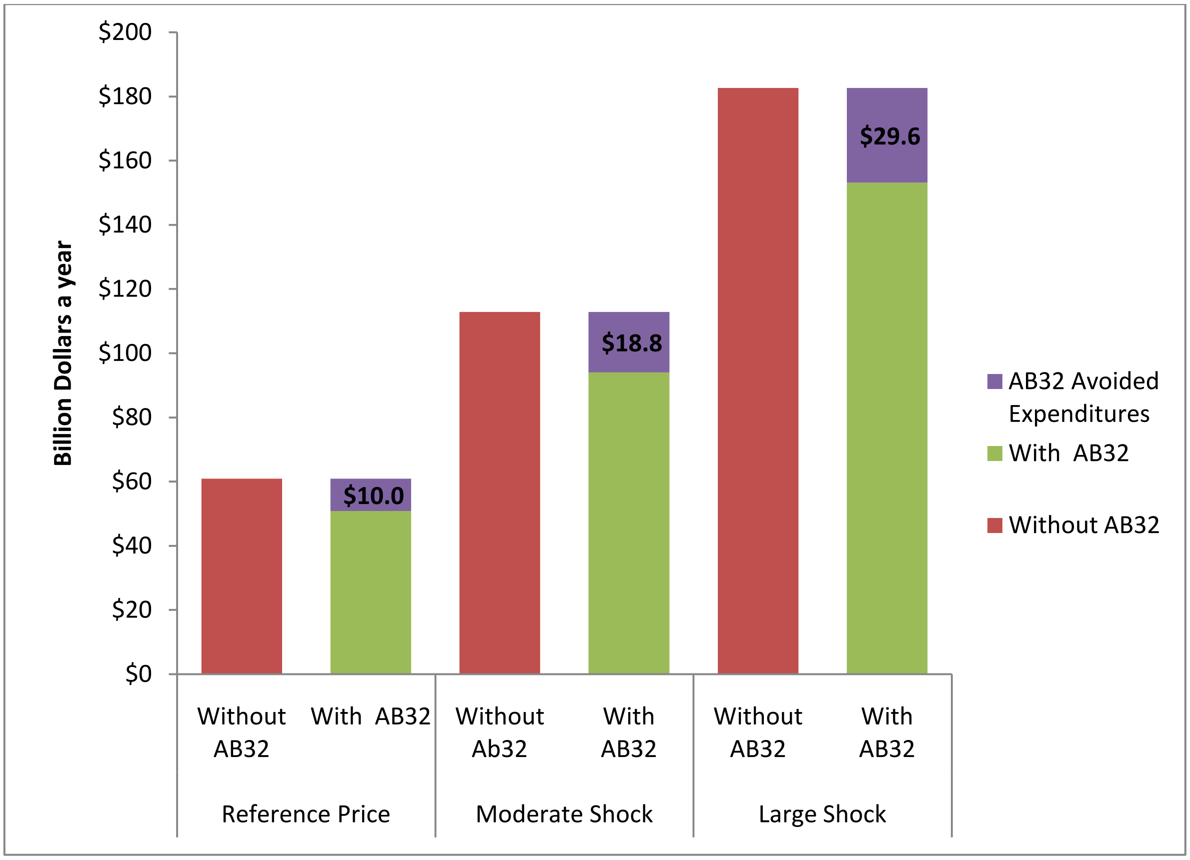
**Figure 3-I:** AB 32 Avoided Expenditures for Oil and Natural Gas Imports in Price Shocks ($2007)

*The amount that California would save on energy imports by implementing AB 32 is shown for three situations in year 2020: AEO reference price, moderate price shock, and large price shock.*

(Source: SHOCK-CA)



# 4. CONCLUSIONS

During this time of economic challenges, the economic implications of climate policy are of great importance to policymakers planning a clean energy future. Through this study, we provide insights into a valuable benefit of AB 32 that has heretofore not been quantified, which we define as “energy economic security.” AB 32 will help California reduce its reliance on imported fuels, like crude oil and natural gas. Therefore, AB 32 will provide a degree of insulation against the risks of price spikes associated with these commodities. This value has been left out of macroeconomic studies, which are often treated inappropriately as holistic cost-benefit analyses.

Most macroeconomic models, including the ones that have been used to analyze AB 32, consider emissions-abatement costs and the single benefit of avoided energy expenditures from efficiency investments, but they do not consider several important benefits, including reduced vulnerability of California’s economy to oil and natural gas price shocks, or improved energy economic security. While California will remain tied to the global economy—a linkage that provides clear benefits—clean energy policy will help to safeguard California’s economy through increased diversification, independence, and efficiency. To date, no macroeconomic studies have put a value on this intuitively important benefit of clean energy policy.

We have investigated two different perspectives on the single benefit of energy economic security. We explored how AB 32 would result in direct savings to California energy consumers should a price shock occur (the retail effect), and we estimated the reduction in import expenditures for oil and natural gas (the importation effect).

The results of our price shock analyses indicate avoided costs to consumers and businesses could be in the range of $4.8 billion to $9.6 billion in 2020. These savings are in addition to the $7.5 billion in reduced energy expenditures that CARB estimates as a result of AB 32 implementation, which is the value of avoided energy use based on the prices in the AEO reference forecast.

We also have calculated benefits from another perspective in our importation effects analysis. Caution is required when interpreting these results. Our estimates related to avoided oil and natural gas imports are derived from the same data on changes in energy use that underlie the retail effect. Therefore, the retail and importation effects should not be summed for a total energy economic security benefit. The reader should approach these two sets of benefits separately. Moreover, each estimate should be considered in conjunction with the particular set of initial prices, price increases, and demand responses upon which they are based.

The importation effect is calculated from a doubling of crude oil and natural gas prices, whereas the results of our regression-based estimation procedure lead to much smaller retail effects. For example, in our moderate price spike scenario, crude oil prices double, but gasoline prices only increase from $3.42 to $4.51 per gallon. In our large price spike scenario, crude oil prices nearly triple (compared to the AEO reference price forecast) but gasoline retail prices increase only by about 50% to $5.77 per gallon. Though this relationship may be questionable, our intention has not been to explore the mechanisms by which prices are set in California, but rather to explore the effects of oil and natural gas price shocks.

Notwithstanding caveats, we do find a large value to reduced reliance on imported oil and natural gas from AB 32 implementation. Measures implemented under AB 32 will avoid about 75 million barrels of oil use (in the form of gasoline, diesel, etc.) in 2020. Depending on crude oil prices in

2020, this translates to savings from avoided imports worth \$10–\$30 billion; mostly from avoided crude oil imports, but avoided natural gas (of which California imports nearly 90%) amounts to about \$1.5 billion.

Our retail effects analysis considers the direct costs of natural gas to industrial energy users, including natural gas use for electricity generation, but we do not explore how electricity consumers would be affected or how price shocks indirectly result in higher prices for consumer goods other than energy. Our energy economic security estimates also do not include the indirect macroeconomic effects that would follow from future price shocks. Our estimates are partial and do not capture the full range of benefits that come from reduced dependence on imported oil and natural gas and reduced exposure to price spikes.

The value of being less dependent on fossil fuels to power California's economy goes beyond the sheer magnitude of avoided payments to energy companies. All of America's price shocks in the past 40 years have played a role in economic recessions.[31] An economy with more diversified energy supply, less dependence on conventional crude oil, and less energy intensity per unit of output is more sustainable and more resilient to natural and human disruptions. While a more diverse energy supply portfolio will expose California to new risks and opportunities, it will reduce exposure to conventional fuel price shocks that history has shown to be both common, associated with crude oil and natural gas prices, and highly influenced by events such as wars and hurricanes.

While real oil scarcity may or may not be felt within current generations, frequent spikes in prices highlight the need for energy economic security through decreased dependence on out-of-state sources and increased supply diversity. The energy industry has managed to avoid supply declines to date, but it is unclear how long new technology and more-intensive exploration will be able to stave off existing trends in production decline. On the demand side, there is no question that the strong growth of major emerging economies as China and India will put upward pressure on the international price of crude oil and related petroleum products.

This report is a cautionary tale of what would happen should California experience energy price spikes, and it estimates the significant value that AB 32 will provide in the event of such events. The macroeconomic analyses that dominate the discussion of economic impacts ignore the vulnerabilities imposed by California's dependence on imported oil and natural gas. These macroeconomic models are based on a smooth price forecast, while history has shown there is high likelihood of future price shocks. Our research shows that AB 32 will deliver significant savings when the next price shock occurs.

