# More Jobs per Gallon:

## How Vehicle Efficiency
## Fuels Growth in California

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# Research Papers on Energy, Resources, and Economic Sustainability

# Executive Summary

## ES 1.  Introduction

California's well known love affair with motor vehicles may be enduring, but it is a mixed blessing for the state economy. While providing essential transport, productivity, and personal services, the infrastructure needs and emissions that arise from all our driving represent large costs to society. Individuals may find direct benefits outweigh costs for their own vehicles, and infrastructure costs can be offset by economic returns and taxes. To address the broader public interest in environmental quality, however, the state has committed to more stringent regulation of transport emissions, which represent about 60% of the California's global warming pollution.

These policies take two main forms, direct standards for vehicle emissions and indirect standards for carbon fuel consumption. Their environmental justification is relatively transparent, but because they represent substantial change to established patterns of behavior, technology, and economic relations, the policies are not without controversy. This study provides new evidence to support more informed public and private dialog on the economic implications of fuel standards. Generally speaking, we find that such measures, by increasing economic efficiency, confer significant long term gains on the California economy.

To elucidate the linkages between transport fuel efficiency, economic growth, and job creation, we used a state-of-the-art economic forecasting model to evaluate different scenarios for vehicle emissions and mileage standards. This model, which closely tracks the evolution of California's vehicle fleet over time, projected macroeconomic aggregates, energy use, and emissions patterns between now and 2025. Before discussing the individual scenarios, we present the most salient findings of our research below.

**Main Research Findings**

- **Vehicle fuel efficiency is a potent catalyst for economic growth.**

- **Fuel efficiency creates jobs across the economy.**

- **Technologies that reduce GHG emission intensity, to the extent that the indirectly promote fossil fuel efficiency, and are thus themselves a source of growth and job creation.**

- **Individual Californians gain from fuel efficiency policy whether they buy new cars or not (but most if they do).**

- **Lower energy prices and higher incomes will increase vehicle use somewhat, but not by enough to offset fuel efficiency gains.**

Vehicle efficiency stimulates economic growth by reducing fuel use and saving money for households and enterprises. These savings return as different expenditures that are, on average, less import dependent and more job intensive than the carbon fuel supply chain. Consequently, the new expenditures have stronger "multiplier" effects on state product and create many more jobs than they displace.

Except for fuel production and distribution, transport fuel efficiency creates new jobs across economic activities where consumers and enterprises spend money. This leads to employment growth far beyond "green" sectors and "green-collar" occupational categories. Indeed, the majority of new demand financed by savings from fuel efficiency goes to in-state services, a source of diverse, bedrock jobs that cannot be outsourced.

The results of this analysis also remind us that lowering energy dependence reduces economic risk, particularly against volatile oil prices that are beyond the state's control. We saw in the 1970s what can happen to growth when energy prices turn up sharply as they are doing today, and greater fuel efficiency directly offsets this cost risk to the state's essential transport services. Our analysis

shows, for example, that California's existing policies, including the Pavley and Low Carbon Fuel regulations, will promote growth via indirect promotion of fossil fuel efficiency.

Energy security is another essential dimension of direct and indirect transport fuel efficiency gains. Buying lower emission, fuel efficient vehicles makes sense at current oil prices, more so at probable higher future prices, but efficiency standards will lower energy costs even for those who hold on to their gas guzzlers. As the changing state vehicle fleet becomes ever more fuel efficient, this reduces pressure on long term California energy prices and confers cost of living benefits on everyone who pays for energy.

There has been much discussion in the efficiency literature about the so-called Rebound effect, which refers to more driving in response to lower vehicle use cost, energy prices, and rising income. Our results show this effect is very modest in California, amounting to less than ten percent of net fuel savings.

For all these reasons, standards that reduce vehicle emission intensity and increase fuel efficiency will enable California to enjoy significant reductions in energy dependence and global warming pollution while stimulating its economy and statewide employment with the resulting fuel savings.

For all these reasons, vehicle emission and fuel efficiency standards will enable California to enjoy significant reductions in energy dependence and global warming pollution while its economy and statewide employment grow faster.

## ES 2.   Research Findings

The following table summarizes the five core scenarios undertaken in this study. After detailed examination of baseline growth characteristics, policies in place or under active discussion, and technology opportunities, these are thought to best represent the leading policy options open to California over the next generation.

**Table ES.1: Policy Scenarios**

| Scenario | Name | Description |
|:---:|:---:|:---|
| 1 | Baseline | Business as usual: Assume California does not implement vehicle standards but continues growth at levels forecast by the Department of Finance. |
| 2 | Cal | California Vehicle Standards: Assume the Low Carbon Fuel Standard and Pavley vehicle emissions legislation remain in force until 2025. |
| 3 | Nat4 | Assume California adheres to US national standards, 2012-2016, and continues with 4%/year efficiency improvements over 2017-2025 |
| 4 | Nat6 | Assume California conforms to US national standards, 2012-2016, and continues with 6%/year efficiency improvements over 2017-2025 |
| 5 | Hzn | Assume California attains state-of-the-art vehicle emissions standards for gasoline powered vehicles (Horizon study, DeCicco:2010). |

**Table ES.2: Technical Assessment Report (TAR) Scenarios**

| Case | GHG Emissions | | Fuel Economy | |
|---|---|---|---|---|
| | Rated gCO$_2$/mile [a] | Annual improvement from 2016 | Consumer label (on-road) mpg [b] | Annual improvement from 2016 |
| Baseline (2008) | 339 | - | 21 | - |
| Baseline (2016) | 250 | - | 27 | - |
| New vehicle target in 2025 | 190 | 3% | 34 | 2.4% |
| | 173 | 4% | 37 | 3.3% |
| | 158 | 5% | 40 | 4.3% |
| | 143 | 6% | 43 | 5.3% |

*Source: EPA, NHTSA, CARB, see Lutsey (2010)*

## Statewide Results

The macroeconomic and other statewide impacts of the five different policy scenarios are summarized in Table ES.3. Generally speaking, these results are consistent with intuition and a large body of related work on energy efficiency and economic growth.[1]

**Table ES.3: Statewide Impacts**

| | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|
| **Real GSP** | 0.03% | 0.82% | 1.13% | 1.31% |
| **Real Consumption** | 0.03% | 0.68% | 0.92% | 1.05% |
| **Employment** | 0.17% | 0.69% | 0.89% | 1.02% |
| **Jobs (1000)** | | | | |
| **Created** | 47 | 179 | 231 | 264 |
| **Lost** | -9 | -21 | -26 | -28 |
| **Net** | 38 | 158 | 205 | 236 |
| **MPG ( Fleet Ave)** | | | | |
| **Gasoline** | 23 | 28 | 32 | 34 |
| **Diesel** | 11 | 13 | 15 | 17 |
| **Emissions** | | | | |
| **Household** | -14% | -22% | -26% | -29% |
| **Industry** | -4% | -9% | -11% | -13% |
| **Total** | -8% | -14% | -17% | -19% |

*Notes: Percentages measure change from Baseline values in 2025.*

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[1] See e.g. Roland-Holst: 2010b, CARB:2009. 2010a, EAAAC:2009.

- **Cal** – Results for the vehicle components of AB32 are consistent with comparable estimates in the leading assessments of the Global Warming Solutions Act (CARB: 2009, 2010a, Roland-Holst: 2010). In the absence of enhanced measures, impacts on 2025 real GSP and employment are relatively modest but positive. These policies contribute to about 8% reduction in trend GHG emissions for the state, and important component of mitigation to be expected from this extensive package.

- **Nat4&6** – National emissions standards are slightly less strict than California for gasoline vehicles up to 2016, more so for diesel, and more so for both fuels from 2016 forward. Moreover, national policies can regulate fuel efficiency directly, rather than relying on indirect effects from emissions standards alone. Because the combination of these leads to higher levels of average fuel efficiency (also envisioned to persist from 2016 onward), they confer even greater growth on the state economy than California's own standards, creating between 158,000 and 205,000 additional jobs by 2025. Substantial emission reductions at both the household and enterprise level reduce California's trend GHG emissions by between 14 and 17 percent by 2025.

- **Hzn** - Engineering evidence tells us that vehicle efficiency technology is beginning an era of dramatic and sustained innovation. Indeed, the authoritative **Horizon Gasoline Efficiency** scenario uses mpg estimates from the Fuel Efficiency Horizon study (DeCiccio: 2010) suggests that "off the shelf" engine technologies of the future will offer mpg levels well above those incorporated in today's standards. Assuming these are incorporated into policy mandates, or voluntarily adopted for gasoline vehicles only, would propel the state economy even further toward a lower carbon, higher growth future. The results of the Horizon scenario indicate that the state would gain an additional 1.3 percent of GSP over

the long term and comparable (1.02%) employment growth. In all, over 236,000 jobs would be added in the state economy by 2025, as households and enterprises redirect expenditure away from carbon fuel supplies to more job intensive (largely in-state) goods and services. Meanwhile, new vehicle technologies would make a dramatic impact on emissions of local toxic gases and global warming pollution, reducing the latter by 19%. Again, macroeconomic impacts of the national policies are much greater because direct and induced efficiency improvements persist beyond 2016.

**Figure ES.1: Macro Results**
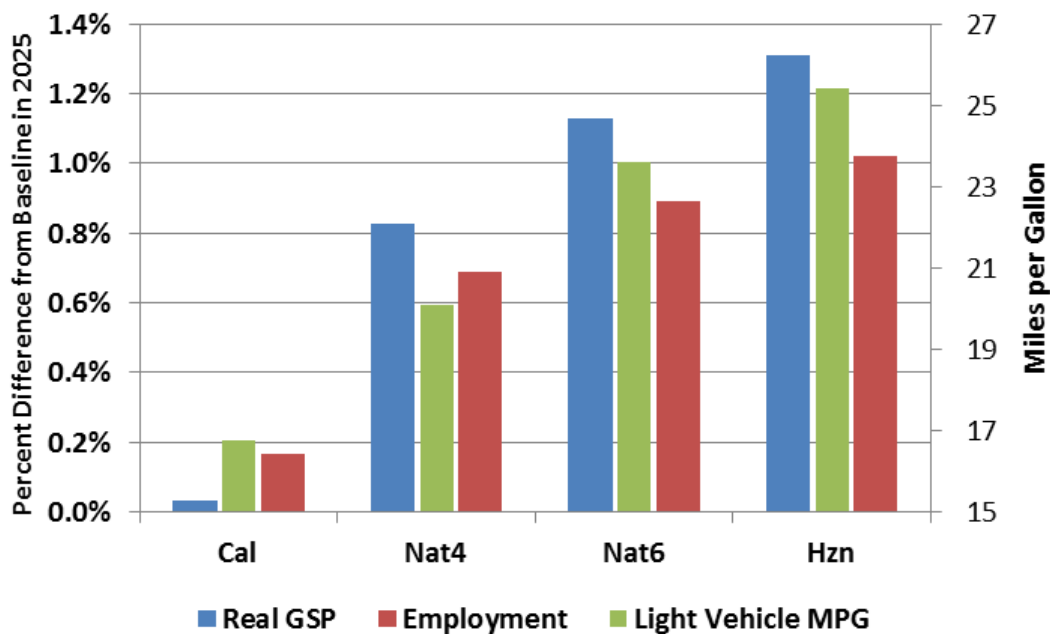


*Note: Real GSP and Employment are percentage changes from Baseline in 2025 (left axis). Fuel Economy is mpg (right).*

Generally speaking, the most robust finding of this study, as illustrated in Figure ES.1, is that statewide economic growth and employment rise with the degree and scope of transport fuel efficiency standards. This is true as regardless of whether standards are direct, targeting fuel consumption, or indirect, targeting emissions. What matters is that the efficiency technologies have positive net value to those who adopt them, inclusive of any secondary increases in vehicle use. If these savings accrue to vehicle owners, be they households or

enterprises, they will reappear as demand for goods and services outside the carbon fuel supply chain, and the results will be higher domestic growth employment.[2]

**Figure ES.2: Job Creation and Economic Rewards of Efficiency**
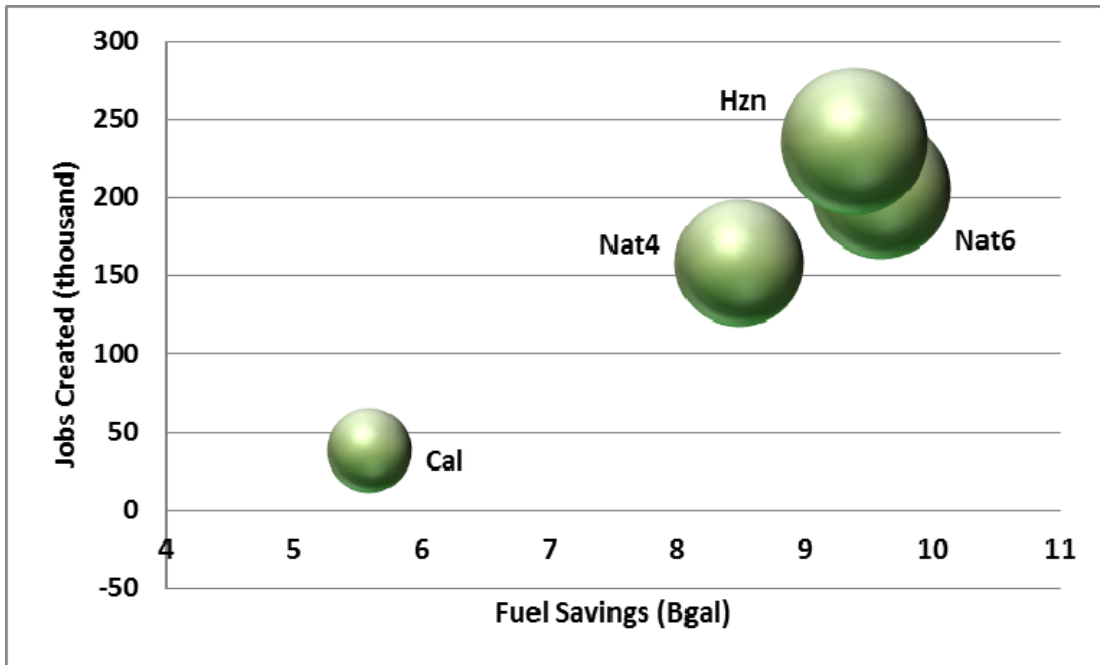


*Notes: Author estimates. Bubble diameter is proportional to household energy cost savings.*

The next two figures illustrate a new, macroeconomic concept in the fuel efficiency literature, one that probably deserves more recognition. In Figure ES.2, we see the five policy scenarios in terms of fuel saving (horizontal axis), job creation (vertical), and vehicle cost dividend to households (bubble diameter). Clearly, the more effective the fuel efficiency target, the more economic benefit to California. California's own policies confer substantial

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[2] These findings are wholly consistent with a recent meta-review of some 48 past state and regional policy assessments (Laitner and McKinney 2008) which notes that significant energy efficiency improvements of all kinds can yield net positive employment and GDP benefit to the economy (see,). These finding were further reinforced by major assessment of the American Power Act (APA) (Laitner et al 2010).

benefit, but there would be much greater long term gains if annual improvements in fuel efficiency were increased beyond 2016.

The next figure presents the same results from a different perspective, new jobs per gallon saved in aggregate fuel efficiency. Again, the results make clear that more effective fuel efficiency standards confer greater economic benefits, as well as a dividend of greater economic security. Moreover, the "job mileage," or effectiveness of the standard in terms of jobs created per gallon of fuel saved, increases with the standard. This is true because higher standards increase in-state expenditure shares, leading to stronger multiplier effects.

**Figure ES.3: New Jobs per Gallon Saved, by Scenario**
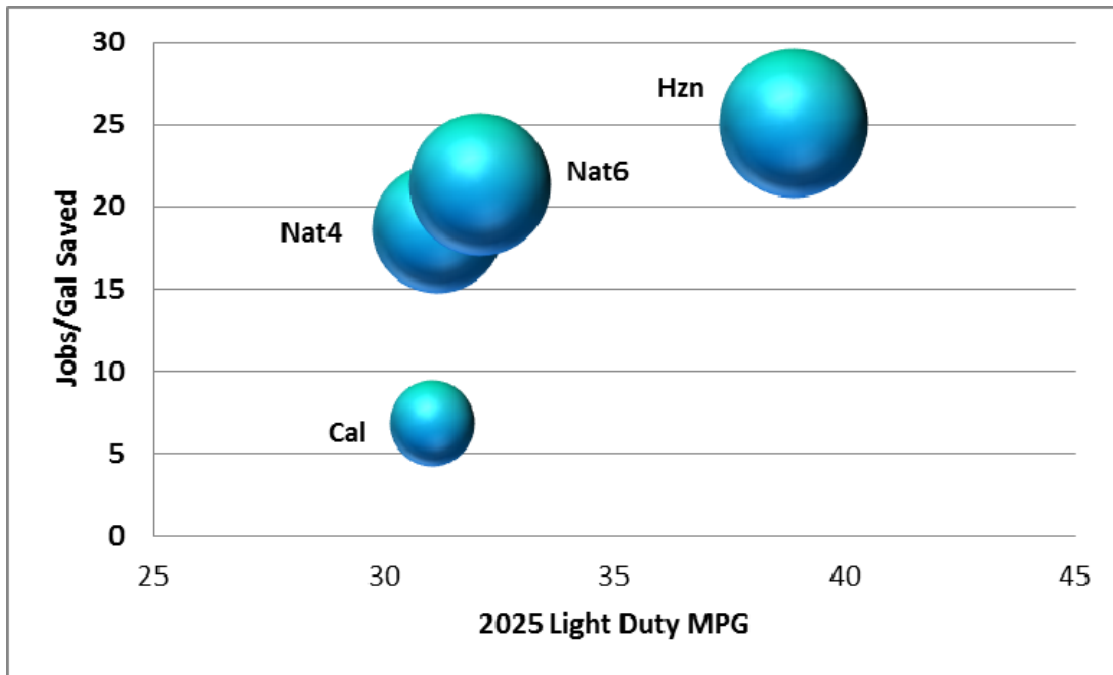


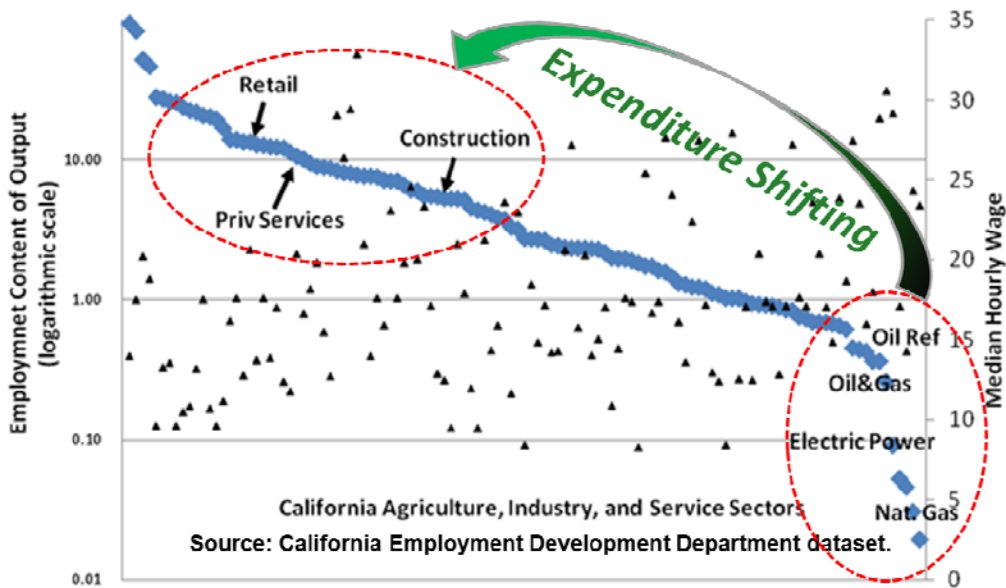*Notes: Author estimates. Bubble diameter is proportional to household energy cost savings.*

## Why Vehicle Efficiency Promotes Growth

The following figure explains why more efficient vehicles stimulate aggregate job growth. Different goods and services require different amounts of labor to produce and deliver them, and this figure shows the ratio of FTE work hours to

output across the California economy. Production is divided into 124 different economic activity sectors, ordered from left to right from highest to lowest job content (blue diamonds). Note that labor intensity across the economy varies so much that a logarithmic scale is needed to encompass it. Also shown are median wages for each activity (black triangles, right axis).