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[31] Scholars have debated the role of energy price shocks in causing economic recessions. While some (e.g., Bernanke et al, 1997) have suggested that contractionary monetary policy responses have had more influence on economic output than price shocks themselves, others (e.g., Hamilton & Herrara (2000), Leduc & Sill, (2004)) have found that monetary policies do not offset the recessionary consequences of oil price shocks. Still others observe that the economic consequences of price shocks have been declining; Kubarych (2005, pg. 32) observed that "the latest surge in oil prices has been largely taken in stride within the financial markets, in contrast to past responses."

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# APPENDIX A: METHODS

This appendix provides a detailed description of the methodology used in Chapter 2. A spreadsheet showing all data, formulas, and calculations is available upon request. We call that spreadsheet the SHOCK-CA (Statewide Holistic Oil Cost Kalculator for California) model. At the end of this appendix, our calculations of oil and gas import benefits from AB 32 are described briefly; these calculations are a sub-module of SHOCK-CA. We welcome suggestions on ways to improve this analysis.

## a. Price Shock Analysis

Our methods involved five major steps that are discussed in detail below:

1. **AB 32-induced changes in energy use:** Obtain CARB's estimated changes in energy use induced by the measures in the AB 32 Scoping Plan.
2. **Develop retail price relationships:** Develop relationships between the retail energy prices and crude oil or wholesale natural gas prices.
3. **Develop price spike scenarios:** Review historical prices to determine if a one-year doubling of wholesale prices for crude oil and natural gas is a reasonable scenario for analysis, and obtain 2020 fuel price forecasts of pre-doubling prices.
4. **Incorporate price elasticity of demand:** Adjust energy demand to reflect potential responses to price spikes.
5. **Calculate benefit as energy saved, multiplied by price spike increments:** Using changes in prices (price spikes) and changes in energy consumed due to AB 32 (after incorporating a price elasticity of demand response), estimate savings in fuel expenditures attributable to AB 32 should price spikes occur.

### *1. AB 32-Induced Changes in Energy Use*

The starting point for the analysis are the changes in energy use forecast to result from implementation of the AB 32 Scoping Plan measures. These estimates are published in a recently updated economic analysis developed by CARB (2010). CARB's analysis coupled a macroeconomic model with a detailed model of energy supply and demand. The macroeconomic model is a computable general equilibrium type known as the Environmental Dynamic Revenue Assessment Model (E-DRAM). The energy model, Energy 2020, represents energy supply (including technology and location-specific details for electricity generation) and the specific end uses that drive demand for energy.

Using this modeling framework, CARB first developed a reference case forecast of what the economy would look like in the year 2020 in the absence of AB 32 implementation. CARB's forecast used as inputs crude oil and natural gas prices forecast through 2020 by the DOE EIA (U.S. Department of Energy's Energy Information Agency), which every year publishes an Annual Energy Outlook (AEO) that predicts a multitude of future price, production, and consumption variables. The particular price inputs CARB used are the AEO 2009 reference case (the most likely forecast of future energy trends). In our study, we used the AEO 2009 Updated forecast; the difference is $2 per barrel of crude oil in the 2020 mid-value reference price forecast.[32]

Having developed its reference case forecast of future economic growth (including energy production and use), CARB compared its own analysis to a number of policy scenarios that reflect different assumptions about the type and effectiveness of policies implemented to achieve AB 32. We focus on CARB's "Case 1," which reflects the policy instruments included in CARB's proposed blueprint for achieving the AB 32 emission reductions (AB 32's legislative language refers to this as the "Scoping Plan"), and CARB's best estimates of the costs and energy savings associated with each of these policies. We refer to CARB's "Case 1" and associated economic and energy implications as our AB 32 implementation scenario.

Each of these two scenarios, with and without AB 32, implies different energy use patterns. We explore primary energy use based on a subset of five fuels: gasoline, diesel, propane, aviation fuels (e.g. Avgas, Jet fuel), natural gas, and a composite category that we call "Other Oils," including oil products directly combusted for industrial use. Energy 2020 labels these oils as "oil unspecified."

Together, these six fuels comprise 83% and 77%, respectively, of the total 2020 primary energy demand forecast by CARB with and without AB 32. CARB's update economic analysis lists the total primary energy use without AB 32 (i.e. the business-as-usual case) for all fuels (CARB 2010, p. 23). Table B-6 (p. 100) lists the changes due to AB 32 in Case 1, the scenario that represents AB 32 Scoping Plan implementation, including a cap-and-trade program with an equilibrium trading price of $21 per ton of carbon dioxide equivalent emissions.

### *2. Develop Retail Price Relationships*

The next step involves determining what price spike scenarios to test. We have developed a regression analysis approach to translate increases in wholesale oil and natural gas prices that are set in national or international markets to spikes in California retail prices. Although California is a large economy, in the case of very valuable and frequently traded energy commodities, the state is what economists would call a "price taker." Prices within the state are substantially determined by external events for commodities such as crude oil or natural gas.

Before further describing our rationale and approach, we observe that the reader need not be convinced that the procedure we have developed completely and perfectly captures price dynamics. Indeed, we recognize that the causal process by which energy prices are set is much more complicated than we are representing. We simply use an analytical approach to develop the price shocks that we test, so that we can characterize how their effects on California are different with or without AB 32 implementation. A different approach would have been to directly test different levels of retail price shocks. The point is that the procedure we use to derive retail price shocks is not central to the exploration of the implications of price shocks in general. We know there will be price variation, and that price spikes will occur. We chose to provide some theoretical and quantitative basis for the price shocks we examine, rather than going the simpler route of assuming future price shocks without any justification. If the reader so chooses, they can judge whether the price changes we test make intuitive sense.

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[32] The AEO 2009a forecast for 2020 crude oil is $112.50 per barrel, whereas the updated AEO 2009 forecast is $114.50 per barrel in 2020.

Regression analysis is used to test for and estimate a causal relationship between one or more independent variables (also called explanatory variables) and a dependent variable. For the purposes of our retail effects analysis, our dependent variables are the six retail prices that we are interested in: gasoline, diesel, natural gas, aviation fuel, propane, and industrial oils. Our dependent variables are future retail energy prices for the state of California as determined by Energy 2020 and provided to us by CARB. For gasoline and diesel fuels, we look at transportation sector retail prices. For natural gas, propane, aviation fuel, and oil products directly combusted, we use industrial sector retail prices. All of these values are shown in Table A-A.

The independent variables in the analysis are the crude oil price and the main wholesale natural gas price from the AEO 2009 reference case. For natural gas we use the “Henry Hub” price, generally seen to be the primary price set for the North American natural gas market. These are the same price forecasts used as an input to CARB’s modeling of AB 32. Overall, the regression results show that the relationships we find (essentially a linear trend line relating AEO price forecasts and California retail prices) fit the data very well. The adjusted R square is a statistic that explains how well the trend line fits the data. It indicates how much the variation in the dependent variable (retail price forecasts in our analysis) is explained by independent variables (the AOE crude oil or natural gas price in our analysis).

As shown in Table A-B, the adjusted R square statistics range from 0.70–0.92 in our results, which the reader can interpret in rough terms as meaning that between 70–92% of the variation in retail prices is explained by changes in the price of crude oil (or in the price of the Henry Hub price in the case of natural gas).

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## **Table A-A:** Regression Data (all values in 2007 dollars)

| Year | **AEO Reference Forecast 2020 Imported Crude Oil price** | **AEO Reference Forecast 2020 Henry Hub Gas price** | **Energy 2020 Natural Gas price for CA** | **Energy 2020 Other Oils price for CA** | **Energy 2020 Propane price for CA** | **Energy 2020 Gasoline price for CA** | **Energy 2020 Diesel price for CA** | **Energy 2020 Aviation Fuel price for CA** |
|---|---|---|---|---|---|---|---|---|
| | $/barrel | $/MMBtu | $/MMBtu | $/MMBtu | $/MMBtu | $/MMBtu | $/MMBtu | $/MMBtu |
| **2009** | 58.6 | 6.5 | 11.1 | 20.0 | 22.1 | 23.1 | 22.8 | 17.3 |
| **2010** | 77.6 | 6.7 | 11.1 | 20.4 | 22.5 | 23.5 | 23.2 | 17.6 |
| **2011** | 85.6 | 6.6 | 11.2 | 20.8 | 22.9 | 23.9 | 23.6 | 18.0 |
| **2012** | 94.8 | 6.8 | 11.3 | 21.2 | 23.3 | 24.3 | 24.0 | 18.4 |
| **2013** | 99.8 | 6.8 | 11.4 | 21.6 | 23.7 | 24.7 | 24.4 | 18.9 |
| **2014** | 105.0 | 6.8 | 11.5 | 22.0 | 24.1 | 25.1 | 24.8 | 19.2 |
| **2015** | 108.5 | 6.9 | 11.6 | 22.4 | 24.5 | 25.5 | 25.2 | 19.7 |
| **2016** | 109.8 | 7.0 | 11.7 | 22.8 | 24.9 | 25.9 | 25.6 | 20.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **2017** | 110.7 | 7.2 | 11.8 | 23.4 | 25.4 | 26.4 | 26.1 | 20.6 |
| **2018** | 111.6 | 7.4 | 12.0 | 23.6 | 25.7 | 26.7 | 26.4 | 20.9 |
| **2019** | 112.5 | 7.6 | 12.1 | 24.1 | 26.2 | 27.1 | 26.8 | 21.3 |
| **2020** | 112.0 | 7.4 | 12.2 | 24.5 | 26.6 | 27.6 | 27.3 | 21.7 |

## **Table A-B:** Regression Results

**Gasoline price regression results**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.882435 |
| R Square | 0.778691 |
| Adjusted R Square | 0.75656 |
| Standard Error | 0.72636 |
| Observations | 12 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* | |
|---|---|---|---|---|---|---|
| Regression | 1 | 18.56388 | 18.56388 | 35.18564 | 0.000145 | |
| Residual | 10 | 5.275981 | 0.527598 | | | |
| Total | 11 | 23.83986 | | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
| Intercept | 17.74649 | 1.290871 | 13.74768 | 8.06E-08 | 14.87025 | 20.62273 |
| AEO Crude Oil | 0.076417 | 0.012883 | 5.931748 | 0.000145 | 0.047712 | 0.105121 |

**Diesel regression results**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.882489 |
| R Square | 0.778786 |
| Adjusted R Square | 0.756665 |
| Standard Error | 0.726234 |
| Observations | 12 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* | |
|---|---|---|---|---|---|---|
| Regression | 1 | 18.56775 | 18.56775 | 35.20518 | 0.000144 | |
| Residual | 10 | 5.274154 | 0.527415 | | | |
| Total | 11 | 23.84191 | | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
| Intercept | 17.45545 | 1.290648 | 13.52456 | 9.42E-08 | 14.5797 | 20.33119 |
| AEO Crude Oil | 0.076425 | 0.01288 | 5.933395 | 0.000144 | 0.047725 | 0.105124 |

## **Table A-B:** Regression Results (*continued*)

**Liquid Petroleum Gas (Propane) regression results**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.882514 |
| R Square | 0.77883 |
| Adjusted R Square | 0.756713 |
| Standard Error | 0.726153 |
| Observations | 12 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 18.56836 | 18.56836 | 35.21417 | 0.000144 |
| Residual | 10 | 5.272979 | 0.527298 | | |
| Total | 11 | 23.84134 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 16.76091 | 1.290504 | 12.98788 | 1.38E-07 | 13.88548 | 19.63633 |
| AEO Crude Oil | 0.076426 | 0.012879 | 5.934153 | 0.000144 | 0.04773 | 0.105122 |

**Industrial oil regression results**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.882425464 |
| R Square | 0.778674699 |
| Adjusted R Square | 0.756542169 |
| Standard Error | 0.726424468 |
| Observations | 12 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 18.56547 | 18.56547 | 35.18236 | 0.000145 |
| Residual | 10 | 5.276925 | 0.527693 | | |
| Total | 11 | 23.84239 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 14.67499471 | 1.290987 | 11.36727 | 4.85E-07 | 11.7985 | 17.55149 |
| AEO Crude Oil | 0.076419985 | 0.012884 | 5.931472 | 0.000145 | 0.047713 | 0.105127 |

## **Table A-B:** Regression Results (*continued*)

**Aviation Fuel**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.882483334 |
| R Square | 0.778776835 |
| Adjusted R Square | 0.756654518 |
| Standard Error | 0.726250746 |
| Observations | 12 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 18.56759291 | 18.56759291 | 35.20322265 | 0.000144455 |
| Residual | 10 | 5.274401464 | 0.527440146 | | |
| Total | 11 | 23.84199437 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 11.9181 | 1.2906 | 9.23403 | 0.0000 | 9.0423 | 14.793 | 9.042 | 14.793 |
| AEO Crude Oil | 0.07642 | 0.01288 | 5.93323 | 0.00014 | 0.0477 | 0.1051 | 0.0477 | 0.1051 |

**Natural gas regression results**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.96818 |
| R Square | 0.937373 |
| Adjusted R Square | 0.93111 |
| Standard Error | 0.098513 |
| Observations | 12 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 1.452586 | 1.452586 | 149.6754 | 2.44E-07 |
| Residual | 10 | 0.097049 | 0.009705 | | |
| Total | 11 | 1.549635 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|
| Intercept | 4.215075 | 0.603245 | 6.987334 | 3.77E-05 | 2.870961 | 5.559189 |
| Henry hub price | 1.057916 | 0.086472 | 12.23419 | 2.44E-07 | 0.865244 | 1.250587 |

A bit more about the retail energy prices that we focus on: Diesel, gasoline, and aviation fuel prices in the transportation sector are a natural fit for our exploration of energy independence benefits. We also explore linkages to natural gas, oil, and propane directly consumed in the industrial sector (including electricity generation). This is where most primary energy use occurs outside the transportation sector, and that is the reasoning behind the approach. The industrial oil use category—"Other Oils"—is an aggregation of the following: asphalt, coke oven gas, heavy fuel oil, kerosene, light fuel oil, lubricants, naphtha, petrochemical feedstocks, and petroleum coke. This category is called, "Oil, Unspecified" in the Energy 2020 modeling. Since we are building on the Energy 2020 results that came out of the collaborative modeling process initiated by CARB, it makes sense for us to apply category definitions used in that work to the greatest extent possible.

We know that much more than these underlying prices go in to the determination of the retail prices than the simple relationships we estimate. Nevertheless, there is impressive correlation between the AEO price forecasts and the Energy 2020 forecast prices in California. In no small part, this is by construction. Energy 2020 itself uses the same underlying AEO price forecasts to develop retail prices using empirical data from past years. We cannot independently run the Energy 2020 model, and cannot go back to re-estimate the implications of changes to the AEO price forecasts. Given this, we have followed the path described above, estimating a relationship between the AEO price forecasts and retail prices of interest.

*3. Develop Price Spike Scenarios*

Having developed the relationships between underlying crude oil and natural gas prices, we then explore two price spike scenarios:

1. **Moderate price spike:** In this scenario, the AEO 2009 reference case prices for crude oil and Henry Hub natural gas double in the year 2020. This price is $114.50 per barrel in 2007 Consumer Price Index adjusted dollars.

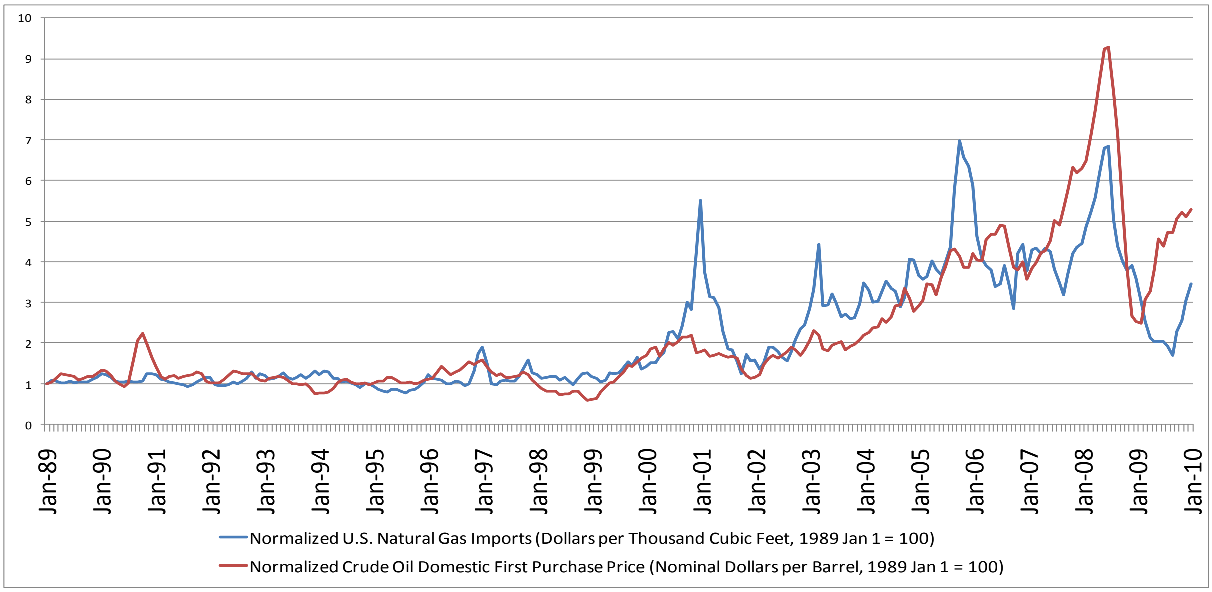
2. **Large price spike:** In this scenario, the AEO 2009 high price forecast for crude oil and Henry Hub natural gas double in the year 2020. This price is $181.18 per barrel in 2007 Consumer Price Index adjusted dollars. When we calculate the change in fuel prices, we examine the jump from crude oil at $114.50 per barrel to $362 per barrel.