When households and enterprises reduce fuel needs, these savings are removed from the carbon fuel energy supply chain, among the least employment intensive in the economy (lower right circle). Since about 70% of household demand and a significant portion of enterprise spending on non-energy inputs goes to services (upper right circle), the resulting expenditure shifting will result in substantial net job creation. Simply put, a dollar saved on traditional energy is a dollar earned by 10-100 times as many new workers.

**Figure ES.4: Employment Intensity and Median Wage by Sector (labor/output ratios and wages for 124 California sectors)**



*Source: California Employment Development Department dataset.*

Other aspects of this job creation process are also noteworthy. Firstly, it is apparent that energy fuel sector wages can be high, but they are not higher than

service sector wages by anything like the employment multiples evident here. Moreover, jobs created from this expenditure diversion are distributed across a broad spectrum of sectors and occupational categories, not restricted to green technology or import-dependent energy fuels and services. On the contrary, most of the jobs created by fuel economy are in service sectors with high levels of in-state inputs and value added. Jobs like this have stronger and longer multiplier linkages inside the state economy, and they are at very low risk of being outsourced.

## Composition of Job Growth

Beneath the smooth veneer of macroeconomic aggregates, pervasive structural changes can take place. In particular, aggregate benefits can mast tradeoffs between difference stakeholder groups across the economy, and both fuel efficiency and emissions intensity exemplify this issue. While the overall state economy and average households gain from the policies considered here, the composition of impacts is more complex. In particular, transition to a lower carbon future obviously challenges enterprises in the carbon fuel supply chain, and this effect is plainly evident in the results of Table ES.4.

These figures break down the aggregate employment results of Table ES.2 on a sector-by-sector basis. Employment impacts within sectors are net job creation effects, while the last three rows present statewide sector aggregates that reveal patterns of job creation and reduction. What is perhaps most noteworthy is that only one in twenty sectors experiences net employment reduction, the carbon fuel sector (Oil and Gas) targeted directly by the fuel economy policies and indirectly by the emissions intensity measures. Because of the expenditure shifting process described in the last subsection, job creation in each scenario outweighs job reduction by a factor of 4 to 9 jobs created for each lost. These results strongly support the notion that restructuring California's economy for a lower carbon future will benefit many more people than are adversely affected.

**Table ES.4: Employment Effects by Sector**

**(change from 2025 Baseline in thousands of FTE jobs)**

| Sector | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|
| Agriculture | 0 | 0 | 0 | 0 |
| Other Primary | 0 | 0 | 0 | 0 |
| Oil and Gas | -9 | -21 | -26 | -28 |
| Electric Power | 0 | 0 | 1 | 1 |
| Natural Gas Dist. | 0 | 0 | 0 | 0 |
| Other Utilities | 0 | 1 | 1 | 1 |
| Processed Food | 0 | 1 | 2 | 2 |
| Construction - Residential | 0 | 4 | 5 | 6 |
| Construction - NonRes | 1 | 8 | 11 | 13 |
| Light Industry | 4 | 13 | 16 | 19 |
| Heavy Industry | 0 | 3 | 5 | 5 |
| Machinery | 0 | 1 | 1 | 1 |
| Technology | 0 | 3 | 4 | 5 |
| Electronic Appliances | 0 | 0 | 0 | 0 |
| Automobiles and Parts | 0 | 0 | 0 | 0 |
| Trucks and Parts | 0 | 0 | 0 | 0 |
| Other Vehicles | 0 | 1 | 1 | 1 |
| Wholesale, Retail Trade | 17 | 55 | 69 | 79 |
| Transport Services | 1 | 7 | 9 | 11 |
| Other Services | 24 | 83 | 105 | 120 |
| Total Net Jobs | 38 | 158 | 205 | 236 |
| New Employment | 47 | 179 | 231 | 264 |
| Employment Reductions | -9 | -21 | -26 | -28 |

## Benefits to Households

Although this study emphasized the economywide benefits of fuel savings, including extensive indirect effects of household expenditure shifting and structural adjustment, energy efficiency stories generally begin at the microeconomic level. Individual economic agents are assumed to make technology adoption and use decisions based on their own perception of costs and benefits that will accrue to themselves personally, their household, or their enterprise. These direct effects are the primary determinate of market oriented

technology diffusion as well as the primary target of policies that seek to influence adoption behavior, including standards, incentives, and fees.

Because of their importance, microeconomic technology costs and benefits are the subject of intensive scrutiny and controversy. To more effectively support public discussion of its own policies, EPA, NTHSA, and CARB have been working individually and in concert to improve this evidence. Their results, summarized by Lutsey (2010) and reprinted in the following table, also reflect extensive consultations with vehicle and energy sector participants. Generally speaking, these estimates suggest that energy and emissions efficiency are very sound individual investments, with payback periods of 2-4 years and returns on incremental investment of over 100% across the lifetime of vehicles.

**Table ES.5: Vehicle Efficiency Costs and Benefits Joint Agency Estimates**

| Scenario[a] | Rated new vehicle gCO$_2$/mile | New vehicle consumer label fuel economy (MPGe)[b] | Technology Path | Per-Vehicle Cost Increase ($) | Payback Period [c] (years) | Net Lifetime Owner Savings [c] ($) |
|---|---|---|---|---|---|---|
| 4%/year | 173 | 37 | A | $1,700 | 2.5 | $5,900 |
| | | | B | $1,500 | 2.2 | $6,000 |
| | | | C | $1,400 | 1.9 | $6,200 |
| | | | D | $1,900 | 2.9 | $5,300 |
| 5%/year | 158 | 40 | A | $2,500 | 3.1 | $6,500 |
| | | | B | $2,300 | 2.8 | $6,700 |
| | | | C | $2,100 | 2.5 | $7,000 |
| | | | D | $2,600 | 3.6 | $5,500 |
| 6%/year | 143 | 43 | A | $3,500 | 4.1 | $6,200 |
| | | | B | $3,200 | 3.7 | $6,600 |
| | | | C | $2,800 | 3.1 | $7,400 |
| | | | D | $3,400 | 4.2 | $5,700 |

*Source: EPA, NHTSA, CARB, see Lutsey (2010)*

In addition to individual financial benefits from more efficient vehicles, large scale adoption creates general equilibrium, or spillover benefits across the state economy. These take two primary forms, the expenditure shifting benefits already discussed, and cost of living benefits from reduced aggregate energy demand. The second benefit arises from the fact that, taken together, individual efficiency choices reduce aggregate energy demand and exert downward pressure on prices. For a small economy, these might not affect national or

global energy markets, but because California comprises 11% of US GDP and is itself the eighth largest economy in the world, substantial changes in California energy demand certainly will affect both national and global prices.

For the scenarios considered, energy price changes from the Baseline scenario in 2025 are given in the next table. Clearly,

**Table ES.6: Changes in Final Energy Goods Prices**

**(percent difference from Baseline in 2025)**

|  | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|
| **Transport Fuel** | -4.5% | -17.3% | -22.4% | -25.3% |
| **Electricity** | -1.0% | -4.9% | -6.5% | -7.4% |
| **Natural Gas** | -0.9% | -4.4% | -5.7% | -6.5% |

*Source: Author estimates.*

To see the overall cost of living effect on households, we must take account of changes in total energy demand as well as incremental costs attributable to energy efficient technologies. The next table estimates these for California households by income status. One caveat is needed before interpreting these results. Although we have baseline consumption data on households by income level, we do not predict which income groups will adopt which vehicles, and thus assume that new vehicles are dispersed uniformly across the population. Because new vehicle adoption is more highly concentrated in higher income groups, we are probably underestimating the efficiency gains for high income groups and overestimating them for others.

**Table ES.7: Changes in Energy Expenditure by Household**

**(CA percent income tax brackets, percent difference from Baseline in 2025)**

| Household | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|
| 1.0 Percent | -3.3% | -13.2% | -17.1% | -19.3% |
| 2.0 Percent | -3.6% | -14.0% | -18.1% | -20.5% |
| 4.0 Percent | -3.6% | -14.2% | -18.4% | -20.8% |
| 6.0 Percent | -3.6% | -14.2% | -18.4% | -20.8% |
| 8.0 Percent | -3.6% | -14.2% | -18.4% | -20.9% |
| 9.3 Percent<200k | -3.5% | -14.0% | -18.1% | -20.5% |
| 9.3 Percent>200k | -3.5% | -13.9% | -18.1% | -20.5% |
| Average | -3.5% | -14.0% | -18.1% | -20.5% |

*Source: Author estimates.*

**Table ES.8: Energy Savings by Household**

**(CA percent income tax brackets, percent difference from Baseline in 2025)**

| Household | Ave Inc | Number | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|---|---|
| 1.0 Percent | 9 | 2,637 | 0.4 | 0.8 | 0.9 | 1.0 |
| 2.0 Percent | 27 | 3,509 | 1.2 | 2.4 | 2.9 | 3.1 |
| 4.0 Percent | 48 | 1,857 | 1.3 | 2.6 | 3.2 | 3.5 |
| 6.0 Percent | 70 | 1,997 | 0.9 | 1.7 | 2.1 | 2.3 |
| 8.0 Percent | 98 | 1,158 | 0.4 | 0.8 | 1.0 | 1.1 |
| 9.3 Percent<200k | 163 | 1,774 | 0.3 | 0.7 | 0.8 | 0.9 |
| 9.3 Percent>200k | 1,037 | 415 | 0.1 | 0.2 | 0.2 | 0.3 |
| Average | | | 0.8 | 1.9 | 2.3 | 2.5 |

*Notes: Average Income and Number of households in thousands. Scenario results stated as percent of income reductions in household energy expenditure. Average row population weighted. Source: Author estimates.*

More research is needed to elucidate this important equity issue, but meanwhile we see interesting dynamics in these adjustments. Energy expenditure changes are driven by two forces: technology (efficiency) reductions in quantity demanded and market reductions in prices. The combination of both these downward trends leads to substantial household savings, reducing energy expenses by about a third in the more optimistic scenarios. These savings take account of the TAR individual cost and benefit estimates cited above, but aggregate them across a diverse population and vehicle stock for a late sample

year (2025). Across an economy as large and heterogeneous as California, households have vehicles of differing ages and efficiency levels, yet the aggregate efficiency progress confers price benefits on all of them. Moreover, because lower income groups are likely to have less fuel efficient vehicles, indirect savings will be greater for them as a proportion of income and overall vehicle operating costs. For higher income groups, more likely to adopt new vehicle technologies, direct savings will predominate. The overall message of both effects is simple, however, vehicle efficiency saves household money whether they themselves buy a new vehicle or not.

## ES 3.  Conclusions

The idea that there is a necessary trade-off between environmental goals and economic growth is a fallacy, and in California we have proven this before with electricity use and will prove it again with transport fuel. Thirty years of efficiency policies in the electric power sector contributed to substantially higher California economic growth and employment, and efficiency measures in the vehicle sector will expand incomes and jobs in the same way.

Using a long term economic forecasting model that details patterns of vehicle ownership and use across the state, we evaluated a variety of scenarios from existing vehicle emission rules to standards representing the highest expectations for emerging vehicle technology. In all cases, direct and induced fuel savings translated into combinations of significant emissions reduction and new demand for more job intensive goods and services, most of which were in sectors with less import dependence and more extensive in-state multiplier linkages. Fuel savings, whether direct from mileage standards or induced from emissions standards, results in expenditure shifting, moving household and enterprise demand from the carbon fuel supply chain to demand-induced income and job creation across a broad spectrum of local activities and local jobs.

These results also support the important insight that fuel efficiency confers economic security against volatile energy prices. Even for an economy the size

of California's, energy markets are outside our control. The smaller the share of energy costs in personal and commercial transport services, the less vulnerable we are to adverse income and profitability shocks from energy prices.

The results obtained for transport fuel and (earlier) electric power remind us that efficiency deserves deeper consideration across the full spectrum of energy uses, including reconfiguration of transport services, infrastructure, and many non-transport energy uses.[3]  At the same time, rapid innovation in energy supporting and supported IT, communication, materials science, and electronics are all converging toward lower carbon, more energy efficient patterns of future production and use.

Finally, although fuel savings promote growth and energy security for the vast majority of Californians, there are of course some actors linked to the fossil fuel supply chain that will be adversely affected by these policies. Temporary adjustment assistance could be considered to facilitate their support in helping us realize our efficiency potential, and it could be a small price to pay for the lasting benefits of transition to a lower carbon future.

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[3] The Urban Land Institute, for example, sponsored a recent study (Cambridge Systematics: 2009) that profiled a broad range of transportation options which could reduce U.S. greenhouse gas emissions 35 percent below 2010 levels by the year 2050.

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## 1 Introduction

California's well known love affair with motor vehicles may be enduring, but it is a mixed blessing for the state economy. While providing essential transport, productivity, and personal services, the infrastructure needs and emissions that arise from all our driving represent large costs to society. Individuals may find direct benefits outweigh costs for their own vehicles, and infrastructure costs can be offset by economic returns and taxes. To address the broader public interest in environmental quality, however, the state has committed to more stringent regulation of transport emissions, which represent about 60% of the California's global warming pollution.

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### Table 1.1: Main Findings

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- **Fuel efficiency creates jobs across the economy.**

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- **Individual Californians gain from fuel efficiency policy whether they buy new cars or not (but most if they do).**

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To elucidate the linkages between transport fuel efficiency, economic growth, and job creation, we used a state-of-the-art economic forecasting model to evaluate different scenarios for vehicle emissions and mileage standards. This model, which closely tracks the evolution of California's vehicle fleet over time, projected macroeconomic aggregates, energy use, and emissions patterns between now and 2025. Before discussing the individual scenarios, we present the most salient findings of our research in Table 1.1.

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Energy security is another essential dimension of direct and indirect transport fuel efficiency gains. Buying lower emission, fuel efficient vehicles makes sense at current oil prices, more so at probable higher future prices, but efficiency standards will lower energy costs even for those who hold on to their gas guzzlers. The changing state vehicle fleet, because as becomes ever more fuel efficient, reduces pressure on long term California energy prices and confers cost of living benefits on everyone who pays for energy.

There has been much discussion in the efficiency literature about the so-called Rebound Effect, which refers to more driving in response to lower vehicle use

cost, energy prices, and rising income. Our results show this effect is very modest in California, amounting to less than ten percent of net fuel savings.[5]

For all these reasons, standards that reduce vehicle emission intensity and increase fuel efficiency will enable California to enjoy significant reductions in energy dependence and global warming pollution while stimulating its economy and statewide employment with the resulting fuel savings.

## 2 Overview of Vehicle Fuel and Emission Standards

### 2.1 California Emission Reduction Regulations and AB 32

This section provides a brief overview of California's current vehicle emission reduction policies, as well as their implications for induced fuel efficiency. More historical background on these issues is also included in an annex to this report. Assembly Bill 32 (AB 32) is the current framework under which the State of California is setting goals to reach significant reductions in greenhouse gas emissions (GHGs). The bill passed by Legislature and signed by Governor Schwarzenegger in 2006 sought to identify the statewide level of GHG emissions in 1990 which would serve as the emissions limit to be achieved by 2020. The 2020 emission limit of 427 million metric tons of carbon dioxide equivalent (MMTCO$_2$E) of GHGs was approved by California's Air Resources Board (CARB). The AB 32 scoping plan was approved by the Board on December 12, 2008. Among the programs that are part of AB 32 are: (1) the Low Carbon Fuel Standard (LCFS) which regulates carbon intensity of fuel in the state; (2) Assembly Bill 1493, known as the Pavley regulations, which regulate light-duty vehicle GHG emission standards (CARB, 2010a; CARB, 2011b); (3)

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[5] In an extensive review of the literature, Greening et al: 2000 suggest a range of 10-30% for this effect as a percent of vehicle fuel savings. Our estimates are at the low end for two reasons. California's fuel demand price elasticity and expenditure share are both among the nation's lowest.

Low-Emission Vehicle (LEV) program; and (4) Heavy-duty vehicle emission regulations.

## 2.2 Low Carbon Fuel Standard

The LCFS is one part of the AB 32 framework. The goal of the LCFS regulation is to mitigate GHG emissions in California by the reduction of the average carbon intensity of transportation fuels used in the State by 10 percent by the year 2020. The regulation is expressed as grams $CO_2$ equivalent per megajoule ($gCO_2E/MJ$). Table 2.1 displays the gasoline standards and Table 2.2 displays the diesel fuel standards, both of which are compulsory as of 2011 (CARB, 2009).

***Table 2.1*** - **LCFS Compliance Schedule for 2011 to 2020 for Gasoline and Fuels Used as a Substitute for Gasoline Scenarios**

| Year | Average Carbon Intensity ($gCO_2E/MJ$) | % Reduction |
|------|------|------|
| 2010 | Reporting only | |
| 2011 | 95.61 | 0.25% |
| 2012 | 95.37 | 0.5% |
| 2013 | 94.89 | 1.0% |
| 2014 | 94.41 | 1.5% |
| 2015 | 93.45 | 2.5% |
| 2016 | 92.50 | 3.5% |
| 2017 | 91.06 | 5.0% |
| 2018 | 89.62 | 6.5% |
| 2019 | 88.18 | 8.0% |
| 2020+ | 86.27 | 10.0% |

Source: CARB (2009)

**Table 2.2 -** **LCFS Compliance Schedule for 2011 to 2020 for Diesel Fuel and Fuels Used as a Substitute for Diesel Fuel**

| Year | Average Carbon Intensity (gCO$_2$E/MJ) | % Reduction |
|------|---------------------------------------|-------------|
| 2010 | Reporting only | |
| 2011 | 94.47 | 0.25% |
| 2012 | 94.24 | 0.5% |
| 2013 | 93.76 | 1.0% |
| 2014 | 93.29 | 1.5% |
| 2015 | 92.34 | 2.5% |
| 2016 | 91.40 | 3.5% |
| 2017 | 89.97 | 5.0% |
| 2018 | 88.55 | 6.5% |
| 2019 | 87.13 | 8.0% |
| 2020+ | 85.24 | 10.0% |

Source: CARB (2009)

## 2.3 Pavley Regulations

On June 30, 2009 the U.S. EPA granted a waiver giving California the authority to implement GHG emission standards for passenger cars, pickup trucks and sport utility vehicles. These standards, known as the Pavley regulations, are expected to reduce GHG emissions from passenger vehicles in California by 30 percent by 2016. On September 24, 2009 CARB adopted amendments to the Pavley regulations that would "cement" California's enforcement of the regulations beginning in 2009 while providing compliance flexibility to vehicle manufacturers (CARB, 2010c). Table 2.3 (below) outlines the emission requirements according to the Pavley regulations.