We considered doing different scenarios that would only look at a price spike in either crude oil or natural gas. We chose to explore scenarios in which the prices of both commodities spike at the same time. A review of the historical record reveals that crude oil and natural gas prices have frequently moved in unison, as shown in Figure A-1.

## **Figure A-1:** Historic Crude Oil and Natural Gas Prices, 1989–2010

*Crude oil and natural gas prices have historically risen and fallen along similar paths.*

(Source: Data from EIA, Petroleum Production Data, 1981–2010 and Natural Gas Wellhead Price, 1976–2010)



We have not investigated separate crude oil and natural gas price shocks, but we have decomposed the price effects so that the reader could focus on only one or the other.

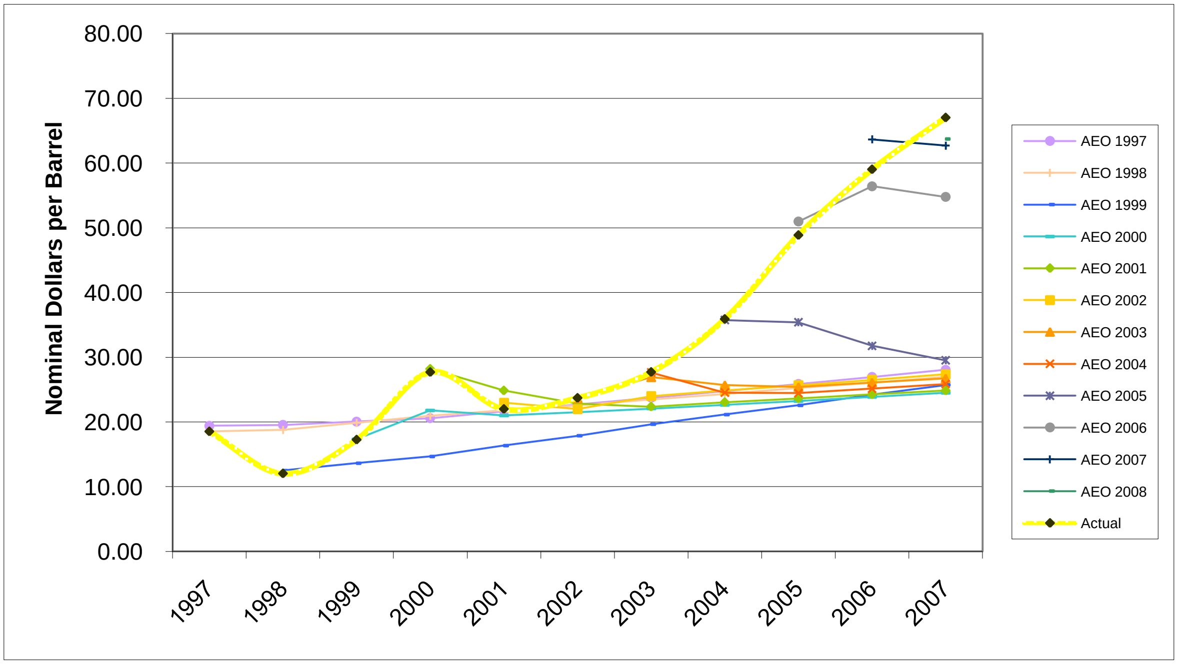
We also considered representing the AEO low price forecast, but concluded that $46.77 per barrel in 2020 was too unrealistic to merit careful analysis. The low price scenario requires one to accept a prediction of gasoline costing $2.08 per gallon in 2020, and that a price doubling would translate to an additional $0.44 per gallon at the pump. The unrealistic scenario yields a savings in the range of $2.5 billion due to avoided energy use from AB 32 policies, not accounting for the increased energy use that would be expected at lower energy prices. We are joined by many experts in rejecting the AEO low price forecast as highly improbable. Dr. Daniel Kammen (2008), Director of the UC Berkeley Renewable and Appropriate Energy Laboratory wrote: “The overriding consensus is that oil prices will not drop back to the $20, $30 or even the $40 or $50 per barrel range. I think we’re much more likely to see $150 per barrel than we are ever to see $50 per barrel again. This fundamentally changes the debate about our energy future.”

We also observe that the history of AEO price forecasts reveals a tendency to underestimate future prices. Figure A-2 shows that the actual price is in hindsight consistently higher than the AEO published forecast for that year. If this were a consequence of random error (i.e. no bias), then we would expect to see errors of prediction on both sides of actual, but we see only erring toward lower prices.

**Figure A-2:** EIA Forecasted Vs Actual World Oil Prices, 1997–2007

*The actual price of crude oil has historically risen faster than predicted by EIA.*

(Source: Data from EIA, AEO 2009, [www.eia.doe.gov/oiaf/analysispaper/retrospective/excel/table4.xls](www.eia.doe.gov/oiaf/analysispaper/retrospective/excel/table4.xls))



During the last price spike in California (2008), oil and gas prices rose in tandem and peaked at about the same time (Roesser, 2009, p.15). Yet we are not *predicting* that the two will spike at the same time exactly as modeled in the small or large price spike scenarios; we are exploring the implications of this happening.

The true relationship between oil and natural gas prices is complex. The following is a passage from a California Energy Commission (CEC) report on the topic:

Investigating the relationship between oil and natural gas price movements, a February 2007 research paper by the Federal Reserve Bank of Dallas concludes, “the relationship has complex short-term dynamics, but is quite stable in the long run,” (Brown and Yucel, 2007). The authors acknowledge that fuel switching between oil and natural gas has significantly diminished in recent years and natural gas prices have in fact shown “considerable independent movement.” They argue that seasonal factors such as weather, storage, and shut-in production can independently affect natural gas prices in the short-term. However, they add, “when these additional factors are taken into account, movements in natural gas prices are well explained by crude oil prices.” In 2007, a CEC-sponsored analysis of this subject concludes: “In summary, based on the reviewed literature and market data observations, the relationship between oil and natural gas prices is complex: there is a relationship, but it is difficult to characterize and it is not constant (CEC 2007, p. 104).

### *4. Incorporate Price Elasticity of Demand Response*

With the pricing implication of the shock scenarios defined, we then represent an assumption that some energy users will change their behavior in response to a sudden price increase.

Economists call the rate at which consumers change demand in response to changes in price the “price elasticity of demand.” While the concept is intuitively easy to grasp, ascribing quantitative values is not. To represent the uncertainty in price elasticity of demand, we reviewed the literature on the topic and select low, mid, and high values for each fuel type.

The price elasticity of demand is determined by consumers’ ability and willingness to change behavior once they become aware of price changes. Our scenarios consider a one-year (i.e. short-term) price shock, so only short-term responses are viable. That is, our price shock scenarios might trigger more determined efforts to invest in public transit, for example, but that investment is not going to result in real substitutes for drivers in the event of a price shock because such projects take years, even decades, to develop and implement. An example of a short-term response to an oil spike would be to avoid driving by cycling or walking, or to make more use of existing public transit.

The elasticity ranges for each fuel type that we use in our analysis are presented in Table 2-B. We do not treat income effects explicitly, nor do we use macroeconomic or energy models to estimate adjustments to consumption when price doubles.