**Table 2.3 -** Fleet Average Greenhouse Gas Exhaust Mass Emission Requirements for Passenger Car, Light-Duty Truck, and Medium-Duty Passenger Vehicle Weight Classes (4,000 mile Durability Vehicle Basis)

| Model Year | Fleet Average Greenhouse Gas Emissions (grams per mile $CO_2$-equivalent) | |
| :---: | :---: | :---: |
| | All PCs; LDTs 0-3750 lbs. LVW | LDTs 3751 lbs. LVW - 8500 lbs. GVW; MDPVs |
| 2009 | 323 | 439 |
| 2010 | 301 | 420 |
| 2011 | 267 | 390 |
| 2012 | 233 | 361 |
| 2013 | 227 | 355 |
| 2014 | 222 | 350 |
| 2015 | 213 | 341 |
| 2016+ | 205 | 332 |

Source: CARB (2010b)

As shown in Table 2.3, GHG emission levels are restricted to specific $CO_2$ equivalent emission levels. $CO_2$ equivalent is determined by the following equation:

**$CO_2$ Equivalent Value** = $CO_2$ + 296 x $N_2O$ + 23 x $CH_4$ - A/C DEA - A/C IEA

In the equation A/C DEA represents Air Conditioning Direct Emissions Allowance and A/C IEA is Air Conditioning Indirect Emissions Allowance. A/C DEA is achieved by detailed analysis of system specifications and components and determination of system emissions and quality of fittings and joints and the extent to which they have been proven to minimize leakage. A/C IEA is a value determined by a detailed analysis of the energy efficiency of a vehicle's air conditioning system (CARB, 2010b).

## 2.4 EPA Regulations, The CAFE Program and Coordination with California's Pavley Standards

The Corporate Average Fuel Economy (CAFE) program, enacted by Congress in 1975, enforces fleet-wide fuel economy standards for light-weight vehicles. The CAFE program is administered by the National Highway Traffic Safety Administration (NHTSA) while the U.S. EPA is the body in charge of testing and providing fuel economy data. Until recently, the CAFE fuel economy standards had changed little over the past two decades. The CAFE fuel economy standard for passenger cars was frozen at 27.5 mpg from 1990 through 2010 while the standard for light trucks was 20.2 in 1990 and has risen to 22.5, 23.1 and 23.5 mpg in model years (MY) 2008, 2009 and 2010 respectively under the unreformed CAFE standards (NHTSA, 2011).

In May 2010, the U.S. EPA and the NHTSA finalized a joint rule to establish a national program including a footprint-based system to regulate vehicle emissions and fuel economy in MY 2012-2016. Under this program the NHTSA will regulate fuel economy (CAFE) standards while the EPA will regulate GHG emission standards. This combination of standards is known as the "National Program" (NHTSA, 2010b).

**Figure 2.1 - Footprint-based CAFE fuel economy targets for passenger cars 2011-2016**
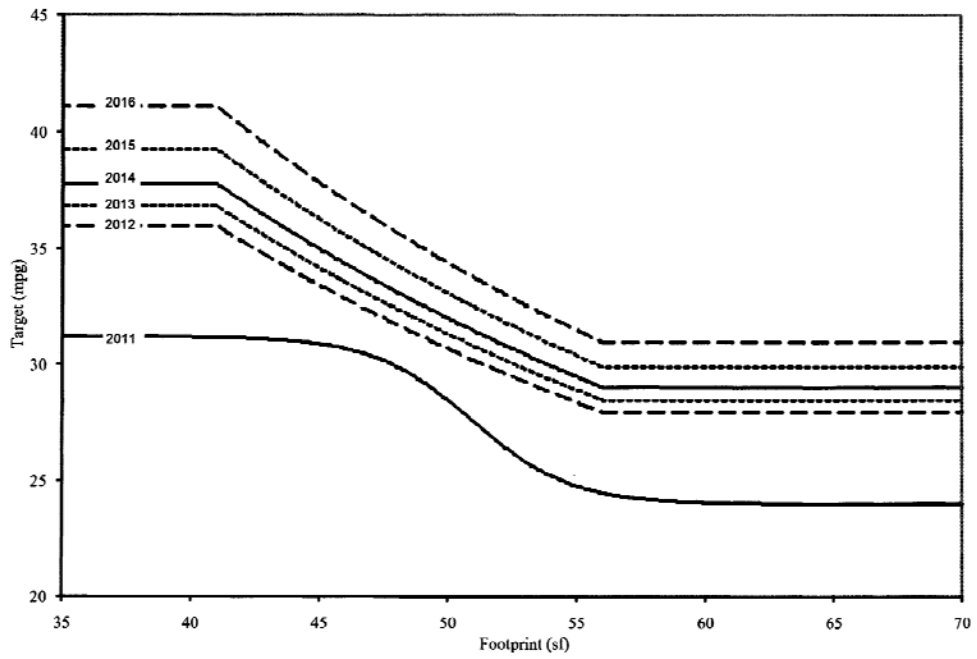


Source: Fed. Reg. (2010)

**Figure 2.2 - Footprint-based CAFE fuel economy targets for light trucks 2011-2016**
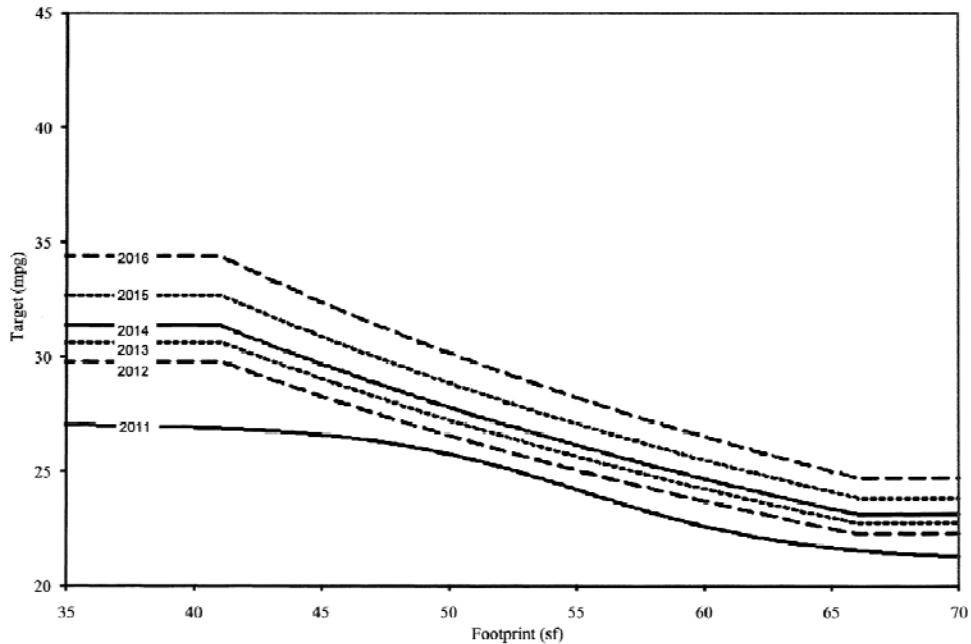


Source: Fed. Reg. (2010)

Manufacturers will be required to meet both the NHTSA and the EPA standards. These final standards are expressed as mathematical functions depending on vehicle footprints. A vehicle's footprint is determined by multiplying a vehicle's wheelbase by the average track width expressed in square footage. The footprint-based system determines emissions standards based on this footprint value with larger allowances for larger vehicles. A manufacturer's fleet-wide standard (passenger car fleet and light truck fleets assessed separately) will be determined by a sales-weighted average therefore it will depend upon the mix of vehicles sold and will vary among different manufacturers (Fed. Reg., 2010).

Figures 2.1 and 2.2 display the mathematical functions that determine target fuel economy based on vehicle footprints for passenger cars and light-trucks. This represents the NHTSA's CAFE standards with increasing stringency throughout the program years.

Figures 2.3 and 2.4 display the mathematical functions that determine EPA's $CO_2$ emission targets for passenger cars and light-trucks.

**Figure 2.3 - Footprint-based EPA CO$_2$ emissions targets for passenger cars 2012-2016**



Source: Fed. Reg. (2010)

**Figure 2.4 - Footprint-based EPA CO$_2$ emissions targets for light trucks 2012-2016**
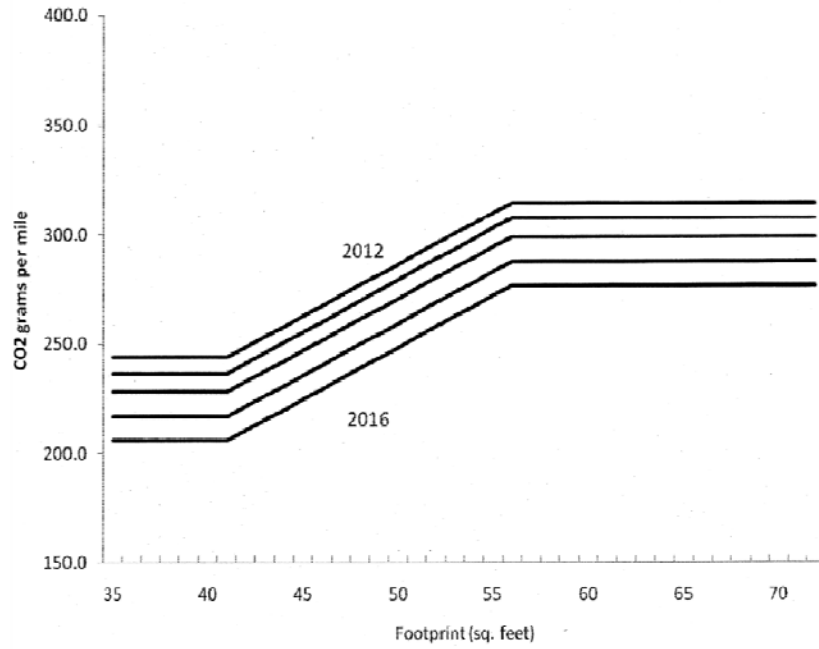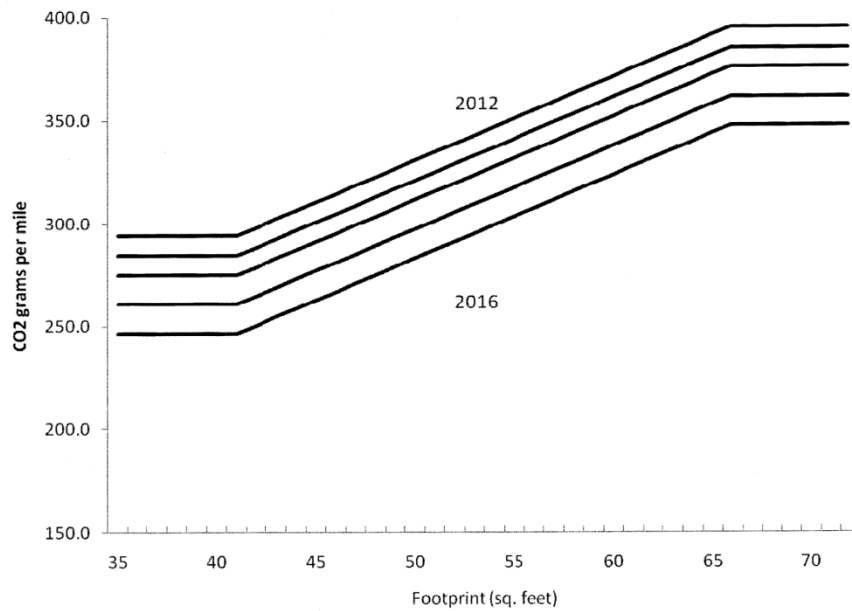


Source: Fed. Reg. (2010)

Table 2.8 (below) indicates the projected average required fuel economy under the NHTSA CAFE footprint-based system while Table 2.9 indicates estimated achieved fuel economy levels.

*Table 2.4 -* **Average Required Fuel Economy (mpg) Under Final CAFE Standards**

|  | 2011-base | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Passenger Cars | 30.4 | 33.3 | 34.2 | 34.9 | 36.2 | 37.8 |
| Light Trucks | 24.4 | 25.4 | 26.0 | 26.6 | 27.5 | 28.8 |
| Combined Cars & Trucks | 27.6 | 29.7 | 30.5 | 31.3 | 32.6 | 34.1 |

Source: Fed. Reg. (2010)

*Table 2.5 -* **Projected Fleet-Wide Achieved CAFE Levels Under the Final Footprint-Based CAFE Standards (mpg)**

|  | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| Passenger Cars | 32.3 | 33.5 | 34.2 | 35.0 | 36.2 |
| Light Trucks | 24.5 | 25.1 | 25.9 | 26.7 | 27.5 |
| Combined Cars & Trucks | 28.7 | 29.7 | 30.6 | 31.5 | 32.7 |

Source: Fed. Reg. (2010)

Table 2.10 displays the projected average fleet-wide $CO_2$ emissions standards under the EPA's footprint-based system and Table 2.11 displays estimations of achieved emission levels.

*Table 2.6 -* **Projected Fleet-Wide Emissions Compliance Levels Under the Footprint-Based $CO_2$ Standards (g/mi)**

|  | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| Passenger Cars | 263 | 256 | 247 | 236 | 225 |
| Light Trucks | 346 | 337 | 326 | 312 | 298 |
| Combined Cars & Trucks | 295 | 286 | 276 | 263 | 250 |

Source: Fed. Reg. (2010)

*Table 2.7 -* **Projected Fleet-Wide Achieved Emission Levels Under the Footprint-Based $CO_2$ Standards**

|  | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| Passenger Cars | 267 | 256 | 245 | 234 | 223 |
| Light Trucks | 365 | 353 | 340 | 324 | 303 |
| Combined Cars & Trucks | 305 | 293 | 280 | 266 | 250 |

Source: Fed. Reg. (2010)

Under the standards there will be a significant amount of flexibility for manufacturers to comply. Manufacturers will earn credits for "over-compliance" that can be applied to any of the five subsequent model years or the three previous model years. They can also be transferred between a manufacturer's fleet's (i.e. car fleet to truck fleet or vice-versa) or even sold to another manufacturer. Credits will also be available for production of alternative or dual-fueled (flex-fueled) vehicles, although this part of the program is scheduled be phased-out by MY 2019 (NHTSA, 2010b).

This program is an effort to create a cohesive national strategy to reduce GHG emissions from small and mid size vehicles. In California, beginning with MY 2012 manufacturers will have the option to demonstrate compliance with the State (Pavley) regulations or, alternatively, demonstrate compliance with the national standards. Although based on different criteria, the standards of California and the national standards have been designed to converge by MY 2016 to achieve comparable reductions in fleet-wide GHG emissions and will result in a single, cohesive nationwide set of regulations.

## 2.5 Low-Emission Vehicle Program

The Low Emission Vehicle (LEV) Program is another important piece of California's effort to reduce vehicle emissions. This regulation requires manufactures to meet LEV emission levels in new vehicles produced for sale in California. Table 2.12 (below) displays the LEV standards.

**Table 2.8 -** **LEV II Exhaust Mass Emission Standards for New 2004 and Subsequent Model LEVs, ULEVs, and SULEVs in the Passenger Car, Light-Duty Truck and Medium-Duty Vehicle Classes**

| Vehicle Type | Durability Vehicle Basis (mi) | Vehicle Emission Category | NMOG (g/mi) | Carbon Monoxide (g/mi) | Oxides of Nitrogen (g/mi) | Formaldehyde (mg/mi) | Particulates (g/mi) |
|---|---|---|---|---|---|---|---|
| All PCs; LDTs 8,500 lbs. GVW or less | 50,000 | LEV | 0.075 | 3.4 | 0.05 | 15 | n/a |
| | | LEV, Option 1 | 0.075 | 3.4 | 0.07 | 15 | n/a |
| | | ULEV | 0.040 | 1.7 | 0.05 | 8 | n/a |
| Vehicles in this category are tested at their loaded vehicle weight. | 120,000 | LEV | 0.090 | 4.2 | 0.07 | 18 | 0.01 |
| | | LEV, Option 1 | 0.090 | 4.2 | 0.10 | 18 | 0.01 |
| | | ULEV | 0.055 | 2.1 | 0.07 | 11 | 0.01 |
| | | SULEV | 0.010 | 1.0 | 0.02 | 4 | 0.01 |
| | 150,000 (optional) | LEV | 0.090 | 4.2 | 0.07 | 18 | 0.01 |
| | | LEV, Option 1 | 0.090 | 4.2 | 0.10 | 18 | 0.01 |
| | | ULEV | 0.055 | 2.1 | 0.07 | 11 | 0.01 |
| | | SULEV | 0.010 | 1.0 | 0.02 | 4 | 0.01 |
| MDVs 8,501 - 10,000 lbs. GVW | 120,000 | LEV | 0.195 | 6.4 | 0.2 | 32 | 0.12 |
| | | ULEV | 0.143 | 6.4 | 0.2 | 16 | 0.06 |
| Vehicles in this category are tested at their adjusted loaded vehicle weight. | | SULEV | 0.100 | 3.2 | 0.1 | 8 | 0.06 |
| | 150,000 (Optional) | LEV | 0.195 | 6.4 | 0.2 | 32 | 0.12 |
| | | ULEV | 0.143 | 6.4 | 0.2 | 16 | 0.06 |
| | | SULEV | 0.100 | 3.2 | 0.1 | 8 | 0.06 |
| MDVs 10,001-14,000 lbs. GVW | 120,000 | LEV | 0.230 | 7.3 | 0.4 | 40 | 0.12 |
| | | ULEV | 0.167 | 7.3 | 0.4 | 21 | 0.06 |
| Vehicles in this category are tested at their adjusted loaded vehicle weight. | | SULEV | 0.117 | 3.7 | 0.2 | 10 | 0.06 |
| | 150,000 (Optional) | LEV | 0.230 | 7.3 | 0.4 | 40 | 0.12 |
| | | ULEV | 0.167 | 7.3 | 0.4 | 21 | 0.06 |
| | | SULEV | 0.117 | 3.7 | 0.2 | 10 | 0.06 |

Source: CARB (2010b)

On a fleet-wide basis manufacturers are required to meet increasingly stringent regulations of Non-Methane Organic Gas (NMOG) exhaust emissions. These regulations are displayed in Table 2.13.

**Table 2.9 -** **Fleet Average Non-Methane Organic Gas[A] Exhaust Emission Requirements for Light-Duty Vehicle Weight Classes (50,000 mile Durability Vehicle Basis)**

| Model Year | Fleet Average NMOG (g/mi) | |
|---|---|---|
| | All PCs; LDTs 0-3750 lbs. LVW | LDTs 3751 lbs. LVW - 8500 lbs. GVW |
| 2001 | 0.070 | 0.098 |
| 2002 | 0.068 | 0.095 |
| 2003 | 0.062 | 0.093 |
| 2004 | 0.053 | 0.085 |
| 2005 | 0.049 | 0.076 |
| 2006 | 0.046 | 0.062 |
| 2007 | 0.043 | 0.055 |
| 2008 | 0.040 | 0.050 |
| 2009 | 0.038 | 0.047 |
| 2010+ | 0.035 | 0.043 |

[A] Non-Methane Organic Gas (NMOG) is the sum of oxygenated and non-oxygenated hydrocarbons contained in a gas sample as measured in accordance with the "California Non-Methane Organic Gas Test Procedures"
Source: CARB (2010b)

In addition to setting limits on vehicle emissions the LEV program contains provisions to promote the increased use of zero emission and near-zero emission vehicles. California's Zero Emission Vehicle (ZEV) requirement was first adopted in 1990 as part of the LEV regulation. The goal of the regulation was to promote the commercial viability of zero emission technologies many of which are now on California's roads today (CARB, 2011c).

Newly proposed amendments to the LEV regulations, known as LEV III, are scheduled to be considered by the Board later this year. The proposed amendments will make tailpipe and GHG emission standards more stringent. The new approach will also further encourage increased numbers of plug-in hybrids and zero-emission vehicles in the state (CARB, 2011a).

## 2.6 Heavy-Duty Vehicle Emission Reduction Regulations

California has various regulations and programs in place in an effort to mitigate heavy-duty vehicle emissions. Current emission regulations for heavy-duty vehicles operating in California are outlined below.

*Table 2.10 -* **Exhaust Emission Standards for 2004 and Subsequent Model Heavy-Duty Diesel Engines (grams per brake horsepower-hour [g/bhp-hr])**

| Oxides of Nitrogen | Non-methane Hydrocarbons | Carbon Monoxide | Particulates |
|---|---|---|---|
| 0.20 | 0.14 | 15.5 | 0.01 |

Source: CCR (2011)

*Table 2.11 -* **Emission Standards for 2008 and Subsequent Model Heavy-Duty (> 14,000 lbs. GVW) Otto-Cycle Engines (g/bhp-hr)**

| Non-methane Hydrocarbons | Oxides of Nitrogen | Carbon Monoxide | Formaldehyde | Particulate Matter |
|---|---|---|---|---|
| 0.14 | 0.20 | 14.4 | 0.01 | 0.01 |

Source: CCR (2011)

In addition to emission standards California has instituted other programs aimed at reducing emissions of heavy-duty vehicles with in the state. One such program adopted by CARB in December 2008 is a regulation to be in effect over the 11 years 2010-2020 that reduces GHG emissions by improving the fuel efficiency of heavy-duty tractors that pull 53-foot or longer "box-type" trailers. The tractors and trailers subject the regulation will be required to use U.S. EPA SmartWay certified tractors and trailers or retrofit current fleets with SmartWay certified technologies. This program requires tractor-trailers in California to use aerodynamic tractors and trailers while requiring the tractors and trailers to be equipped with low rolling resistance tires. All owners of vehicles that operate in California will be required to comply with the regulation regardless of the state of registration of the vehicle (CARB, 2011d).

Regulation that was initially considered in 2008, called the "Truck and Bus On-Road Heavy-Duty Diesel Vehicles (In-Use) Regulation", is another program aimed at mitigating heavy-duty vehicle emissions. The regulation will require

fleets that operate in California to reduce emissions of diesel-fueled trucks and busses by retrofitting or replacing existing engines to meet current standards. Nearly all privately and federally owned diesel fueled trucks and buses (including school buses) with a GVWR in excess of 14,000 lbs are subject to the regulation. In December 2010 amendments were considered that would extend the compliance timeline requiring installation of PM retrofits beginning on January 1, 2012 and replacement of older trucks in 2015. By 2023 almost all vehicles subject to the regulation would be required to have 2010 MY engines (or equivalent). Certain vehicles will be exempt or provided extended compliance times, such as agricultural vehicles, fleets of fewer than three vehicles or trucks transporting marine containers that comply with the Drayage Truck Regulation (CARB, 2011e).

NHTSA and the U.S. EPA have proposed joint regulation that would impose fuel efficiency and emission regulations on medium- and heavy-duty vehicles in similar fashion as the National Program for light-duty vehicles discussed above. Like the National Program the proposed regulation (referred to as the "HD National Program") would comprise of a combination of EPA emission standards and NHTSA fuel consumption standards. Heavy-duty pickup trucks and vans, vocational vehicles and combination tractors would be subject to the regulation. It is expected that the EPA standards for medium- and heavy-duty vehicles beginning in MY 2014 would result in 17 and 12 percent reductions in GHG emissions for diesel and gasoline engines respectively. The NHTSA standards (voluntary until 2016) would result in reductions of fuel consumption of 15 percent for diesel vehicles and 10 percent for gasoline vehicles. Standards for vocational vehicles to be phased in by 2017 would achieve a seven to 10 percent reduction in emissions while combination tractor regulations, also to be phased in by 2017, would result in an estimated seven to 20 percent reduction in emissions and fuel consumption (both from a 2010 baseline) (NHTSA, 2010a).

# 3  Research Findings

The following table summarizes the five core scenarios undertaken in this study. After detailed examination of baseline growth characteristics, policies in place or under active discussion, and technology opportunities, these are thought to best represent the leading policy options open to California over the next generation.[6] New initiatives may appear in the interim, but today the vehicle efficiency component state and national climate policy dialog has coalesced around measures in force and ways to extend these incrementally over time.

**Table 3.1: Policy Scenarios**

| Scenario | Name | Description |
|---|---|---|
| 1 | Baseline | Business as usual: Assume California does not implement vehicle standards but continues growth at levels forecast by the Department of Finance. |
| 2 | Cal | California Vehicle Standards: Assume the Low Carbon Fuel Standard and Pavley vehicle emissions legislation remain in force until 2025. |
| 3 | Nat4 | Assume California adheres to US national standards, 2012-2016, and continues with 4%/year efficiency improvements over 2017-2025 |
| 4 | Nat6 | Assume California conforms to US national standards, 2012-2016, and continues with 6%/year efficiency improvements over 2017-2025 |
| 5 | Hzn | Assume California attains state-of-the-art vehicle emissions standards for gasoline powered vehicles (Horizon study, DeCicco:2010). |

The first scenario below represents existing California commitments, merely continued at existing levels to 2025.[7] The national policy scenarios, sustaining 4% and 6% annual efficiency improvements, bracket a range thought to be most

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[6] See Lutsey: 2010, for a survey of the broader spectrum of policies.
[7] Note also that the states have authority to regulate vehicle emissions, but not fuel efficiency. Thus California's policy has similar objectives, but different instruments than its national counterparts.

likely for implementation. Finally, the Horizon scenario is representative of "aspirational" rates of efficiency improvement that have been put forward by independent researchers.

**Table 3.2: Technical Assessment Report (TAR) Scenarios**

| Case | GHG Emissions | | Fuel Economy | |
|---|---|---|---|---|
| | Rated gCO$_2$/mile [a] | Annual improvement from 2016 | Consumer label (on-road) mpg [b] | Annual improvement from 2016 |
| Baseline (2008) | 339 | – | 21 | – |
| Baseline (2016) | 250 | – | 27 | – |
| New vehicle target in 2025 | 190 | 3% | 34 | 2.4% |
| | 173 | 4% | 37 | 3.3% |
| | 158 | 5% | 40 | 4.3% |
| | 143 | 6% | 43 | 5.3% |

*Source: EPA, NHTSA, CARB, see Lutsey (2010)*

## 3.1 Statewide Results

The macroeconomic and other statewide impacts of the five different policy scenarios are summarized in Table 3.3. Generally speaking, these results are consistent with intuition and a large body of related work on energy efficiency and economic growth.[8]

**Table 3.3: Statewide Impacts**

|  | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|
| **Real GSP** | 0.03% | 0.82% | 1.13% | 1.31% |
| **Real Consumption** | 0.03% | 0.68% | 0.92% | 1.05% |
| **Employment** | 0.17% | 0.69% | 0.89% | 1.02% |
| **Jobs (1000)** | | | | |
| **Created** | 47 | 179 | 231 | 264 |
| **Lost** | -9 | -21 | -26 | -28 |
| **Net** | 38 | 158 | 205 | 236 |
| **MPG ( Fleet Ave)** | | | | |
| **Gasoline** | 23 | 28 | 32 | 34 |
| **Diesel** | 11 | 13 | 15 | 17 |
| **Emissions** | | | | |
| **Household** | -14% | -22% | -26% | -29% |
| **Industry** | -4% | -9% | -11% | -13% |
| **Total** | -8% | -14% | -17% | -19% |

*Notes: Percentages measure change from Baseline values in 2025.*

- **Cal** – Results for the vehicle components of AB32 are consistent with comparable estimates in the leading assessments of the Global Warming Solutions Act (CARB: 2010, Roland-Holst: 2010). In the absence of enhanced efficiency measures, impacts on 2025 real GSP and employment are relatively modest but positive. These policies contribute to about 8% reduction in trend GHG emissions for the state, and important component of mitigation to be expected from this extensive package.

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[8] See e.g. Roland-Holst: 2010, CARB:2010, EAAAC:2009.

- **Nat4&6** – National emissions standards are slightly less strict than California for gasoline vehicles up to 2016, more so for diesel, and more so for both fuels from 2016 forward. Moreover, national policies can regulate fuel efficiency directly, rather than relying on indirect effects from emissions standards alone. Because the combination of these leads to higher levels of average fuel efficiency (also envisioned to persist from 2016 onward), they confer even greater growth on the state economy than California's own standards, creating between 158,000 and 205,000 additional jobs by 2025. Substantial emission reductions at both the household and enterprise level reduce California's trend GHG emissions by between 14 and 17 percent by 2025.

- **Hzn** - Engineering evidence tells us that vehicle efficiency technology is beginning an era of dramatic and sustained innovation. Indeed, the authoritative **Horizon Gasoline Efficiency** scenario uses mpg estimates from the Fuel Efficiency Horizon study (DeCiccio: 2010) suggests that "off the shelf" engine technologies of the future will offer mpg levels well above those incorporated in today's standards. Assuming these are incorporated into policy mandates, or voluntarily adopted for gasoline vehicles only, would propel the state economy even further toward a lower carbon, higher growth future. The results of the Horizon scenario indicate that the state would gain an additional 1.3 percent of GSP over the long term and comparable (1.02%) employment growth. In all, over 236,000 jobs would be added in the state economy by 2025, as households and enterprises redirect expenditure away from carbon fuel supplies to more job intensive (largely in-state) goods and services. Meanwhile, new vehicle technologies would make a dramatic impact on emissions of local toxic gases and global warming pollution, reducing the latter by 19%. Again, macroeconomic impacts of the national policies are much greater because direct and induced efficiency improvements persist beyond 2016.

**Figure 3.1: Macro Results**
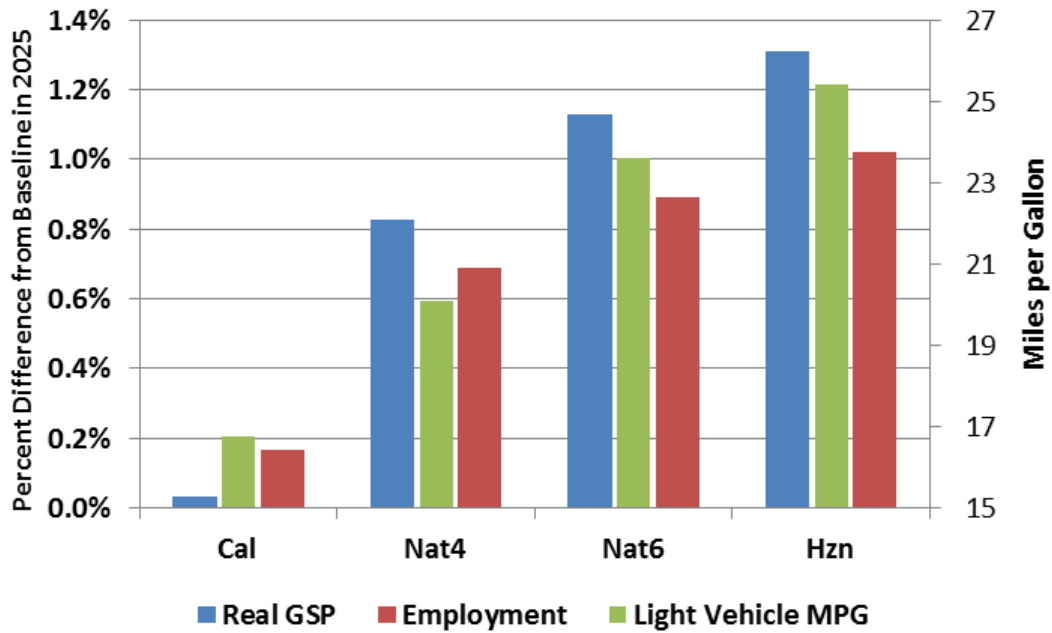


*Note: Real GSP and Employment are percentage changes from Baseline in 2025 (left axis). Fuel Economy is mpg (right).*

Generally speaking, the most robust finding of this study, as illustrated in Figure 3.1, is that statewide economic growth and employment rise with the degree and scope of transport fuel efficiency standards. This is true as regardless of whether standards are direct, targeting fuel consumption, or indirect, targeting emissions. What matters is that the efficiency technologies have positive net value to those who adopt them, inclusive of any secondary increases in vehicle use. If these savings accrue to vehicle owners, be they households or enterprises, they will reappear as demand for goods and services outside the carbon fuel supply chain, and the results will be higher domestic growth employment. [9]

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[9] These findings are wholly consistent with a recent meta-review of some 48 past state and regional policy assessments (Laitner and McKinney 2008) which notes that significant energy efficiency improvements of all kinds can yield net positive employment and GDP benefit to the economy (see,). These finding were further reinforced by major assessment of the American Power Act (APA) (Laitner et al 2010).

**Figure 3.2: Job Creation and Economic Rewards of Efficiency**
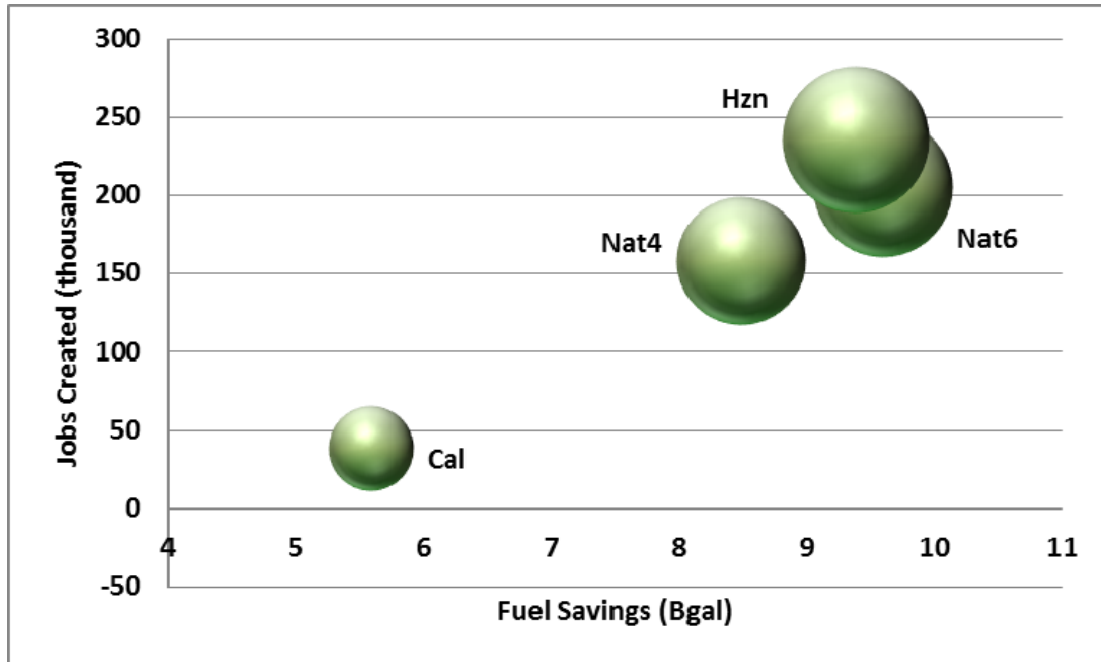


*Notes: Author estimates. Bubble diameter is proportional to household energy cost savings.*

The next two figures illustrate a new, macroeconomic concept in the fuel efficiency literature, one that probably deserves more recognition. In Figure 3.2, we see the five policy scenarios in terms of fuel saving (horizontal axis), job creation (vertical), and vehicle cost dividend to households (bubble diameter). Clearly, the more effective the fuel efficiency target, the more economic benefit to California. The state's own policies confer substantial benefit, but there would be much greater long term gains if annual improvements in fuel efficiency were increased beyond 2016.

The next figure presents the same results from a different perspective, new jobs per gallon saved in aggregate fuel efficiency. Again, the results make clear that more effective fuel efficiency standards confer greater economic benefits, as well as a dividend of greater economic security. Moreover, the "job mileage," or effectiveness of the standard in terms of jobs created per gallon of fuel saved,

increases with the standard. This is true because higher standards increase in-state expenditure shares, leading to stronger multiplier effects.

**Figure 3.3: New Jobs per Gallon Saved, by Effective Fuel Standard**
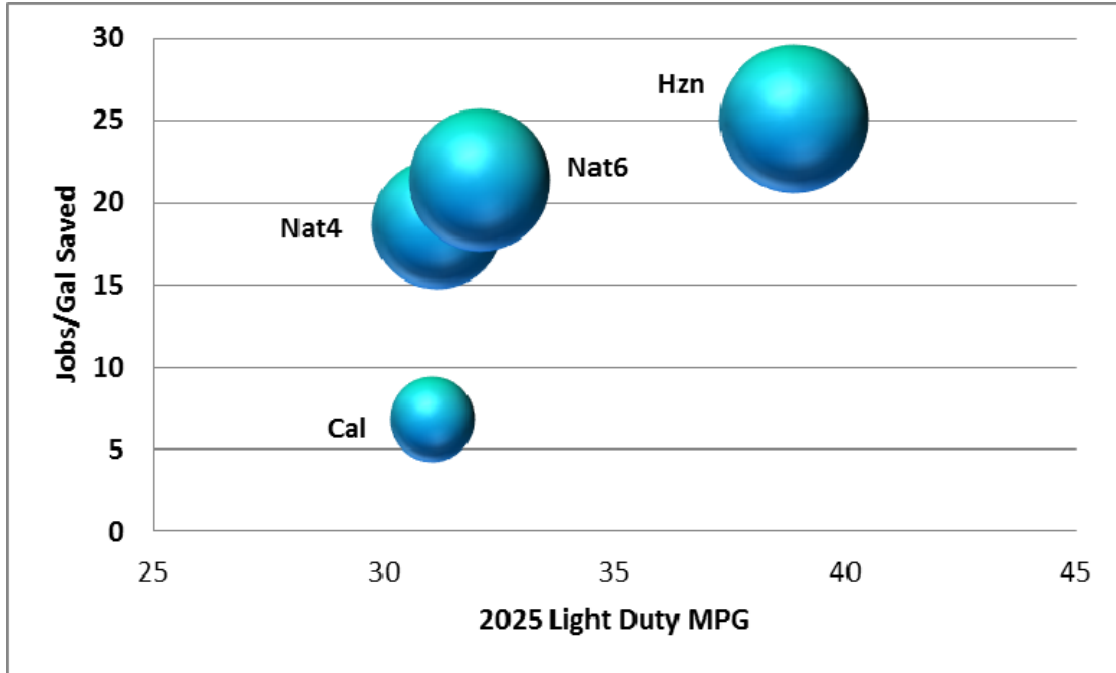


*Notes: Author estimates. Bubble diameter is proportional to household energy cost savings.*

## 3.2 Why Vehicle Efficiency Promotes Growth

The following figure explains why more efficient vehicles stimulate aggregate job growth. Different goods and services require different amounts of labor to produce and deliver them, and this figure shows the ratio of FTE work hours to output across the California economy. Production is divided into 124 different economic activity sectors, ordered from left to right from highest to lowest job content (blue diamonds). Note that labor intensity across the economy varies so much that a logarithmic scale is needed to encompass it. Also shown are median wages for each activity (black triangles, right axis).

When households and enterprises reduce fuel needs, these savings are removed from the carbon fuel energy supply chain, among the least employment

intensive in the economy (lower right circle). Since about 70% of household demand and a significant portion of enterprise spending on non-energy inputs goes to services (upper right circle), the resulting expenditure shifting will result in substantial net job creation. Simply put, a dollar saved on traditional energy is a dollar earned by 10-100 times as many new workers.

**Figure 3.4: Employment Intensity and Median Wage by Sector**
**(labor/output ratios and wages for 124 California sectors)**



*Source: California Employment Development Department dataset.*

Other aspects of this job creation process are also noteworthy. Firstly, it is apparent that energy fuel sector wages can be high, but they are not higher than service sector wages by anything like the employment multiples evident here. Moreover, jobs created from this expenditure diversion are distributed across a broad spectrum of sectors and occupational categories, not restricted to green technology or import-dependent energy fuels and services. On the contrary, most of the jobs created by fuel economy are in service sectors with high levels of in-state inputs and value added. Jobs like this have stronger and longer multiplier linkages inside the state economy, and they are at very low risk of being outsourced.