There is another interesting, underlying uncertainty in demand response that we cannot represent explicitly. As envisioned, the AB 32 Scoping Plan will increase the universe of low-carbon technological and behavioral options, and thus would be expected to increase the ability for consumers to respond to price shocks. With AB 32 implemented, the price elasticity of demand should be larger than without AB 32 implementation. Such subtleties are not represented in our analysis explicitly.

We recognize that California's use of renewable energy sources will be significantly larger in the AB 32 implementation scenario, and we assume there is no world oil price risk inherent in these energy sources. We treat renewable energy generating facilities as domestic sources; yet building them could require reliance on imported resources, which in turn could be closely affected by the price of petroleum. At the same time, AB 32 will result in a more diversified energy system for California—AB 32 does not flip the state from dependence on petroleum to dependence on renewable energy sources—and diversification is a standard risk minimization strategy.

*5. Calculate Benefit as Energy Saved, Multiplied by Price Spike Increment*

The last step in our estimation method is the easiest. It involves multiplying the price change and the quantity change to calculate the savings associated with each type of fuel. Then, we sum the total avoided energy costs due to AB 32 to find the benefit of climate action should such price spikes occur. We present a decomposition of the effects by fuel type. Also, we present results for low, middle, and high price elasticity of demand.

### b. Consumer Surplus

In Chapter 2 of this study, we provide an estimate of the retail effects of a price shock: additional expenditures for energy paid by people and businesses in the near term (i.e., over the course of one year) when energy prices spike. Though we chose to focus on actual energy expenditures, some independent reviewers suggested we consider the change in consumer surplus. Here we calculate consumer surplus changes for the moderate and large shock scenarios and compare them to our estimates of changes in energy expenditures, finding the two measures to be remarkably similar.

We start by defining the concept of a demand curve for energy. A demand curve can be shown graphically with the price on the Y-axis and quantity demanded on the X-axis, as in Figure A-3. A demand curve shows the amount of energy that would be demanded (purchased) at different price points. At higher prices, consumers demand less; at lower prices, they demand more. Economists refer to the height of the demand curve as the willingness to pay. Ultimately, the market price is determined by the intersection of demand and supply curves, a core economic insight. For the last unit of energy consumed, demand equals willingness to pay at that price. However, for every unit of energy other than the last one, willingness to pay will exceed the price paid. It is this divergence between willingness to pay and price that defines consumer surplus. For any given consumption good, such as energy, consumer surplus will equal the area below the demand curve and above the price line.

Knowledge of a price level and a demand curve is all that is necessary for analyzing consumer surplus dynamics. California is a so-called “price taker”: it buys at the prevailing international price without influencing that price significantly. As is true throughout this analysis, we take price changes as given.

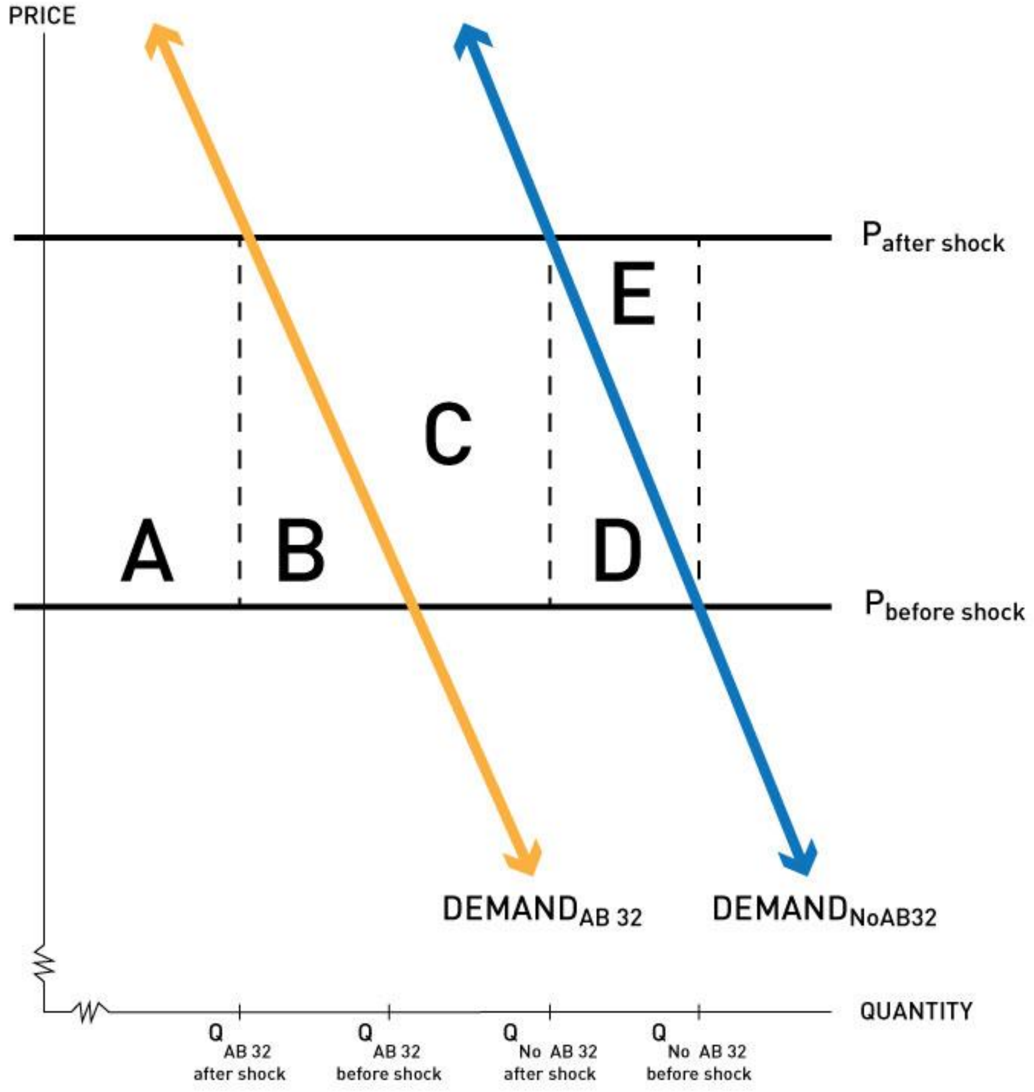
In figure A-3 below we illustrate consumer surplus dynamics as they relate to our analysis. The figure shows a shift in the price of one of our energy commodities, gasoline, which increases from $P_{\text{before shock}}$ to $P_{\text{after shock}}$ . Implementing AB 32 will change California’s energy demand, whatever the price. Graphically, California’s demand shifts from $\text{Demand}_{\text{NoAB32}}$to $\text{Demand}_{\text{AB 32}}$. When the price increases, as in our shock scenarios, the amount demanded will decline as shown by the points at which the demand lines cross the price lines. (Note that this is not a shift in the demand curve, but movement along the demand curve.) Without AB 32 implementation, a price spike will result in change in demand from $Q_{\text{No AB 32 before shock}}$ to $Q_{\text{No AB 32 after shock}}$. With implementation of AB 32, demand will move from $Q_{\text{AB 32 before shock}}$ to $Q_{\text{AB 32 after shock}}$.

When price shifts from $P_{\text{before shock}}$ up to $P_{\text{after shock}}$, there is a reduction of consumer surplus in both cases, with and without AB 32. That is, the area above the Price line and left of the Demand line gets smaller. The benefit of AB 32 in terms of avoided lost consumer surplus is the difference between consumer surplus loss in both cases, with and without AB 32. This area is represented as C + D in Figure A-3.

In our report, we estimate the changes in energy expenditures avoided due to AB 32 by calculating B + C. Below we compare our avoided expenditures estimates to calculations of consumer surplus effects (i.e., areas C + D) explicitly. The two measures are remarkably similar. Our estimation technique captures over 95% of the value of avoided losses in consumer surplus due to AB 32 in the two price shock scenarios. This comparison is summarized in Table A-C and Figure A-4.

We understand that economists may be interested in the consumer surplus question, which is why we have presented the findings here. However, policymakers and the public are likely to find this metric confusing. In contrast, the concept of money saved on energy expenditures is easier to grasp. While we have undertaken this exercise and presented the results in response to reviewer comments, we focus on changes in energy expenditures in the body of the report.