## 3.3 Composition of Job Growth

Beneath the smooth veneer of macroeconomic aggregates, pervasive structural changes can take place. In particular, aggregate benefits can mast tradeoffs between difference stakeholder groups across the economy, and both fuel efficiency and emissions intensity exemplify this issue. While the overall state economy and average households gain from the policies considered here, the composition of impacts is more complex. In particular, transition to a lower carbon future obviously challenges enterprises in the carbon fuel supply chain, and this effect is plainly evident in the results of Table 3.4.

**Table 3.4: Employment Effects by Sector**
**(change from 2025 Baseline in thousands of FTE jobs)**

| Sector | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|
| Agriculture | 0 | 0 | 0 | 0 |
| Other Primary | 0 | 0 | 0 | 0 |
| Oil and Gas | -9 | -21 | -26 | -28 |
| Electric Power | 0 | 0 | 1 | 1 |
| Natural Gas Dist. | 0 | 0 | 0 | 0 |
| Other Utilities | 0 | 1 | 1 | 1 |
| Processed Food | 0 | 1 | 2 | 2 |
| Construction - Residential | 0 | 4 | 5 | 6 |
| Construction - NonRes | 1 | 8 | 11 | 13 |
| Light Industry | 4 | 13 | 16 | 19 |
| Heavy Industry | 0 | 3 | 5 | 5 |
| Machinery | 0 | 1 | 1 | 1 |
| Technology | 0 | 3 | 4 | 5 |
| Electronic Appliances | 0 | 0 | 0 | 0 |
| Automobiles and Parts | 0 | 0 | 0 | 0 |
| Trucks and Parts | 0 | 0 | 0 | 0 |
| Other Vehicles | 0 | 1 | 1 | 1 |
| Wholesale, Retail Trade | 17 | 55 | 69 | 79 |
| Transport Services | 1 | 7 | 9 | 11 |
| Other Services | 24 | 83 | 105 | 120 |
| Total Net Jobs | 38 | 158 | 205 | 236 |
| New Employment | 47 | 179 | 231 | 264 |
| Employment Reductions | -9 | -21 | -26 | -28 |

These figures break down the aggregate employment results of Table 3.3 on a sector-by-sector basis. Employment impacts within sectors are net job creation effects, while the last three rows present statewide sector aggregates that reveal patterns of job creation and reduction. What is perhaps most noteworthy is that only one in twenty sectors experiences net employment reduction, the carbon fuel sector (Oil and Gas) targeted directly by the fuel economy policies and indirectly by the emissions intensity measures. Because of the expenditure shifting process described in the last subsection, job creation in each scenario outweighs job reduction by a factor of 4 to 9 jobs created for each lost. These results strongly support the notion that restructuring California's economy for a lower carbon future will benefit many more people than are adversely affected.

## 3.4 Benefits to Households

Although this study emphasized the economywide benefits of fuel savings, including extensive indirect effects of household expenditure shifting and structural adjustment, energy efficiency stories generally begin at the microeconomic level. Individual economic agents are assumed to make technology adoption and use decisions based on their own perception of costs and benefits that will accrue to themselves personally, their household, or their enterprise. These direct effects are the primary determinate of market oriented technology diffusion as well as the primary target of policies that seek to influence adoption behavior, including standards, incentives, and fees.

Because of their importance, microeconomic technology costs and benefits are the subject of intensive scrutiny and controversy. To more effectively support public discussion of its own policies, EPA, NTHSA, and CARB have been working individually and in concert to improve this evidence. Their results, summarized by Lutsey (2010) and reprinted in the following table, also reflect extensive consultations with vehicle and energy sector participants. Generally speaking, these estimates suggest that energy and emissions efficiency are very sound individual investments, with payback periods of 2-4 years and returns on incremental investment of over 100% across the lifetime of vehicles.

**Table 3.5: Vehicle Efficiency Costs and Benefits Joint Agency Estimates**

| Scenario[a] | Rated new vehicle gCO$_2$/mile | New vehicle consumer label fuel economy (MPGe)[b] | Technology Path | Per-Vehicle Cost Increase ($) | Payback Period [c] (years) | Net Lifetime Owner Savings [c] ($) |
|---|---|---|---|---|---|---|
| 4%/year | 173 | 37 | A | $1,700 | 2.5 | $5,900 |
| | | | B | $1,500 | 2.2 | $6,000 |
| | | | C | $1,400 | 1.9 | $6,200 |
| | | | D | $1,900 | 2.9 | $5,300 |
| 5%/year | 158 | 40 | A | $2,500 | 3.1 | $6,500 |
| | | | B | $2,300 | 2.8 | $6,700 |
| | | | C | $2,100 | 2.5 | $7,000 |
| | | | D | $2,600 | 3.6 | $5,500 |
| 6%/year | 143 | 43 | A | $3,500 | 4.1 | $6,200 |
| | | | B | $3,200 | 3.7 | $6,600 |
| | | | C | $2,800 | 3.1 | $7,400 |
| | | | D | $3,400 | 4.2 | $5,700 |

*Source: EPA, NHTSA, CARB, see Lutsey (2010)*

In addition to individual financial benefits from more efficient vehicles, large scale adoption creates general equilibrium, or spillover benefits across the state economy. These take two primary forms, the expenditure shifting benefits already discussed, and cost of living benefits from reduced aggregate energy demand. The second benefit arises from the fact that, taken together, individual efficiency choices reduce aggregate energy demand and exert downward pressure on prices. For a small economy, these might not affect national or global energy markets, but because California comprises 11% of US GDP and is itself the eighth largest economy in the world, substantial changes in California energy demand certainly will affect both national and global prices.

**Table 3.6: Changes in Final Energy Goods Prices**
**(percent difference from Baseline in 2025)**

| | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|
| **Transport Fuel** | -4.5% | -17.3% | -22.4% | -25.3% |
| **Electricity** | -1.0% | -4.9% | -6.5% | -7.4% |
| **Natural Gas** | -0.9% | -4.4% | -5.7% | -6.5% |

*Source: Author estimates.*

For the scenarios considered, energy price changes from the Baseline scenario in 2025 are given in the next table. Clearly, energy efficiency in a market as large as California will reduce prices from baseline trends.

**Table 3.7: Changes in Energy Expenditure by Household**

**(CA percent income tax brackets, percent difference from Baseline in 2025)**

| Household | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|
| 1.0 Percent | -3.3% | -13.2% | -17.1% | -19.3% |
| 2.0 Percent | -3.6% | -14.0% | -18.1% | -20.5% |
| 4.0 Percent | -3.6% | -14.2% | -18.4% | -20.8% |
| 6.0 Percent | -3.6% | -14.2% | -18.4% | -20.8% |
| 8.0 Percent | -3.6% | -14.2% | -18.4% | -20.9% |
| 9.3 Percent<200k | -3.5% | -14.0% | -18.1% | -20.5% |
| 9.3 Percent>200k | -3.5% | -13.9% | -18.1% | -20.5% |
| Average | -3.5% | -14.0% | -18.1% | -20.5% |

*Source: Author estimates.*

**Table 3.8: Energy Savings by Household**

**(CA percent income tax brackets, percent difference from Baseline in 2025)**

| Household | Ave Inc | Number | Cal | Nat4 | Nat6 | Hzn |
|---|---|---|---|---|---|---|
| 1.0 Percent | 9 | 2,637 | 0.4 | 0.8 | 0.9 | 1.0 |
| 2.0 Percent | 27 | 3,509 | 1.2 | 2.4 | 2.9 | 3.1 |
| 4.0 Percent | 48 | 1,857 | 1.3 | 2.6 | 3.2 | 3.5 |
| 6.0 Percent | 70 | 1,997 | 0.9 | 1.7 | 2.1 | 2.3 |
| 8.0 Percent | 98 | 1,158 | 0.4 | 0.8 | 1.0 | 1.1 |
| 9.3 Percent<200k | 163 | 1,774 | 0.3 | 0.7 | 0.8 | 0.9 |
| 9.3 Percent>200k | 1,037 | 415 | 0.1 | 0.2 | 0.2 | 0.3 |
| Average | | | 0.8 | 1.9 | 2.3 | 2.5 |

*Notes: Average Income and Number of households in thousands. Scenario results stated as percent of income reductions in household energy expenditure. Average row population weighted. Source: Author estimates.*

To see the overall cost of living effect on households, we must take account of changes in total energy demand as well as incremental costs attributable to energy efficient technologies. The next table estimates these for California households by income status. One caveat is needed before interpreting these results. Although we have baseline consumption data on households by income

level, we do not predict which income groups will adopt which vehicles, and thus assume that new vehicles are dispersed uniformly across the population. Of course this contradicts intuition, which suggests that new vehicles will be more highly concentrated in higher income groups. What this means is we are probably underestimating the efficiency gains for high income groups and overestimating them for others.

Before concluding this results section, it is important to mention a few salient caveats. While the author believes these results to be robust subject to reasonable uncertainty regarding external events, and the BEAR model earned such a reputation in the past, it is always worth emphasizing that forecasting is not a crystal ball. Our results do not follow individual decisions, but only model behavior of representative agents subject to generic changes in the economic environment. The real world is full of heterogeneity and complex events beyond the ken of modelers, particularly over a time horizon as long as 15 years. For this reason, it is important to see the most intrinsic aspects of the present results, including the growth potential of energy efficiency and patterns of employment creation, without focusing too closely on detailed timing or stakeholder outcomes. Such information is obtainable, but only with more intensive data development and analysis.

More research is needed to elucidate this important equity issue, but meanwhile we see interesting dynamics in these adjustments. Energy expenditure changes are driven by two forces, technology (efficiency) reductions in demand and market reductions in prices. The combination of both these downward trends leads to substantial household savings, reducing energy expenses by about a third in the more optimistic scenarios. These savings take account of the TAR individual cost and benefit estimates cited above, but aggregate them across a diverse population and vehicle stock for a late sample year (2025). Across the diverse state economy, households have vehicles of differing ages and efficiency levels, but the aggregate efficiency progress confers price benefits on all of them. The basic message of these results is simple, vehicle efficiency

saves household money whether they themselves buy a new vehicle or not, but most so if they do.

# 4 Methodology – Overview of the BEAR Model

For the last three years, University of California at Berkeley's Center for Energy, Resources, and Economic Sustainability (CERES) has been conducting independent research to inform public and private dialogue surrounding California climate policy. Among these efforts has been the development and implementation of a statewide, long term economic forecasting model, the Berkeley Energy and Resources (BEAR) model, the most detailed and comprehensive decision tool of its kind.[10]

BEAR is a computable general equilibrium model of California's economy that simulates demand and supply relationships across many sectors of the economy and tracks the linkages among them. It can thus be used to trace the ripple effects, throughout the economy and over time, of new economic and technology policies. In addition to detailed modeling of demand, supply, and trade across 20 sectors of the state economy, a new version of BEAR models the complete California vehicle fleet. Incorporating data on 12 vehicle and 4 fuel types, the model traces annual changes in vehicle adoption patterns, use (vehicle miles traveled), energy consumption, and operating costs. Together, these comprise the most detailed structural model extant for the state's economy.

In reality, the BEAR model is a constellation of research tools designed to elucidate economy-environment linkages in California. The schematics in Figures 4.1 and 4.2 describe the four generic components of the modeling

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[10] CGE models have been applied by many others in other places and contexts. Environmental applications include global work with the ENVISAGE model of the world bank (van der Mensbrugghe: 2010) and MIT's IGSM model (Winchester et al: 2010). National models include ADAGE from RTI (Ross: 2007) and IGEM (Jorgensen et al: 2009). Other economywide, non-CGE approaches, rely on detailed structural models like REMI (see e.g. Rose and Wei: 2010, Rose and Oladosu: 2002).

facility and their interactions. This section provides a brief summary of the formal structure of the BEAR model.[11] For the purposes of this report, the 2008 California Social Accounting Matrix (SAM), was aggregated along certain dimensions. The current version of the model includes 20 activity sectors and ten households aggregated from the original California SAM. The equations of the model are completely documented elsewhere (Roland-Holst: 2005), and for the present we only discuss its salient structural components.

Technically, a CGE model is a system of simultaneous equations that simulate price-directed interactions between firms and households in commodity and factor markets. The role of government, capital markets, and other trading partners are also specified, with varying degrees of detail and passivity, to close the model and account for economywide resource allocation, production, and income determination.

The role of markets is to mediate exchange, usually with a flexible system of prices, the most important endogenous variables in a typical CGE model. As in a real market economy, commodity and factor price changes induce changes in the level and composition of supply and demand, production and income, and the remaining endogenous variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economywide (and regional) effects of alternative policies or external events.

The distinguishing feature of a general equilibrium model, applied or theoretical, is its closed-form specification of all activities in the economic system under study. This can be contrasted with more traditional partial equilibrium analysis, where linkages to other domestic markets and agents are deliberately excluded from consideration. A large and growing body of evidence suggests that indirect

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[11] See Roland-Holst (2005) for a complete model description.

effects (e.g., upstream and downstream production linkages) arising from policy changes are not only substantial, but may in some cases even outweigh direct effects. Only a model that consistently specifies economywide interactions can fully assess the implications of economic policies or business strategies. In a multi-country model like the one used in this study, indirect effects include the trade linkages between countries and regions which themselves can have policy implications.

The model we use for this work has been constructed according to generally accepted specification standards, implemented in the GAMS programming language, and calibrated to the new California SAM estimated for the year 2003.[12] The result is a single economy model calibrated over the twenty-five year time path from 2010 to 2025.[13] Using the detailed accounts of the California SAM, we include the following in the present model:

## 4.1 Production

All sectors are assumed to operate under constant returns to scale and cost optimization. Production technology is modeled by a nesting of constant-elasticity-of-substitution (CES) functions.[14]

In each period, the supply of primary factors — capital, land, and labor — is usually predetermined.[15] The model includes adjustment rigidities. An important feature is the distinction between old and new capital goods. In addition, capital is assumed to be partially mobile, reflecting differences in the marketability of capital goods across sectors.[16]

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[12] See e.g. Meeraus et al (1992) for GAMS. Berck et al (2004) for discussion of the California SAM.

[13] The present specification is one of the most advanced examples of this empirical method, already applied to over 50 individual countries or combinations thereof.

[14] For detailed explanations of the CES, CET, and other functional forms, the reader should consult either the complete BEAR documentation (Roland-Holst: 2010) or Sydsæter et al (2005).

[15] Capital supply is to some extent influenced by the current period's level of investment.

[16] For simplicity, it is assumed that old capital goods supplied in second-hand markets and new capital goods are homogeneous. This formulation makes it possible to introduce downward

Once the optimal combination of inputs is determined, sector output prices are calculated assuming competitive supply conditions in all markets.

## 4.2 Consumption and Closure Rule

To encompass activity across an entire economy, as CGE models do, consistency requires that large scale expenditure and income, as well as financial accounts, be reconciled or balanced. To do this, we specify so-called Closure Rules. For example, the government's budget must be consistently defined as expenditure, income, and savings. Likewise, international balances must be defined for export income, import expenditure, and capital flows.

For households, all income generated by economic activity is assumed to be distributed to consumers. Each representative consumer allocates optimally his/her disposable income among the different commodities and saving. The consumption/saving decision is completely static: saving is treated as a "good" and its amount is determined simultaneously with the demand for the other commodities, the price of saving being set arbitrarily equal to the average price of consumer goods.

The government collects income taxes, indirect taxes on intermediate inputs, outputs and consumer expenditures. The default closure of the model assumes that the government deficit/saving is exogenously specified.[17] The indirect tax schedule will shift to accommodate any changes in the balance between government revenues and government expenditures.

The current account surplus (deficit) is fixed in nominal terms. The counterpart of this imbalance is a net outflow (inflow) of capital, which is subtracted (added to) the domestic flow of saving. In each period, the model equates gross investment to net saving (equal to the sum of saving by households, the net budget position

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rigidities in the adjustment of capital without increasing excessively the number of equilibrium prices to be determined by the model.

[17] In the reference simulation, the real government fiscal balance converges (linearly) towards 0 by the final period of the simulation.

of the government and foreign capital inflows). This particular closure rule implies that investment is driven by saving.

## 4.3 Trade

Goods are assumed to be differentiated by region of origin. In other words, goods classified in the same sector are different according to whether they are produced domestically or imported. This assumption is frequently known as the *Armington* assumption. The degree of substitutability, as well as the import penetration shares are allowed to vary across commodities. The model assumes a single Armington agent. This strong assumption implies that the propensity to import and the degree of substitutability between domestic and imported goods is uniform across economic agents. This assumption reduces tremendously the dimensionality of the model. In many cases this assumption is imposed by the data. A symmetric assumption is made on the export side where domestic producers are assumed to differentiate the domestic market and the export market. This is modeled using a *Constant-Elasticity-of-Transformation* (CET) function.

**Figure 4.1: Component Structure of the Modeling Facility**

BEAR is being developed in four areas and implemented over two time horizons.

Components:

1. Core GE model

2. Technology module

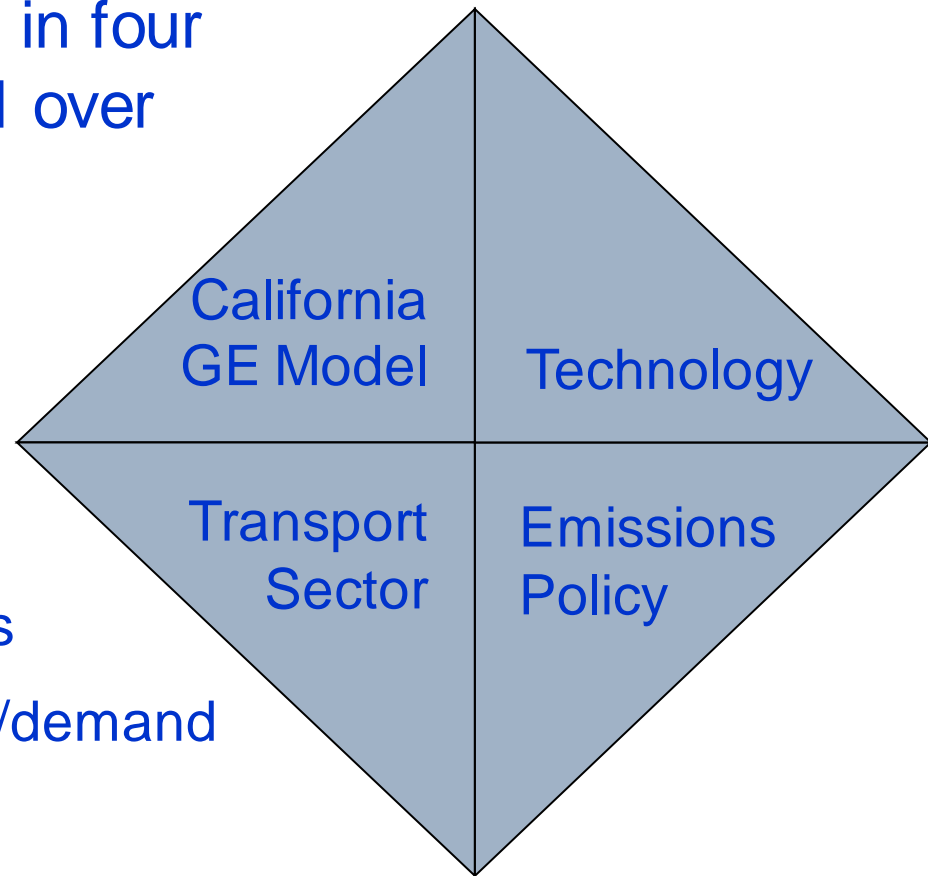3. Emissions Policy Analysis

4. Transportation services/demand

California GE Model

Technology

Transport Sector

Emissions Policy

# Figure 4.2: Schematic Linkage between Model Components



**National and International Initial Conditions, Trends, and External Shocks**

**Standards Trading Mechanisms Producer and Consumer Policies**

**California GE Model**

**Prices Demand Sectoral Outputs Resource Use**

**Innovation: Production Consumer Demand**

**Detailed Emissions of C02 and non-C02**

**Technology**

**Emission Data LBL Energy Balances Engineering Estimates Adoption Research Trends in Technical Change**

**Technology Policies Learning Carbon Sequestration**

**Fuel efficiency Incentives and taxes**

**Transport Sector**

**Detailed State Output, Trade, Employment, Income, Consumption, Govt. Balance Sheets**

**Emissions Policy**

**Cap and trade Energy Regulation RPS, CHP, PV**

**Household and Commercial Vehicle Choice/Use**

**Initial Generation Data Engineering Estimates**

- Data    - Results    - Policy Intervention

## 4.4 Dynamic Features and Calibration

The current version of the model has a simple recursive dynamic structure as agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. Dynamics in the model originate in three sources: i) accumulation of productive capital and labor growth; ii) shifts in production technology; and iii) the putty/semi-putty specification of technology.

## 4.5 Capital accumulation

In the aggregate, the basic capital accumulation function equates the current capital stock to the depreciated stock inherited from the previous period plus gross investment. However, at the sector level, the specific accumulation functions may differ because the demand for (old and new) capital can be less than the depreciated stock of old capital. In this case, the sector contracts over time by releasing old capital goods. Consequently, in each period, the new capital vintage availa=ble to expanding industries is equal to the sum of disinvested capital in contracting industries plus total saving generated by the economy, consistent with the closure rule of the model.

## 4.6 The putty/semi-putty specification

The substitution possibilities among production factors are assumed to be higher with the new than the old capital vintages — technology has a putty/semi-putty specification. Hence, when a shock to relative prices occurs (e.g. the imposition of an emissions fee), the demands for production factors adjust gradually to the long-run optimum because the substitution effects are delayed over time. The adjustment path depends on the values of the short-run elasticities of substitution and the replacement rate of capital. As the latter determines the pace at which new vintages are installed, the larger is the volume of new investment, the greater the possibility to achieve the long-run total amount of substitution among production factors.

## 4.7 Dynamic calibration

The model is calibrated on exogenous growth rates of population, labor force, factor productivity, and GSP.[18] In the so-called Baseline scenario, the dynamics are calibrated in each region by imposing the assumption of a balanced growth path. This implies that the ratio between labor and capital (in efficiency units) is held constant over time.[19] When alternative scenarios around the baseline are simulated, the technical efficiency parameter is held constant, and the growth of capital is endogenously determined by the saving/investment relation.

## 4.8 Emissions

The BEAR model captures emissions from production activities in agriculture, industry, and services, as well as in final demand and use of final goods (e.g. appliances and autos). This is done by calibrating emission functions to each of these activities that vary depending upon the emission intensity of the inputs used for the activity in question. We model both $CO_2$ and the other primary greenhouse gases, which are converted to $CO_2$ equivalent. Following standards set in the research literature, emissions in production are modeled as factors inputs. The base version of the model does not have a full representation of emission reduction or abatement. Emissions abatement occurs by substituting additional labor or capital for emissions when an emissions tax is applied. This is an accepted modeling practice, although in specific instances it may either understate or overstate actual emissions reduction potential.[20] In this framework, emission levels have an underlying monotone relationship with production levels, but can be reduced by increasing use of other, productive factors such as capital and labor. The latter represent investments in lower intensity technologies, process cleaning activities, etc. An overall calibration procedure fits observed intensity levels to baseline activity and other factor/resource use levels. In

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[18] Baseline rates of GSP, population, and labor force growth are obtained from official statistics (Department of Finance). Labor and capital factor productivity growth are assumed to mirror California's historic trends with a five year moving average, time and investment trends.
[19] This involves computing in each period a measure of Harrod-neutral technical progress in the capital-labor bundle as a residual. This is a standard calibration procedure in dynamic CGE modeling.
[20] See e.g. Babiker et al (2001) for details on a standard implementation of this approach.

some of the policy simulations we evaluate sector emission reduction scenarios, using specific cost and emission reduction factors, based on our earlier analysis (Hanemann and Farrell: 2006).

## Table 4.1 Emission Categories

*Air Pollutants*
| | | |
|---|---|---|
| 1. | Suspended particulates | PART |
| 2. | Sulfur dioxide ($SO_2$) | SO2 |
| 3. | Nitrogen dioxide ($NO_2$) | NO2 |
| 4. | Volatile organic compounds | VOC |
| 5. | Carbon monoxide (CO) | CO |
| 6. | Toxic air index | TOXAIR |
| 7. | Biological air index | BIOAIR |
| 8. | Carbon Dioxide ($CO_2$) | |

*Water Pollutants*
| | | |
|---|---|---|
| 8. | Biochemical oxygen demand | BOD |
| 9. | Total suspended solids | TSS |
| 10. | Toxic water index | TOXWAT |
| 11. | Biological water index | BIOWAT |

*Land Pollutants*
| | | |
|---|---|---|
| 12. | Toxic land index | TOXSOL |
| 13. | Biological land index | BIOSOL |

The model has the capacity to track 13 categories of individual pollutants and consolidated emission indexes, each of which is listed in Table 4.1. Our focus in the

current study is the emission of CO2 and other greenhouse gases, but the other effluents are of relevance to a variety of environmental policy issues. For more detail, please consult the full model documentation.

An essential characteristic of the BEAR approach to emissions modeling is endogeneity. Contrary to assertions made elsewhere (Stavins et al:2007), the BEAR model permits emission rates by sector and input to be exogenous or endogenous, and in either case the level of emissions from the sector in question is endogenous unless a cap is imposed. This feature is essential to capture structural adjustments arising from market based climate policies, as well as the effects of technological change.

## 4.9 Vehicle Fleet and Fuel Use

The current version of BEAR is distinguished by modeling the changing composition of the California vehicle fleet in considerable detail. In particular, we track 12 kinds of motor vehicles (table below) using four alternative sources of energy: Gasoline, Diesel, CNG, and Electricity. Using historical data from a variety of official (California DOT, ARB, and CEC), we track the state's fleet composition, vehicle miles travelled, and fuel consumption annually across the policy time horizon 2010-2025.[21]

**Table 4.2: Vehicle Types in the BEAR Model**

|  | Label | Definition |
|---|---|---|
| 1 | P | Passenger Car |
| 2 | T1 | Light duty Truck 1     <6000 lb GVWR   <3450 lb Curb wt |
| 3 | T2 | Light duty Truck 2     <6000 lb GVWR   >3450 lb Curb wt |
| 4 | T3 | Light duty Truck 3     6000-8500 lb GVWR |
| 5 | T4 | Medium duty Truck 4    8500-10000 lb GVWR |
| 6 | T5 | Medium duty Truck 5    10000-14000 lb GVWR |
| 7 | T6 | Heavy duty Truck Light&Med     14000-33000 lb GVWR |
| 8 | T7 | Heavy duty Truck Heavy   33000-80000 lb GVWR |
| 9 | B | Other Bus |
| 10 | BS | School Bus |
| 11 | BT | Urban Transit Bus |
| 12 | MC | Motorcycle |
| 13 | MH | Motor Home |

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[21] Special thanks are due Mohammad Assadi and Soheila Kohli of CA DOT for sharing results from their MVSTAFF research project.

Turnover in the vehicle stock is driven in the model by three factors:

1. Autonomous changes in current demand - This is determined by historical composition of annual sales, using moving averages, supplemented by exogenous assumptions about technology diffusion.

2. Policy – This is the supply side impact of policies like standards, which alter the menu of new vehicles available.

3. Depreciation – Retirement or replacement of vehicles. This again is simulated with moving average estimates of average vehicle life and ownership time.

Taking account of these three components, BEAR computes a given annual solution for statewide fuel use by household and industry, updates the estimated composition of the vehicle fleet annually based on exogenous information of fleet composition, Vehicle Miles Travelled (VMT), fuel efficiency, and emissions intensity for each vehicle category above.[22] Fleet turnover is also accounted for in terms of new vehicle cost estimates from independent sources (CARB: 2010 and Dicicco: 2010), adjusting enterprise and household savings accordingly. This information is then incorporated into the next year's model solution process by calculating weighted averages of more aggregate fuel and emission intensities. For example, based on VMT assumptions, fuel demand shares are adjusted for (California Department of Transportation projected) VMT changes and higher fuel or emissions efficiency.[23]

The advantages of the current approach are simplicity and detail. The main disadvantage is the absence of more complex endogenous behavior governing vehicle adoption. This has been a very active area of academic research for three decades, but it is fair to say that there is no clear consensus on a universal model of vehicle demand. We provide a succinct overview of the main behavioral issues in an annex below, but for the present implementation of BEAR we take the more direct approach, to facilitate transparency and believe this to be quite serviceable for macroeconomic assessment.

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[22] These data are regularly published by California state agencies.
[23] See e.g. Sydsæter et al (2005).

Having said this, more intensive research into adoption decisions would doubtless be an important contribution to further understanding of vehicle and fuel policies.

## 5 Conclusions

The idea that there is a necessary trade-off between environmental goals and economic growth is a fallacy, and in California we have proven this before with electricity use and can prove it again with transport fuel. Thirty years of efficiency policies in the electric power sector contributed to substantially higher California economic growth and employment, and efficiency measures in the vehicle sector will expand incomes and jobs in the same way.

Using a long term economic forecasting model that details patterns of vehicle ownership and use across the state, we evaluated a variety of scenarios from existing vehicle emission rules to standards representing the highest expectations for emerging vehicle technology. In all cases, direct and induced fuel savings translated into combinations of significant emissions reduction and new demand for more job intensive goods and services, most of which were in sectors with less import dependence and more extensive in-state multiplier linkages. Fuel savings, whether direct from mileage standards or induced from emissions standards, results in expenditure shifting, moving household and enterprise demand from the carbon fuel supply chain to demand-induced income and job creation across a broad spectrum of local activities and local jobs.

These results also support the important insight that fuel efficiency confers economic security against volatile energy prices.[24] Even for an economy the size of California's, energy markets are outside our control. The smaller the share of energy costs in personal and commercial transport services, the less vulnerable we are to adverse income and profitability shocks from energy prices.

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[24] This argument has been made by many researchers, most recently and forcefully by Fine, Busch, and Garderet (2010).

The results obtained for transport fuel and (earlier) electric power remind us that efficiency deserves deeper consideration across the full spectrum of energy uses, including reconfiguration of transport services, infrastructure, and many non-transport energy uses.[25] At the same time, rapid innovation in energy supporting and supported IT, communication, materials science, and electronics are all converging toward lower carbon, more energy efficient patterns of future production and use.

Finally, although fuel savings promote growth and energy security for the vast majority of Californians, there are of course some actors linked to the fossil fuel supply chain that will be adversely affected by these policies. Temporary adjustment assistance could be considered to facilitate their support in helping us realize our efficiency potential, and it could be a small price to pay for the lasting benefits of transition to a lower carbon future.

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[25] The Urban Land Institute, for example, sponsored a recent study (Cambridge Systematics: 2009) that profiled a broad range of transportation options which could reduce U.S. greenhouse gas emissions 35 percent below 2010 levels by the year 2050.

## Annex 1 - Overview of Modeling Approaches to Vehicle Adoption Behavior

The present study uses a relatively simple approach to modeling vehicle adoption decisions. This is appropriate for macroeconomic analysis, but it would eventually be useful to conduct more detailed analysis that improves our foresight regarding what kinds of efficiency choices households will make. To support such work in the present context, we could draw upon a large literature examining the microeconomics of transport technology choice, part of which is summarized in this annex. Vehicle adoption behavior is dependent on a range of variables which influence consumers' decisions of engaging in vehicle transactions (see e.g. Schmalensee and Stoker:1999, and Kayser:2000). Variables including public policies, incentives associated with buying fuel efficient or low-emission vehicles, new available vehicle technologies, and household locations and economic-sufficiency characteristics are some of these variables which determine a household's vehicle behavior. Changes in these variables, along with changes in income and population growth, can be used to forecast future trends of household vehicle fleet composition, utilization and evolution. In addition to, the data could give an insightful look of how the increasing rate of vehicle ownership effects the global oil market in developing countries and the emerging market, along with estimating energy consumption and green house gas emissions.

The vehicle behavior system described in "The Design of a Comprehensive Microsimulator of Household Vehicle Fleet Composition, Utilization and Evolution" is a two module system which explores the trends in vehicle transaction behavior. One module models the current fleet composition and utilization for a household, referred to as the baseline composition. Another module evolves the baseline fleet over time, taking into account changes such as buying, replacing, or disposing vehicles.

The results of the studies and models used in the household vehicle adoption behavior are then summarized as the following:

1) Annual mileage driven for larger vehicles is larger than mileage for cars (b/c households use larger vehicles for longer trips.

2) Higher preference to own compact car to other vehicle types.

3) Gasoline fuel vehicles most preferred; CNG (compressed gas) and EV (electric vehicles) least preferred.

4) Higher preference for newer cars.

5) As cost-related variables for cars increases, the preference for vehicle type decreases.

   a)Fuel efficiency (miles/gallon) has positive impact on utility.

6) Vehicle with more powerful engines are preferred (time to accelerate 0-60mph has negative effect on the utility of an alternative)

7) Policy variables which incentivize driving/buying vehicles, significantly affect vehicle type choice.

   a)Free parking, car pooling, tax credit, reduced tolls, purchase price rebates.


When a range of demographic and economic variables which affect consumers' vehicle type choice were studied, the following results were obtained:

1) Households with more male adults have higher preference for larger vehicles than compact cars, and had lower preference for hybrid electric and hybrid plug-in vehicles than households with fewer males.

2) Households with more female adults have "higher preference to own SUVs and move toward owning fully electric vehicles, while also shying away from diesel-powered vehicles" (Paleti, Eluru, Bhat).

3) Those with a higher education level show higher preference for newer vehicles and alternative fuel.

   a)Possibly, b/c they are more conscious of the environmental quality, prefer less polluting vehicles.

4) Households with younger children prefer larger vehicles.

5) Households with older children prefer older cars; households with senior adults prefer newer cars.

a) "Perhaps because parents get teenagers older vehicles when they first begin driving" (Paleti et al: 2010)

b) vehicles.

6) Households more likely to replace a vehicle with the same body type of vehicle; if the replaced vehicle is a compact car it is likely to be replaced by a non-gasoline fueled vehicle but also not the newest of vehicles.

a) "Possibly because current compact car owners are more environmentally conscious but also cost-conscious, which leads them to seek "green" vehicles but not the newest vehicles" (Paleti et al:2010)

b) Households which replace a gasoline fueled vehicle are more likely to replace it with an alternative fuel vehicle rather than a diesel fuel vehicle.

7) Exhibits interest in considering newer alternative fuel vehicles. Incentives which are targeted at the margins may encourage and promote consumers in the direction of 'greener' cars.

8) Households with higher incomes tend to have higher travel mileage (more financial freedom to travel).

9) Households in suburbs travel more than average households, suburbs are more auto-oriented.

10) Households in which individuals live farther from their work places accumulate more miles on their vehicles; households with more workers accumulate more mileage (extensive travel).

## 5.1 Vehicle Replacement Model Results:

1) Studies show that higher income households are more likely to replace vehicles

2) Households with older children are more likely to replace a vehicle; less likely to replace with younger children.

## 5.2 Vehicle Addition Model Results:

1) Larger households and households with more adults are more likely to add new vehicle to their fleet.

2) Lower income households are more likely to add a vehicle as opposed to higher income households.

   a) lower income households might not have enough cars and need to add additional vehicle.

3) Households in rural regions are more likely to add a vehicle.


The results described above exhibit how changes in income, demographics, household locations, public policies and incentives influence household vehicle ownership and utilization. The behavioral trends can be of added importance in order to understand the concerns of greenhouse gas emissions, global energy sustainability, and community livability in regions around the world.

A deeper analysis of vehicle adoption behavior studies the rate of vehicle ownership expansion in developing countries and the emerging market. To model this expansion which is based on data using pooled-time series estimations, the Gompertz function is used to demonstrate the relationship between vehicle ownership and GDP, or income per capita. The model explains the vehicle saturation level in terms of a country's population density and urbanization. The model is estimated on the basis of a pooled time series from 1960-2002, and cross section data for 45 countries (that comprises 75% of world's population). The estimated data is used for future projections of vehicle stock expansions and future oil demand growths.

The historical patterns of vehicle ownership and per-capita income turns out to be highly non-linear, with the ownership growing slowly at the lowest per-capita incomes, to growing twice as fast as income at the middle-income level ($3000-$10,000 per capita), to the point where finally, ownership grows as fast as income at the higher

income levels before reaching saturation. An example of where this is occurring currently is in developing countries, mostly in Asia, where the income ranges from $3000-$10,000 and vehicle ownership is increasing twice as fast as per-capita income. On the contrary, in most of the OECD countries where income levels are very high, vehicle ownership growth is experiencing a deceleration and approaching the saturation level. There is a pattern in the  income elasticity across the 45 countries as well. The income elasticity increases at the lowest levels of per-capita income, peaking in the range of $5000-$10,000, followed by a gradual decline in elasticity at higher income levels.

Using these trends as a basis to forecast future trends, it is estimated that the world's total vehicle stock will be 2.5 times greater in 2025 than in 2002.  which is an increase of more than two billion vehicles. Projections of Vehicle Ownership to 2030:

1) Non-OECD countries' total share of ownership will increase from 24% to 56% with the acquisition of 3/4 of the additional vehicles.

2) China's stock will increase about twenty-fold, to 390 million vehicles by 2030.

3) China, India, Indonesia, and most other countries will exhibit ownership to rise twice as rapidly as per-capita income with their middle-income levels falling in the $3000-$10,000 per-capita range.

4) By 2030, the ownership in OECD countries will have reached the point of saturation, yet most of Asia will still only have attained 15-45% of the ownership saturation levels.

These projections suggest a significant increase in future oil demand from the transportation sector in developing countries. It is projected for the annual worldwide growth in fuel demand to be in the range of 2.5-2.8%.  This poses a major challenge to policymakers and environmental agencies since many environmental concerns and issues will arise with the strong growth in the vehicle stock. The significant expansion in vehicle stock will have a pivotal role to play in the future, with respect to the rising concerns about global energy sustainability and greenhouse gas emissions. The expansion is capable of being slowed down if policymakers devise fuel-efficient

policies, promote public transportation, and strategically engage in urban planning to curb the negative externalities of an overly-dense worldwide stock of vehicles and its by-products.

From the perspective of this report, these trends suggest that baseline energy price assumptions may be too conservative. This in turn would imply even greater economic benefits from vehicle fuel efficiency. While not reported with the present results, experiments with higher global fuel price trends support the conclusion that fuel efficiency confers important energy security on California.[26]

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[26] Again a point made emphatically by Fine, Busch, and Garderet: 2010.

# Annex 2 - Background on California's Existing Vehicle Policies

## 1. Passenger and Light Duty Vehicles

Being one of the world's largest economies, California's market for motor vehicles is quite large. Due to rising gasoline prices and changes in consumer choice has caused many big American motor vehicle companies to earn less profits due to he lessened demand for high-profit margin cars such as SUVs. With increased global competition and consumer increase in demand for electronic and safety luxury additions to their cars, American auto manufacturer giants, General Motors Corporation and Ford Motors Corp. are losing market share and are facing deteriorating profitability (Standard and Poor's Industry Surveys 2006). The introduction of mandatory fuel efficiency standards and other policies to reduce GHG will further hurt these corporations. GM and Ford already plan to shut down many production facilities to cut costs.