**Figure A-3:** Loss in Consumer Surplus from Energy Price Shock



## **Table A-C:** Comparison of SHOCK Findings with Consumer Surplus

(Source: SHOCK-CA)

**SHOCK Result** $2007 billions

| Fuel Type | Lowest Estimate (Moderate Price shock) | Highest Estimate (Large Price shock) |
|---|---|---|
| Gasoline | 2.3 | 5.5 |
| Diesel | 0.7 | 1.6 |
| Propane | 0.1 | 0.1 |
| Other Oils | 0.1 | 0.3 |
| Aviation Fuel | 0.2 | 0.4 |
| Natural Gas | 1.3 | 1.6 |
| Total | 4.8 | 9.6 |

**Consumer Surplus (CS)** $2007 billions

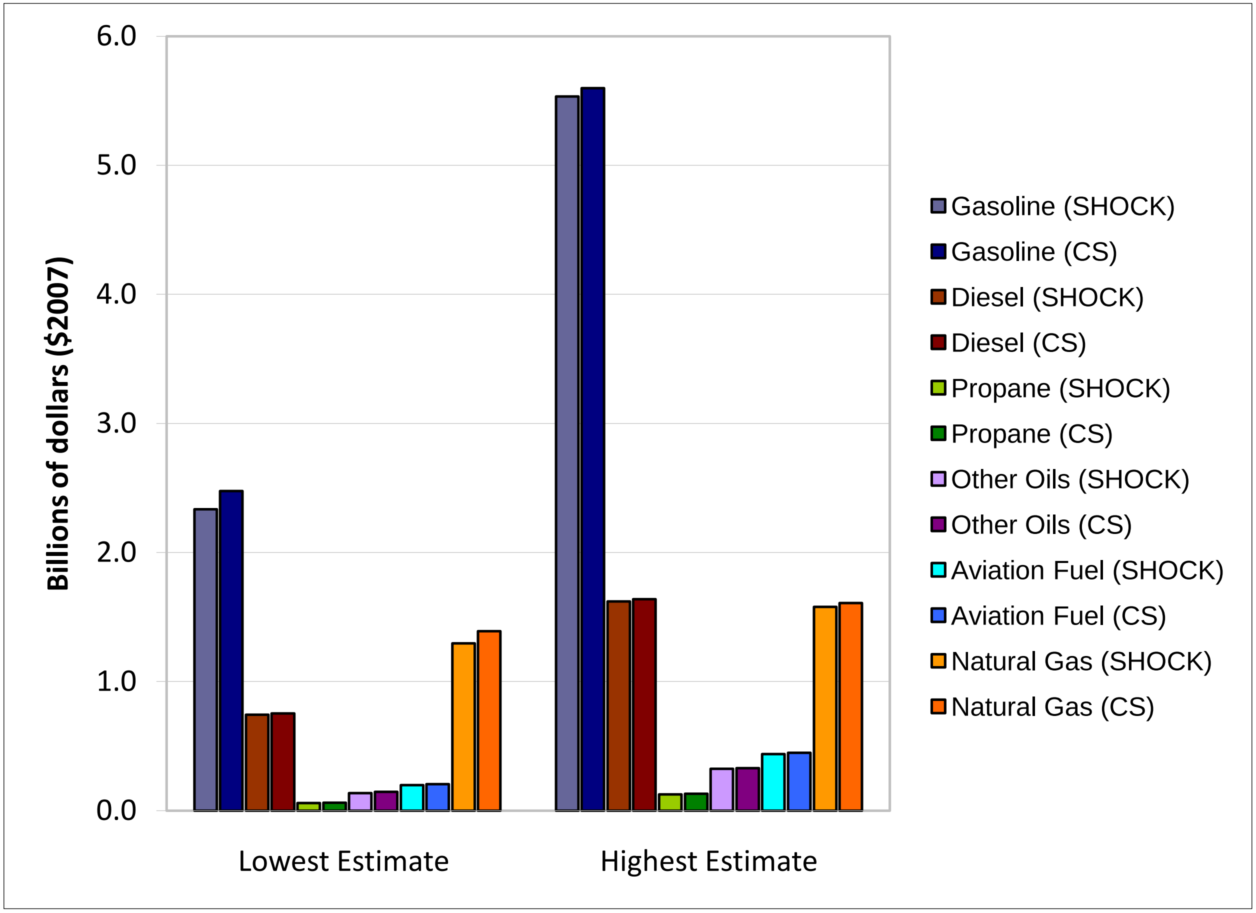
| Fuel Type | Lowest Estimate (Moderate Price shock) | Highest Estimate (Large Price shock) |
|---|---|---|
| Gasoline | 2.5 | 5.6 |
| Diesel | 0.8 | 1.6 |
| Propane | 0.1 | 0.1 |
| Other Oils | 0.1 | 0.3 |
| Aviation Fuel | 0.2 | 0.4 |
| Natural Gas | 1.4 | 1.6 |
| Total | 5.0 | 9.8 |

| **SHOCK: CS Comparison** | Lowest Estimate (Moderate Price shock) | Highest Estimate (Large Price shock) |
|---|---|---|
| Gasoline | 94% | 99% |
| Diesel | 99% | 99% |
| Propane | 97% | 96% |
| Other Oils | 94% | 99% |
| Aviation Fuel | 97% | 98% |
| Natural Gas | 93% | 98% |
| Total | 95% | 99% |

**Figure A-4:** Comparison of SHOCK Findings with Consumer Surplus

*For all fuel types studied, the avoided loss of consumer surplus is very close to, but slightly lower than, the retail effects calculated in this study.*

(Source: SHOCK-CA)



## c. Import Analysis

To calculate California's dependency on oil, we recognize that exports of oil products to neighboring states, as well as the import of petroleum products to make up refinery shortfalls, make the calculation difficult if focused at the California refinery level. Instead, we develop an estimate based on the difference between California's total primary demand for oil-based products, and its in-state oil production. California demand in 2020 is derived by summing the primary energy use estimated in the Energy 2020 model for the AB 32 Scoping Plan, adding aviation fuel, propane, gasoline, diesel, and other oil products, and calculating a barrel equivalency based on Btu content. For the purposes of this study, all California propane is assumed to be produced at California refineries.

The primary energy use of these fuels, which amounts to a total of 3,442 TBtus for 2006, for example, is divided by 5.8 million Btus per barrel, to get an energy-equivalent volume of oil, in barrels. (Source of conversion figure: www.eia.doe.gov/energyexplained).

California oil production values are from the 2009 IEPR report published by the Energy Commission. We do not incorporate energy losses at the refinery. One reviewer of our draft report commented that new enhanced oil recovery techniques and technologies could slow the rate of decline of California oil field production. While this may eventually prove to be true, nothing in the agency forecasts depicts this opportunity, so we have considered how such a technology might increase California production in our study.

To estimate the value of oil imports for two cases—with and without AB 32 implementation—the AEO high and moderate price forecasts are multiplied by estimated oil imports in 2020. In the oil price shock scenarios, oil product demand is first reduced based on the high and low estimates of short-term price elasticity for each fuel type.

For natural gas estimates, historic import dependency is derived directly from U.S. Energy Information Administration reports that provide both California production and consumption figures. These data (given in millions of cubic feet) are divided by 365 to get a very close match with the million cubic ft per day figures reported by the utilities in the annual California Gas Report. To compare these current production figures with future projections, we convert the figures into Btus using one cubic ft gas per 1,027 Btu. We then use the same method as with oil, taking the AB 32 Scoping Plan projections of natural gas primary energy demand (given in TBtu), with and without AB 32 implementation.

We note that there is a discrepancy in figures between the EIA and AB 32 Scoping Plan data, which we have not yet resolved. For example, in 2006, EIA figures show a California consumption of 2,315,721 MMcf, equal to 2,378 TBtu in 2006. The California Natural Gas Report (compiled from utility reports) indicates a similar 2,269 TBtu. However the Energy 2020 modeling figures show 1,952 TBtu.

However, this discrepancy does not influence the key area of study (i.e. the *difference* between the case with and without AB32 implementation). Regarding production, different forecast scenarios for California natural gas production were not found. Instead, a forecasted natural gas production referred to in the IEPR 2009 report (700 MMcf/d by 2020) is used in all scenarios. As in the oil scenarios, the natural gas import volumes are then multiplied by AEO moderate and high price forecasts, with demand adjusted downward based on elasticity estimates for the price shock scenarios.