The California Climate Change Emissions Policy will have two effects on the automobile industry. The first is that manufacturers will need to take to comply with the regulatory standards are expected to lead to price increases for new vehicles. However, many of the technological options they may choose to use to comply with new regulations are expected to reduce operating costs. The negative and positive effects of these policies will produce a small net positive effect to the economy as a whole. The vehicle price increase will be borne by purchasers and may negatively affect businesses. However, the operating cost savings from the use of vehicles that comply with the regulation will positively impact consumers and most businesses (ARB 2007). Low profitability with the adoption of new higher cost technologies in the short run will cause automakers to put price pressures on suppliers. However, increase use of these new technologies will also bring profits to those suppliers.

## 2. Industry Overview

The automobile manufacturers located in California include General Motors, Ford, and Toyota, whose other major plants are centralized in the Midwest and are also located globally. The motor plants are mainly located in suburban areas surrounding major

cities, such as Fremont, Ontario, and Torrance, California. The size of the motor vehicle plants produce about 400,000 each and employ over 5,700 employees (AIAM).

See list of manufacturing and research and development plants in California.

## Production

The motor vehicle manufacturing industry forms generates one-sixth of all U.S. manufacturers' shipments of durable goods and consumes 30% of all the iron, 15% of all the steel, 25% of all the aluminum, and 75% of all the natural rubber bought by all industries in the nation (Pearce 2005).

The increased costs of materials such as steel, plastic resin, rubber, and aluminum is one of the concerns of the automaker's suppliers. The proposed cuts of about 3 million cars in U.S. production from Ford and GM will further hurt their suppliers. Currently, sustainability-conscious automakers such as Nissan, Toyota, and Honda are working diligently to install new technologies to increase efficiency gains. Nissan plans to introduce a new engine valve control technology that will contribute to a 10% reduction in fuel consumption and carbon-dioxide (GreenCarCongress.com).

Auto suppliers are in distress due to a combination of vehicle production cuts, high raw-material costs, unfavorable product mix shifts, and ongoing pricing pressure from a weakened customer demand caused most auto suppliers' earnings and cash flow to decline dramatically. They do not expect much reason for improvement in the near term.

Their main concerns include:
- the success of new vehicle launches, which if good will increase volume of parts demanded, or if bad will decrease the volume of parts demanded by the customer.
- high gasoline prices decrease the demand (though only modestly) for large, high profit margin vehicles, from which many auto suppliers generate a large share of their earnings.
- most auto suppliers are not able to fully offset increased costs of materials such as steel, plastic resin, rubber.
- the decline in market shares of the big American automakers also decreases their sales.

- high debt levels limit auto suppliers to access bank lines leading to negative investor sentiment in its ability to raise new capital.

Though the big automobile manufacturers are trying to protect their industry by suing California for raising the fuel efficiency standards, the smaller suppliers will be the ones hurt more drastically by the change in standards.

## Cutting Production Costs

To cut production costs, automakers are simplifying parts and processes and cutting employee benefits. In automobile manufacturing, fewer parts means lower production costs and reduces assembly errors, which are also costly. Major automakers cut the number of parts they use in each component and vehicle by redesigning existing models and designing new models. In a typical product overhaul or redesign, part counts have dropped by 20% to 30% for individual car models and by as much as 50% for certain subsystems like bumpers and airbags (Standard & Poor's Industry Surveys 2006).  Other ways of reducing production costs and improve quality is by reducing the number of stampings on sheet metal parts between 5 and 7 to 3. Manufacturers are also lowering costs by minimizing industrial waste and pollution. Nearly all component manufacturers now deliver their goods in reusable shipping containers. This saves money for automakers and their suppliers by eliminating excess packaging and disposal costs (Standard & Poor's Industry Surveys 2006).

Many auto manufacturers have just been neglecting the costs they could cut. For example, from General Motors Corporate website, GM in Mexico claims to recycle 94.5% of their hazardous and non-hazardous wastes. They did not eliminate disposal of hazardous wastes in landfills until the beginning of August 2003. The hazardous waste is now recycled or used as alternative fuel. Since 2000, land filled waste has been reduced from 7,369 metric tons to 444 metric tons during 2003. The financial savings from this are calculated to be $990,173. Additionally Non-Hazardous Waste landfill has been reduced from 3,188 to 2,340 metric tons from 2003 to 2004, which is a reduction of 27%.

## 3. Technology

## New Materials

One method of increasing fuel efficiency is using lighter materials to build autos. Against improving fuel efficiency, U.S. consumers are demanding bigger, heavier SUVs and automakers continue to find efforts to increase performance and horsepower. Heavier, more powerful vehicles are typically less fuel-efficient. Passenger car sales accounted for only about 45.1% of the light vehicle market in 2005. Average fuel economy went down to 24.2 in 2005 from 25.1 in 1993. Despite the rising fuel prices, passenger car sales only made a modest comeback with market share rising 1%, though it continues to rise (Standard & Poor's Industry Surveys 2006). Increase use of variety of materials such as aluminum and plastic lowers the weight of vehicles and improves fuel efficiency. Steel use fell from 60% to 54.5%. The use of more aluminum to lighten cars is for better fuel efficiency, but costs much more. One kilogram of aluminum in car production replaces two kilograms of steel, which cuts weights down by almost 50%.

Volkswagen AG's Audi created Audi A2 in 2000 with an all-aluminum body, end production in 2005 and replace it with steel in 2008. The Aluminum body costs $1,206 (based on June 30, 2005 conversion rate) per vehicle (Standard & Poor's Industry Surveys 2006). Higher priced aluminum cars sold poorly. Increase usage of lighter materials also makes designing cars much more challenging, which increase research and development costs.

## Hybrids

Toyota's introduction of the first hybrid car, the Prius five years ago has caused it to decide to increase its production to one million hybrids annually in 2010 or soon afterwards. Cost-cutting efforts on the system's motor, battery and inverter were working so the cost structure would improve drastically by 2010. The executive vice president in charge of powertrain development expects margins to be equal to gasoline cars. "But sales began to suffer late last year after U.S. tax credits whittled down for the model, prompting Toyota to offer incentives of up to $2,000 on each Prius." Despite these pressure on the tough margins on the hybrid. Takimoto saw little impact on profitability before and after the incentives, mainly thanks to larger volumes produced

— Prius production will rise by 40 percent to 280,000 units this year, which will continue to cut costs (MSNB.com). Incentives should be given to consumers who buy hybrid vehicles to increase demand and to help automakers make larger volumes to reduce average costs.

### Diesel Anti-Idling

Diesel PM doesn't yet have a well-defined GWP and thus is not readily incorporated into the AB 32 reduction framework. Anti-idling will be opposed by diesel-users because the official effect is unknown.

### Variable Valve lift

This engine technology controls the flow of air and fuel into the cylinders and exhaust out of them. Optimum timing and lift settings are different for high and low engine speeds. Because traditional engines' timing is fixed, there are efficiency losses. The potential efficiency improvement is estimated to be 5% and savings over a vehicle's lifetime is $1400 (fueleconomy.gov).

### Dual Cam Phasing

A control strategy for controlling internal combustion engines, particularly for controlling valve timing relative to crankshaft position. It optimizes valve timing at lower revolutions to help create a broad torque band and eliminate turbo lag (patentstorm.com)

## 4. Balance Sheets

The length of time it takes for a technology or package of technologies to recoup their costs is called *payback time* (calcleancars.org). The payback time for these technology improvements depends on the price of gasoline. These increases in vehicle price are more than made up over the life of the vehicle (Figure 2).

At the gasoline price of approximately $2.00/gallon, the average driver in California would regain the price of a near-term technology improvement in less than one and a

half years of driving. The increased price of mid-term technology improvement would be made up in just over three and a half years of driving. Because gasoline prices have risen to about $3/gallon, the payback time for the near-term technology falls about a year. Over the lifetime of a vehicle, these savings add up. At a gasoline price of $2.00/gallon, near-term technology improvements will result in a net savings of over $1,700 to the average vehicle owner in California. Vehicles sold between 2009 and 2016 that meet California's greenhouse gas standards will save the operators of these vehicles $10.5 billion (in today's dollars) over the vehicles' lifetime. (calcleancars.org)

**Figure A1.2: Source: California Air Resources Board**

## Payback Time for the Average Passenger Vehicle

|  | | Fuel Price ($/gallon) | | |
|---|---|---|---|---|
|  | Technology Cost | $1.74 | $2.00 | $2.25 |
|  | | Payback time (years) | | |
| Near-term | $326 | 1.6 | 1.4 | 1.2 |
| Mid-term | $1,048 | 4.3 | 3.6 | 3.1 |

The profit margins of motor vehicle manufacturers that include both firms with net income and zero net income are much lower than the profit margins of firms with positive net income. This means that most small automobile manufacturers or suppliers are not able to sell their goods with high price to reap profits. Automakers have limited pricing power on consumers. Therefore, they look for price concessions from their suppliers. These companies in turn make demands on their own suppliers and so on down the production chain. Automakers will be hurt from the increase cost of more research and development for new environmental standards, which will in turn hurt their suppliers. Small suppliers typically have less financial strength, liquidity, and ability to resist their customers' demands, and therefore face the more difficult challenges. Decrease in the production of cars from major customers will be sharply lower leaving them in financial distress (Standard and Poor's Industry Surveys Volume 1 A-D2006).

Looking at Table A.2.1, the marginal cost and benefit for increase in miles per gallon in light trucks are the same at about 13 miles per gallon. "Once these standards are in place, signaling a federal commitment to reducing the fuel consumption of our nation's auto fleet, technological innovation may drive down the cost of new technologies, enabling more ambitious standards in later years" says DeCicco in the "Cost-Effective Targets for a 2008+ Light Truck CAFÉ Rule." Previous studies also indicate that light truck fleet fuel economy improvements of 50% or higher relative to recent levels "can be achieved within a decade cost-effectively through use of available technologies." A 50% improvement within ten years entails annual improvement rates of 4.1%/yr. (DeCicco et al. 2001).

## Conclusion

Because there are mounting pressures on automakers from all areas such as consumer change in tastes, decline in market share, increase in complexity of auto production with the integration of many electronics, fierce competition, the automakers' profits are declining. With the institution of California's new climate change emissions standards, all cars sold to the state must pass those standards, which basically implies the same standards everywhere else in the U.S. Like Toyota's Prius production volume, other car manufacturers should follow suite in implementing cleaner vehicles in large volumes to cut down on marginal costs. Because consumers may not absorb the large volume at first, incentives should be given out to those who do choose to adopt the new technology. Taxes on large SUVs and other bigger cars that are less fuel efficient will cause some consumers to buy more efficient cars, reducing overall carbon emissions.

Because developing new cars and adopting redesign vehicles is very costly and requires a lot of capital investments, the transition will be slow. First, consumers must become more environmentally friendly and sacrifice some of their extravagant needs in order to convince auto manufacturers that energy should be spent on producing more green cars. Eventual adoption of this transition will then drive costs further down and make it feasible for every household to have a more efficient car.

Automobile manufacturers are battling California's new higher efficiency standards in courts. They state that California does not have the power to set higher standards than the Federal government. Many automakers are looking into new technologies to make cars more efficient, but the process is slow and very costly. While GM and Ford are turning their business structures around, they cannot afford to lose any more resources or to continue to lose market share. Cutting costs may cause them to continue to close down plants or move them to cheaper locations such as Mexico.

## 5. Trucking Industry Measures

The trucking industry is a key support network to the state's economy and a large contributor to greenhouse gas emissions.  Though significant emissions-efficiency gains have been made in the industry, room still remains to further emission reductions. Other than the costs of transitioning to cleaner technologies, few obstacles exist in the industry to implement AB32's measures.  The history of environmental regulation of the industry makes it more receptive to regulation than industries unaccustomed to intervention and significant existing and developing technologies are available to help trucking firms meet AB32's provisions.  Improved emission-efficiency practices have the simultaneous result of improved fuel efficiency, offsetting transition costs with reduced energy costs.  The measures of AB32 ask that the trucking industry reduce emissions through a multiplicity of strategies.  State efforts to in the implementation of AB32 can go a long way towards ensuring rapid and frictionless success in meeting its climate change goals.

The California trucking industry is dominated by a few, large national carriers but is largely composed by small, regional carriers.  Approximately 60% of the 11,308 firms operating in California have less than five employees and earn less than half a million dollars in annual revenue (see Figures 1 and 2).  75% of California trucking firms have less than 10 employees, 87% have less than 20 employees and 98% employ less than 100 employees. The majority of small trucking firms in California are privately owned and operated.  The handful of large firms operating in California are publicly held

companies. The trucking industry nationwide is a price competitive market. Large carriers and small carriers are both characterized by small profit margins and price their rates near marginal cost levels.

For more than seventy years, the California Trucking Association (CTA) has provided support services to trucking firms of all sizes and companies that provide services and products to the industry. Its members transport 85% of trucking freight carried in the state. Democratically run by member vote, the CTA has a strong Environmental Affairs Department which lobbies with state agencies to represent member interests and advices its constituency on compliance with environmental regulation.

Altogether, the California trucking industry transports a wide variety of goods and is classified by route distance and shipment size. Local routes deliver goods within metropolitan areas and their surrounding regions whereas long distance routes span multiple commercial areas. Truckload carriers (TL) are direct carriers that deliver large shipments door-to-door from origin to destination whereas Less than Truckload (LTL) carriers sort combined shipments in distribution hubs to coordinate a flow of goods from multiple clients to nearby destinations. 60% of the carriers operating in California are long haul carriers delivering goods in and out of the state in long distance routes. The remainder of the state's carriers are short haul carriers traveling local routes of 50 to 700 miles within the state and within the West Coast region, including Mexico. The LTL market has higher barriers to entry than the TL market due to the costs of large sales forces, logistics technology and distribution terminals. Compared to other industries, however, both sectors have relatively low barriers to entry, are highly competitive and have low profit margins. Trucking firms differentiate themselves by the routes and type of goods they are authorized to carry.

Nationally, the trucking industry dominates the transport of high value goods, carrying 55% of national freight in weight and 75% of national freight in value. It carries 70% of construction goods like steel, sheet metal, wire, pipes and lumber and 85% of household goods like food and furniture. The trucking industry's main competitor is the rail freight industry. Railroads have cost advantages in long distance shipping in routes greater than 500 miles. Rail freight is preferred in the shipment of heavy commodities,

like coal, but is increasingly being turned to for interstate shipment of manufactured goods as well. Intermodal collaboration between railroads and the trucking industry coordinates freight transport between the competing sectors. Other competitors to the trucking industry are pipelines, domestic water freight and air freight.

Competitiveness within the industry is characterized by a firm's financial strength, the quality of its salesforce, availability of tracking technologies, route coverage, efficient claim settlement, fleet size and quality, insurance coverage, safety records and the type of freight firms are authorized to carry.

The industry is highly regulated in terms of the types of goods each carrier is certified to transport, environmental standards and safety standards. The industry underwent significant deregulation in the Motor Carrier Act of 1980, increasing cost competitiveness, reducing barriers to entry and increasing industry efficiency, especially in terms of carriers' abilities to transport full shipments on return trips.

The regional scope of the industry is key to its structure. National carriers with parent companies outside the state are generally operated by California subsidiaries. Routes in the state are connected to shippers and destinations throughout the North American continent. The crossing at Otay Mesa, CA is a significant truck portal between the US and Mexico, handling more than $10 billion in traded goods in 2004.

The trucking industry is a growing industry in California. The transport of goods to and from the Los Angeles and Long Beach ports, for example, is forecasted to increase by 250% from 2005 to 2025 due to increased import activity. Thanks to an abundance of industry innovations which reduce greenhouse gas emissions, high growth rates do not imply increased emission rates or greenhouse gas concentrations.

Due to the number of firms operating in the industry, the small scale of the majority of its firms and the industry's network characteristics, it is challenging to discern precise cost and production statistics for the industry specific to California. This analysis will qualitatively consider the production factors, technologies, costs and perspectives of the trucking industry, providing quantitative state and national data when available. A

snapshot of the overall industry will be followed by nuances among national and regional carriers and an industry wide prognosis.

## Industry Overview

### Production

Production in the trucking industry is measured in ton-mileage, indicating the mass of goods delivered in relation to mileage incurred. While ton-mileage within the state is difficult to separate from national data, mileage of the state's largest heavy-duty trucks, those carrying loads heavier than 33,000 pounds, traveled over 25 million daily miles daily 2005, topping 9 billion annual miles.

Nationally, trucking carries nearly 30% of American freight volume in ton-mileage. Alternate methods of freight include railroad (39%, due to railroad's dominance of heavy commodities like coal), pipeline (19%), domestic water (12%) and air freight (less than 0.5%).

### Inputs

Trucking inputs include: diesel fuel, trucks, trailers, tires and equipment-related inputs, driving labor, management labor, distribution hubs and logistics technology.

Significant to AB32, factors on trucking's energy use include fuel prices, fuel efficiency and fuel composition.

Diesel fuel prices fluctuate between periods but have an overall increasing pattern industry wide and are expected to continue rising in future years. Fuel price per gallon is exogenous to the industry but significant savings opportunities exist to reduce fuel costs with improved fuel efficiency.

Fuel efficiency is a significant factor to both trucking profitability and emissions. Nationally, energy input of freight transport is expected to increase from 2005 levels by 27% by 2010 and 49% by 2020. An equivalent increase in California's fuel input for trucking is significant impetus to improve fuel efficiency and offers a significant

opportunity to reduce greenhouse gas emissions. As proposed regulations are implemented in the state, gains in the industry's fuel efficiency would be partially dictated by regulation measures and partially dictated by firms' inherent motivation to maximize competitiveness in face of rising fuel costs.

Fuel composition would be altered by proposed regulation by blending increased amounts of biomass fuel in diesel stock. Increased use of biofuel changes the composition of the industry's emissions.

AB32 also considers the industry's use of trucks, trailers, tires and equipment-related inputs. Arenas of input decision making that offer significant gains in fuel and emission efficiency include the use of driving labor, management labor, distribution hubs and logistics technology.

In regards to a cap and trade mechanism, the trucking industry will only be affected by a fuel-based allowance strategy. A fuel-based allowance cap and trade mechanism will have the downstream affect of a fuel tax, increasing marginal costs to trucking firms. A fuel-based cap and trade mechanism requires no technological or monitoring adaptations from the industry. Carbon caps and monitoring would occur at point sources upstream of the trucking industry; it would not be involved in the trading process.

## Outputs

Trucking outputs include: transportation services and emittants, including greenhouse gases. Effects on trucking outputs include trucking demand, economies of scale and economies of utilization.

The most significant determinant of trucking demand is consumer demand. Nationwide, fluctuations in trucking demand closely shadow fluctuations in Gross Domestic Product (GDP). In developed economies, trucking demand is near unit-elastic to GDP, increasing slightly with gains in economic wealth. As one of the largest global economies, California's trucking demand is similarly driven by the rate of economic expansion.

Other significant drivers in trucking demand include the price of fuel and insurance costs. As the cost of both fuel and insurance increases, trucking demand decreases. Increasing adoption of practices which maximize tons of goods carried per mile minimize the dampening effects that rising fuel and insurance costs have on industry demand.

Industry wide, economies of scale do not result in gains in transportation services. While this is slightly less so in the LTL sector which benefits from increased ton-mileage per distribution hub, the large number of firms in the overall industry is evidence that firms with a focused scope have similar profit potentials as larger firms broader in scope. In terms of pending regulation, the significance of this characteristic is that, without the threat of monopoly power, trucking prices are not likely to increase above commensurate increases in trucking costs due to the price-minimizing pressure of industry competition.

Economies of scale are not known to affect industry emissions.