# APPENDIX B: SUMMARY OF EXISTING MACROECONOMIC ANALYSES OF AB 32 MEASURES

This appendix provides context for the report by describing existing research related to how the implementation of AB 32 will affect the California economy. We focus on three recently updated forecasts of the economic impact of AB 32, from the California Air Resources Board (CARB 2010), Charles River Associates (CRA 2010), and the University of California's Professor David Roland-Holst (Roland-Holst 2010). These three analyses proceeded under a set of common assumptions in a collaborative modeling experiment organized by CARB. Although the three analyses use different economic modeling frameworks, there is an impressive convergence around the result that AB 32 will be nearly a *zero-cost policy for California*. The collaborative modeling studies used the reference forecast from the 2009 Annual Energy Outlook (AEO) as the basis for determining crude oil and California retail prices. The issue of price variability and the potential for price spikes was not considered.

Under modest assumptions about AB 32 boosting technological innovation in the form of faster improvements in energy efficiency over time, Professor Roland-Holst's findings indicate California would enjoy greater economic growth and faster job growth at the same time that the state reduces greenhouse gas emissions. Most of the analyses in the collaborative modeling experiment assume an annual improvement in energy efficiency of 1.1%, lower than the historical rate of 1.5%. When Professor Roland-Holst analyzes a scenario that assumes AB 32 boosts the annual improvement in energy efficiency to the historical level, the result is 400,000 new jobs in California and a 3% increase in Gross State Product (the total value of goods and services produced in California).Though many commentators treat these studies as though they are comprehensive cost-benefit analyses, it is important to recognize that these studies do not consider many important benefits of AB 32.[33] These unquantified benefits include:

- **improved public health** due to cleaner air
- **technological innovation** that climate policy will induce
- **avoided damages** that would follow from the destabilization of our climate

We explore these benefits to climate change mitigation measures in Appendix C. An expert advisory body convened by CARB and the California Environmental Protection Agency points out one category of economic cost that may not be well captured by these modeling frameworks: depressed economic activity should businesses relocate in an effort to avoid complying with climate policy (EAAC 2010). We point out that study of empirical evidence from the European Union Emissions Trading System impacts on economic output is that losses have not materialized (Grubb et al. 2009).

Another important benefit not accounted for in existing economic analyses of AB 32 is enhanced energy economic security, the focus of our study. These studies all used the same price forecasts from the Annual Energy Outlook (AEO), a report that provides supply, demand, and price forecasts developed by the U.S. Department of Energy's Energy Information Agency. But the AEO forecasts smooth, orderly changes in energy prices over time, not capturing real-world volatility. Moreover, CARB and the other studies use the AEO's *reference* case forecasts for price

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[33] We survey these other oft-ignored benefits of climate policy in Appendix C.

assumptions. This is the mid-range forecast, neither high nor low in the judgment of the forecasters. However, the lack of significant price increases predicted for fossil fuels in this reference case forecast is notable. In the California context, the AEO reference case predicts a gasoline price of $3.42 per gallon (2007 dollars) in 2020, which is not much higher than prices at the pump *today* in 2010.[34]

The modeling frameworks of CARB and DRH anticipate greater potential for cost saving through energy efficiency than Charles River Associates, and this is a principal reason for differences in results. In addition to the direct benefits, savings from energy efficiency also change how people spend money, shifting expenditures from imported energy to other goods and services more likely to be produced in state. This provides a boost to the California economy. Costs are kept low in all the models by the gradual nature of the change, a 20% reduction in greenhouse gas emissions by 2020 compared to an economy that grows without pollution controls. Thus, for CARB and DRH, three favorable factors work to minimize the cost of AB 32 in existing macroeconomic studies: (1) the potential for money saving energy efficiency investments, (2) expenditure shifting to California produced goods and services not spent on energy, and (3) the gradual nature of transition.

Despite their emphasis on costs and not benefits, the different studies all indicate the economy will grow strongly with AB 32 implementation. In the forecast of economic development without AB 32, the measure of goods and services produced in California (Gross State Product, GSP) grows by 35.6%.[35] In the scenario modeling implementation of California's blueprint for action, known as the Scoping Plan, CARB forecasts that the economy will grow 35.4%; CRA forecasts 33.7% growth, and DRH 35.5%.[36] That represents an average difference of less than 1% from GSP without implementing AB 32. This same finding—small changes dwarfed by growth through 2020—holds under a range of five policy scenarios, which were harmonized via the collaborative modeling exercise launched by CARB. For more information about the details associated how the different scenarios vary, see Busch (2010). Results are depicted graphically below in Figure B-1.

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[34] In August 2010, the average retail price for a gallon of gasoline in California is $3.17. Source: www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_home_page.html last visited Aug, 10, 2010.

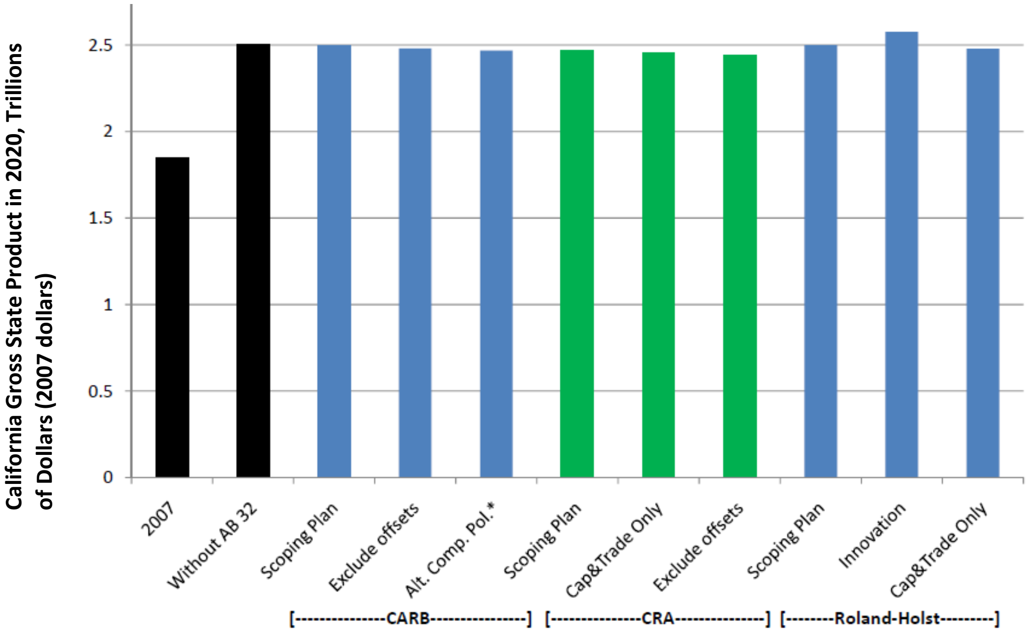
[35] We compare the 2020 forecast to 2007 Gross State Product because CARB's model is calibrated to that year. . Due to a decline in economic performance in 2008 and 2009, the growth through 2020 would appear larger if these years had been used to illustrate the future growth the models forecast.

[36] Thanks are due to CRA's Paul Bernstein who provided Gross State Product impacts via personal communication.

**Figure B-1:** Forecasts of AB 32 Economic Impacts Under Different Policy Assumptions

*The results of studies by CARB, CRA, and Roland-Holst all indicate that the economic impacts of AB 32 policies will be small relative to the growth that is expected with or without AB 32.*

(Source: CARB, 2010; CRA, 2010; Roland Holst, 2010)



*"Alt. Comp. Pol." is the scenario in which all complementary policies underperform.

In sum, existing macroeconomic analyses using different modeling frameworks and assumptions about the cost effectiveness of complementary policies all find the costs of AB 32 to be low. The existing modeling omits consideration of a range of valuable co-benefits as well. All the models fail to recognize how AB 32 will reduce our exposure to energy price shocks by reducing our reliance on conventional fossil fuels. In this report, we offer insight into the size of those benefits.

We have not considered in great detail a controversial study conducted by Professors Varshney and Tootelian (2009) of the California State University, Sacramento. This study has been widely discredited for its inadequate inputs, methods, and unreasonable findings. A principal shortcoming is that this research includes only costs and no benefits, not even the benefit of the money saved due to energy efficiency investments, as is standard practice in such studies. Also, their modeling framework does not allow for input substitution effects in production, thereby implicitly assuming that energy users will continue using fossil fuels as though nothing has changed even as prices of more polluting fuels rise to reflect the introduction of a price on carbon pollution. Here is a sampling of independent assessments of this work:

- "[Varshney and Tootelian's] cost estimates are fatally flawed and vastly over-state the expected costs of compliance with AB 32," UCLA Professor Matthew Kahn (Kahn 2009, p.1).
- "Examination of the [Varshney and Tootelian] analysis leads to the conclusions that their estimates are highly biased, are based on poor logic and unsound economic analysis, and

are likely too high by a factor of at least 10," Stanford Professor James Sweeney (Sweeney 2010, p. 1).

- "The [Varshney and Tootelian] report on the economic impacts of AB 32 is deeply flawed in numerous ways… In short, there is no substance to the outsized claims by Varshney and Tootelian. Their reports contain elementary errors, arbitrary assumptions, and enormous guesswork. Their anti-regulatory bias clearly skews their results toward finding large, unsupported costs…. The losses they project would be serious economic impacts if they were real. They are, however, entirely unreal," Dr. Frank Ackerman (Ackerman 2009, p.1).
- "The [Varshney and Tootelian analysis] contains a number of serious shortcomings that render its estimates of the economic effects of AB 32's proposed implementation through the [Scoping Plan] highly unreliable," California Legislative Analyst's Office (LAO 2010, p.6).

# APPENDIX C: DISCUSSION OF OTHER CO-BENEFITS

A key theme of this paper is that many important benefits of climate policies are ignored in macroeconomic analyses of such policies. Through our analysis, we provide some insights into the benefit of reduced exposure to volatile fossil fuel prices; in this Appendix, we provide some discussion of other valuable co-benefits that are typically ignored in macroeconomic modeling of climate policy impacts.

## a. Avoided Climate Damages

Of course, an important goal of AB 32 is to reduce California's heat-trapping emissions, to catalyze other governments to act as California leaders have done, and to avoid damages to California that would follow from unabated global warming. Significant damages to our natural resources and economy are expected if global warming is not slowed and contained. The overarching goal of AB 32 is to avoid such damages, which would seriously affect the quality of life for the people of California.

Significant research literature has been developed looking at the risks California faces from global warming, much of it funded by the Public Interest Energy Research Program at the California Energy Commission. A full review of the literature is beyond the scope of this paper. Moser et al. (2009) provides an excellent survey. In short, the anticipated impacts of unabated global warming include:

- **Sea-level rise** that occurs at a faster rate
- **Increasing wildfire** frequency
- **Changes in the water cycle** that would require significant changes to California's water use and infrastructure, due to loss of free water storage in the Sierra snowpack
- **Growing stresses** to agricultural production
- **Worsening air quality** (greater smog formation due to higher temperatures)
- **Adverse effects on public health**
- **Disturbances to forests** and other ecosystems

All of these have economic effects and impact the quality of life for the citizens of California.

Other than Moser et al. (2009), research by Roland-Holst and Kahrl (2008) offers perhaps the most comprehensive perspective on the impacts and economic damages that California would suffer in a future of unabated global warming. Roland-Holst and Kahrl survey the state's real estate assets and find that of the $4 trillion in value, $2.5 trillion, or more than 60%, is at risk from "extreme weather events, sea-level rise, and wildfires," (p. 10). The report concludes that annual costs of global warming damage would be in the range of $7.3–$46.6 billion annually (2006 dollars).

## b. Public Health Benefits

Reduced emissions of criteria[37] or toxic air pollution often accompany investments in climate solutions. These are sometimes called co-pollutant reductions because they are achieved concurrently when greenhouse gas emissions from fossil-fuel combustion are avoided through clean energy or energy efficiency alternatives. Nationwide, the National Research Council has estimated that burning fossil fuels such as gasoline or diesel fuel for transportation needs or coal for electricity generation results in air pollution with a massive toll on public health. The total cost to public health was estimated at $120 billion for 2005, the last year for which full data were available (NRC, 2009). Impacts from transportation-related activities comprised $56 billion, which is nearly half of the total estimated by NRC. Nemet et al. (2010) survey 37 peer-reviewed studies of the air quality co-benefits of investment in climate solutions. They find an average co-pollutant reduction benefit of $49 per ton of reduction in carbon dioxide emissions (2008 dollars) and a range of $2–$196 per ton of carbon dioxide reduced. Grossman et al. (2009) estimate the present value of health-related co-benefits from national climate policy from 2006 through 2030 to be $90–$725 billion.

CARB has estimated the magnitude of the co-pollutant reductions that AB 32 will provide. The revised economic analysis provides an estimate of how much it would cost to achieve the co-pollutant reductions expected from AB 32 in 2020 from alternative strategies. CARB estimates the avoided cost of alternative investments in pollution controls for the co-pollutant reductions anticipated due to the Scoping Plan to be $273.7—$322.5 million in 2020 (in 2007 dollars).

CARB's estimate does not account for improved public health, lower healthcare costs, improved worker productivity, or other benefits related to clean air. Valuing public health benefits is challenging because the location of the co-pollutant reduction determines its value. Pollution reductions in densely populated areas will be much more valuable than those in sparely populated areas. NRDC sought to incorporate public health benefits in an assessment of the Scoping Plan's impacts, and their estimate is that AB 32 could result in 700 avoided premature deaths and public health benefits of between $3.2 –$5.0 billion (2007 dollars, Bailey et al. 2008).

## c. Innovation

Well-designed climate policy is expected to inspire innovation that could lead to lower abatement costs as well as new commercial opportunities for California companies. Global markets for clean energy and other clean technologies are rapidly expanding, and could very well lead to significant economic benefits for California. The Tesla Motors–Toyota joint venture to build electric vehicles in California is an example of the type of new possibilities that would be, in part, attributable to AB 32. These policy-induced innovation effects (to be distinguished from innovation that would have happened anyway) are difficult to analyze. The only innovation in the macroeconomic modeling of the type surveyed in Appendix C is an improvement in energy efficiency over time. This is incorporated as an exogenous input to the modeling (i.e. the effect is captured through the Autonomous Energy Efficiency Improvement rate variable of Computable General Equilibrium models). Put differently, the rate of innovation is not endogenous to the model. Some assumption about the expected future rate of innovation is made. There is no structural link in the modeling between the rate of innovation and the policy framework.

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[37] The term "criteria" refers to pollutants, and their precursors, for which there are established National Ambient Air Quality Standards, including oxides of nitrogen, particulate matter, sulfur dioxide, lead and tropospheric ozone.

In the collaborative modeling work we profile in Appendix B, nearly every case the exogenous assumption regarding energy efficiency innovation will occur at a rate less than the historical trend. The exception is Roland-Holst's innovation scenario, where the historical rate is achieved. None of the models considered the lowering of costs for clean energy technologies through learning-by-doing and increasing economies of scale. Such innovation will not just lower abatement cost in California but also increase competitiveness for California cleantech firms in this rapidly expanding global market. For example, none of the models forecasts the likelihood that policies such as AB 32 will increase interest in improving the cost-effectiveness of battery technologies. The International Energy Agency (2000) has documented that these gains will occur over time for emerging energy technologies.

None of the models contemplated the possibility that entirely new products might become available in part due to more focused efforts induced by the AB 32 policy framework.

Support for the notion that innovation can be spurred by policies is found in a survey of leading venture capitalists (VCs) by Environmental Entrepreneurs (2004), which indentified:

- The second most important reason why VCs are motivated to invest in California's cleantech industry is the state's regulatory climate and policies. (The most important reason cited is entrepreneurial culture and management talent)
- 79% of VCs surveyed say that California's current regulatory climate is a factor in their cleantech investment decisions
- 91% say that advancing California's environmental public policies would be a driver for new investment in the state's cleantech industry

University of California Professor Margaret Taylor's research, and the academic literature more broadly, have found two ways that government policy can affect the rate in which innovation occurs: (1) technology push, and (2) demand pull. Technology push involves the supply side of the market. By investing in research and development, policy can lower the supply of clean alternatives or support the invention of new options. On the demand side, government policy can increase the potential profitability of clean technologies, thereby increasing the incentives to innovate and bring cost-competitive options to market. Demand-pull occurs when policy changes the economic position of a new technology in the marketplace, and can take a variety of forms: policies that affect incentives directly (such as taxes, subsidies, tax credits, or the price signal that follows from the introduction of cap and trade) or through performance standards that directly support demand for cleaner alternatives (such as standards for appliances, lighting, buildings, transportation fuels, or the amount of renewable energy generation in electricity delivered by utilities). Taylor agrees with the dominant view of the literature that, "a relatively high degree of regulatory stringency appears to be a necessary condition for inducing higher degrees of innovation," and concludes that, "a combination of policy instruments—both technology push and demand pull—will offer the greatest chance of successfully inducing the innovation to meet [California's] 2050 GHG emission target" (Taylor, 2006, p. 3–11 and p. 3–27).

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