Economies of utilization have significant impact on both ton-mileage of transportation services and industry emissions. Economies of utilization allocate fixed costs and emissions over increased output, maximizing ton-mileage per dollar spent and pollution emitted. Equipment usage is limited by federal labor regulation limiting driver hours of service but can be greatly maximized by technologies and practices that improve fuel and ton-mileage efficiency.

## Technology

Due to existing air quality regulation, basic technology employed by California's trucking industry is relatively homogenous in terms of emissions and fuel efficiency. How the industry's trucks and trailers are used by individual firms, however, can vary efficiency measures depending on route geography, type of goods carried and driving behavior. Regulation pressures have been shown to hasten the adoption of costly technologies. Beyond extending efforts to regulate the fuel and emissions efficiency of trucks purchased in California, emissions can be further reduced by altering three industry characteristics:

1. characteristics of the vehicles currently in use, i.e. improving truck and trailer aerodynamics, reducing tire resistance, replacing existing engines with cleaner engines or retrofitting vehicles with emission control systems

2. characteristics of fuel sold in California, i.e. blending diesel with biodiesel

3. how vehicles are used in California, i.e. optimizing driving behavior and route efficiency

AB32 considers emissions reductions in all of the above strategies. It is significant to note that industry investment in emission-reduction methods offer simultaneous savings benefits in fuel efficiency gains among firms. Extension of existing vehicle and engine scrapping programs in the state would hasten industry adoption of its measures.

Technology adoption that helps firms meet AB32 provisions before its implementation can be registered with the California Climate Action Registry. Registration reduces firms' transition costs without loosing recognition of improvements incurred early on. To date, only one firm out of the industry's 11,000 plus firms has signed on to the registry.

Following is an analysis of AB32's provisions related to trucking technology and the industry's ability to meet regulation requirements with existing capabilities:

## Diesel Anti-Idling

**Objective**: To extend existing anti-idling regulation to further climate change emission reductions by about 4% with significant cost savings to both the industry and trucking consumers and substantial air quality benefits.

**Industry Concerns:** National estimates of engine idling for the purpose of powering cab amenities and running electrical appliances range from 1000 to 5000 hours per year per truck. The industry employs at least four alternative methods of providing cab heating, cooling and electrical supply without the use of idling the engine:

- Direct fire heaters which route heating between the cab and the engine with a small combustion flame and heat exchanger

- Auxiliary power units (APUs) mounted externally on the truck to provide heat, electricity and air conditioning

- Automatic engine idling systems which start and stop truck engines automatically to maintain specified temperatures or minimum battery voltage

- Electrification of truck stops which provide electricity to trucks without engine use or the use of auxiliary units

Truck idling can also be considerably reduced through route mapping that minimizes idling time. Support services are available to the industry, for example, which maps routes without left hand turns, reducing idling time and improving fuel efficiency. Emissions have been reduced in similar ways by automating toll booths for heavy duty trucks.

Industry concerns about anti-idling efforts include safety concerns, retrofitting costs and the unknown reliability of direct fire heaters. The last concern can be refuted by the evidence that 55% of European long-haul trucks are outfitted with direct fire heaters without increased safety hazards or equipment failure.

Another industry concern about anti-idling strategies is that automatic systems are disruptive to long-haul drivers when sleeping. Adoption of technologies unsuitable to trucking needs would not be widely accepted. Improvement to the engineering of automatic systems would be desirable.

It should be noted that the four methods of providing cab heating, cooling and electrical supply do not have cumulative emissions reductions; they are alternate choices. Extension of truck stop electrification would reduce the need for direct fire heaters, APUs and automatic idling systems. If truck stop electrification is not widely extended, firms could choose between direct fire heaters, APUs and automatic idling systems as alternate methods to meet AB32's provisions.

Current limitations on truck idling are enforce by the state's Air Resource Board's inspection teams. Participation of local enforcement agencies, including California Highway Patrol, police and local air district inspectors would improve AB32's effectiveness at reaching its proposed goals.

All technology based anti-idling strategies currently have a low market penetration, offering substantial opportunities to increase fuel efficiency and reduce greenhouse gas emissions with cost savings benefits to the industry.

## Hdrofluorocarbon (HFC) Reductions

**Objective:** In an overall effort to reduce the use of hydrofluorocarbons, require that the trucking industry:

1. use only low-Global Warming Potential (low GWP) refrigerants in new medium and heavy-duty vehicles not already covered by existing regulation by 2010

2. limit the use of GWP refrigerants in refrigerated trucks

3. be subjected to refrigerant use and leakage checks as part of existing smog-check inspections

**Industry Concerns:** Existing environmental regulations already cover most vehicles employed by the state's trucking industry and dictate the availability of vehicles sold in the state. There are no known technological concerns to extend the reduction of HFCs to AB32's standards within the industry.

## Alternative Fuels: Biodiesel Blends

**Objective:** To change the composition of California diesel fuel to include 1 to 4% biodiesel.

**Industry Concerns:** Biodiesel blends of 1 to 4% can be used by existing technology stock without mechanical alterations. There is discussion, however, that fuel efficiency decreases with increased percentages of fuel from biomass sources. If this proves to be the case, price pressures on diesel fuel would be threefold: first, the price of diesel fuel has been increasing in recent years and is expected to continue to rise in the future. Second, the blending of diesel fuel with biofuel is forecasted to raise diesel fuel prices. Thirdly, reduced fuel efficiency due to the addition of biomass will increase fuel demand.

Regional implementation of biofuel blending in the state's neighboring economies would minimize leakage due to trucks fueling up at stations across state boarders.

## Heavy Duty Vehicle Emission Reduction

**Objective:** To reduce vehicle emissions in the trucking industry through a variety of measures, including: improved vehicle aerodynamics, climate-engine based improvement efficiency, vehicle weight reductions, rolling and inertia resistance improvements and educational programs on optimal vehicle operation.

**Industry Concerns:** Significant opportunities exist for emission reductions in this category. Specifically:

- Improved vehicle aerodynamics increase fuel efficiency at highway speeds by reducing aerodynamic resistance. While efforts to improve cab aerodynamics are approaching saturation levels in the industry, improvements to trailer aerodynamics still offer substantial room for emissions reduction. Low-tech, modular solutions which, for example, reduce the gap between tractor and trailer improve fuel and emissions efficiency.

- Climate-engine based improved efficiency, such as the use of low friction engine lubrication and low friction drive train lubricants have low adoption rates in the industry, thereby offering considerable opportunities to reduce greenhouse gas emissions. Additionally, climate-engine efficiency can be improved without scrapping entire trucks by replacing existing engines with cleaner technologies.

- Vehicle weight reductions similarly have low adoption rates in the industry and offer considerable opportunities to reduce greenhouse gas emissions.

- Rolling and inertia resistance improvements, such as wireless tire pressure monitoring systems, tire inflation systems and the use of wide-based tires offer some of the greatest opportunities for the industry to maximize fuel efficiency and reduce greenhouse gases. All approaches currently have low market penetration rates, offering considerable opportunities to reduce emissions.

- Wide-based tires which replace the typical dual-tire configuration with singular, wide tires have thus far been received by the industry with skepticism. Trucking's concerns include that wide-based tires are not consistently legal throughout the continent and that they do not offer the same back up benefits that dual-tire configurations offer when tires blow out. Counterarguments claim that wide-based tires are now legal in all fifty states and that the presence of tandem axels in heavy duty trucks prevent vehicles from being immobilized when wide-based tires fail.

- If paired with effective monitoring and enforcement systems, educational programs on optimal vehicle operation also offer substantial emissions reductions. Encouragement of speed reduction, for example, improves fuel efficiency and reduces greenhouse gas emissions. Truck fuel economy drops as highway speeds increase above 55 miles per hours (mph). An increase from 55 mph to 60 mph reduces fuel efficiency by 7.1 miles per gallon (mpg). An increase from 60 mph to 65 mph reduces fuel efficiency by 6.5 mpg. Further increasing speeds to 70 mph further diminishes fuel efficiency by an additional 6.1 mpg.

## Fuel Efficient Replacement of Tires and Inflation

**Objective**:To improve fuel efficiency by the development and adoption of more fuel-efficient tires and tire usage.

**Industry Concerns:** As highlighted in the above section, increased use of fuel-efficient tires and tire usage is well developed in the industry and low market penetration rates offer significant fuel and emission efficiency improvements.

## Logistics Technology

A substantial area for emissions reductions unmentioned in AB32 is improvements in trucking logistics. Internally motivated by cost and service competitiveness, significant logistics gains have improved fuel and emissions efficiency in the industry. Continued logistics improvements that can be adopted include:

- Route efficiency technologies that optimize the location and status of trucks and trailers with fuel stops, distribution hubs and final destinations.

- Revenue potential technologies that maximize earnings per ton-mile

- Load maximizing technologies that balance inbound and outbound loads to ensure full loads on all trips. Though containerization in the later half of the twentieth century and the Motor Carrier Act of 1980 greatly reduced empty and out-of-route miles, long term contracts, shipment planner software and coordinating services offer further potential to minimize emittant per ton-mile by creating shorter, dedicated and non-random routes and minimizing empty, circuitous miles.

## 6. COSTS

While it is difficult to discern average and marginal costs for the typical trucking firm in California, it is insightful to consider cost effects of rising energy prices, cost effects of improved fuel efficiency and cost factors characteristic to the industry.

### Cost Effects of Rising Energy Prices

A key contributor to the industry's average and marginal cost is the price of diesel fuel. In July 2006, the average diesel fuel price in representative Californian cities was $3.175 per gallon. If the typical long haul truck has an annual mileage of 98,000 and a fuel economy of 6.1 mpg, the marginal cost of fuel per mile during this period was $0.52, totaling fuel expenses per typical truck at $51,008. Increases in fuel prices have a one to one correlation with marginal and total fuel costs; a one percent increase in fuel prices results in a 1% increase in both marginal and total fuel costs.

### Cost Effects of Improved Fuel Efficiency

Improved fuel efficiency has a one to one correlation with marginal and total fuel costs as well, reducing costs as efficiency improves. A $2000 investment in improved fuel

efficiency is covered by the first year of energy cost savings by a 5% minimum fuel efficiency improvement.  A $3800 investment is covered by the first year of energy cost savings with at least a 10% fuel efficiency improvement. Low interest rates and long lifespans of efficiency measures further finance improved fuel efficiency.  Greenhouse gas emissions are reduced by the industry at a cost savings to firms.

## Cost Factors Characteristic to the Industry

Fixed costs in the trucking industry are expenses incurred no matter how many miles are accumulated and variable costs are those attributed to mileage.  Trucking fixed costs include:  equipment costs, interest rates, license fees and taxes, insurance, management costs and overhead costs.  Significant variable costs in the sector include maintenance and repair, fuel costs, labor and tires.

Between firms, fixed and variable costs vary significantly depending on the type of carrier the firm is, the geography of their routes and the type of products they carry.  As an industry, the composition of fixed and variable costs are determined by the type of goods and routes the state's economy demands.  In an industry as competitive and with as many firms as the trucking industry, as statewide demand varies, firms emerge to cover underserved markets and withdraw from saturated markets.

Among fixed and variable costs, it is important to consider the degree to which trucking firms and the industry have control over cost variables.  Exogenous costs beyond decision makers' control include fuel, tire, maintenance and repair expenses, license fees and taxes, insurance costs and interest rates.  Business decisions made by firms and the industry are related the decision-variable costs of equipment, overhead, management and labor expenses.  Driving practices and equipment usage use decision-variable costs to manage exogenous costs.  Both firm competitiveness and industry viability is increased as decision-variable costs and performance practices minimize the effect of exogenous expenses.

## 7. Perspectives:  Uncertainties, Pressures and Trends

## Uncertainties and Pressures

Current pressures on the trucking industry include:

- Fluctuating diesel fuel costs

- Rising insurance costs

- Fluctuations in consumer demand

- High driver turnover rates, reported to be as high as 100% annually

- Driver shortages, especially for long haul routes

- Rising health and liability costs

- Price competition among firms

- Increasing competition from the rail freight industry in the shipment of manufactured goods and from double stacked railcars

## Trends

Trucking is considered relatively immune to economic recession. Despite economic slowdowns which reduced manufacturing and consumer demand in the early 2000s, the trucking industry experienced national growth between 1995 and 2005. The lowest growth rate was 0.7% experienced between 2002 and 2003. The highest growth rate was 4.5%, experienced between 1996 and 1997. The average growth rate in the 10 year period was 2.44%. As California's economy experiences fluctuations in growth rates, the trucking industry is expected to experience commensurate changes in demand.

Due to an improved economy and rise in manufacturer's shipments, intercity national freight volume is expected to grow at a rate of 2.5% in ton-mileage through 2010. This is slightly higher than the expected demand increase of freight services in general (including railroad, pipeline, domestic water transport and air freight) of 1.9%. This indicates that trucking freight is expected to remain competitive in coming years. Intermodal rail and trucking collaboration is expected to continued growing while

domestic water, pipeline and air freight shares of freight transport is expected to remain constant or decline.

Transborder trucking freight with Mexico as part of NAFTA trade is also expected to grow in coming years.

Increasing use of just in time inventory practices as manufactures and retailers move to "zero inventory" methods mean:

- an increase in distribution hubs within two days distance between inputs and manufactures and between manufacturers and retailers.

- that firms able to offer the most inclusive package of logistics, storage services and customer accessible tracking systems are well positioned to absorb a good portion of industry growth. Larger firms tend to offer these services more frequently than smaller firms.

- increased investment in logistics technologies industry wide.

- shortened supply routes.

Continued route maximization practices are expected due to increasing fuel prices and competitive pressures.

- Stable trucking rates due to price competition are expected in the industry in coming years.

- Research and development in safety measures, including cab mounted computers that reduce accidents and improve communication between drivers with dispatchers.

- Research and development in computerized systems that direct trucks to optimal speeds.

- Research and development in shipment planner software that reduces empty trailer miles.

- Increasing horizontal integration and alliances with railroad firms.

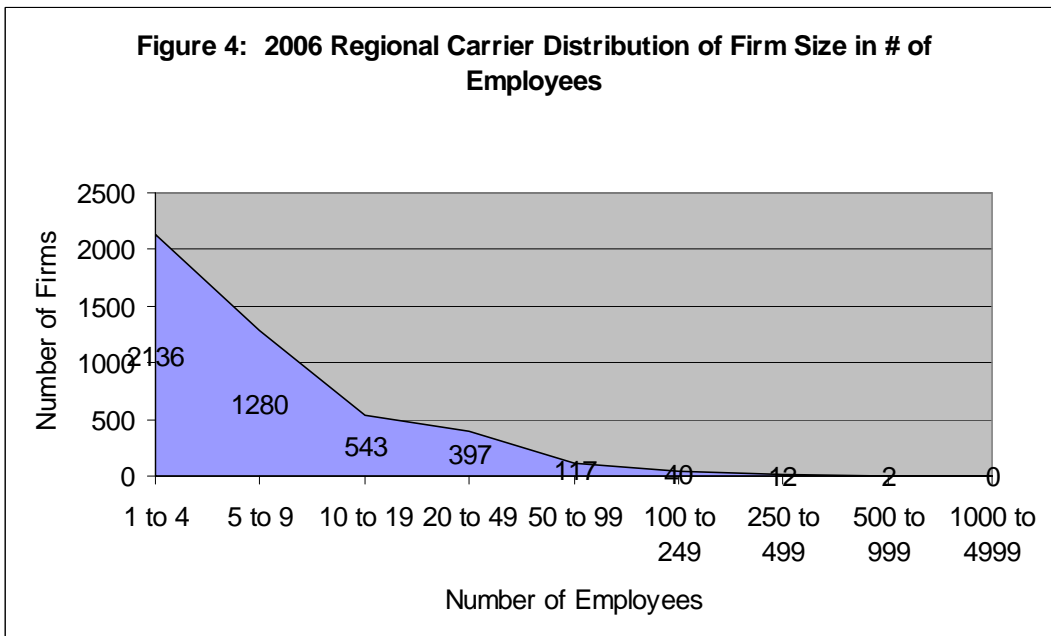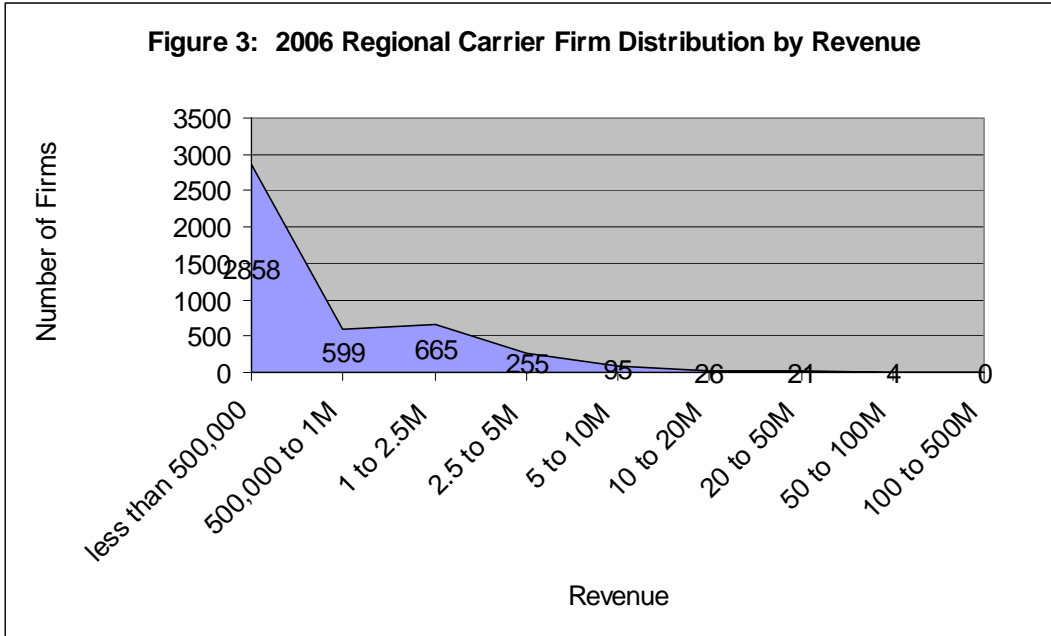## 8. National Carriers Operating in California

### National Carrier Industry Overview

The 6786 firms in the state's national carrier sector make up 60% of California's trucking industry. 60% of national carriers operating in California earn less than half a million dollars in annual state revenue; 90% of the state's national carriers earn less than $5 million in annual state revenue. (Figures 3 and 4)

Due to the network characteristics inherent to the trucking industry, many national carriers operating in California are not owned in California. National carriers with parent companies outside of California are oftentimes operated by state subsidiaries. Leading firms earning more than $50 million in annual revenue include FedEx, Roadway, UPS and Estes Way. Dominant, large national carriers are price competitive with the populous fringe of smaller, national carriers. Some overlap in the LTL and TL sectors occurs among national carriers.

### National Carrier Production Factors

National carriers face the same general inputs and outputs characteristic to the overall industry, with heavier use of management, distribution hubs, logistics and marketing than regional carriers. National carriers benefit most in the industry from economies of scale and have improved capabilities for maximizing economies of utilization due to sophisticated management practices and logistics technologies.

**Figure 3: 2006 Regional Carrier Firm Distribution by Revenue**

Number of Firms (y-axis): 0, 500, 1000, 1500, 2000, 2500, 3000, 3500

Revenue (x-axis): less than 500,000; 500,000 to 1M; 1 to 2.5M; 2.5 to 5M; 5 to 10M; 10 to 20M; 20 to 50M; 50 to 100M; 100 to 500M

Values: 2858, 599, 665, 255, 95, 26, 21, 4, 0

**Figure 4: 2006 Regional Carrier Distribution of Firm Size in # of Employees**

Number of Firms (y-axis): 0, 500, 1000, 1500, 2000, 2500

Number of Employees (x-axis): 1 to 4; 5 to 9; 10 to 19; 20 to 49; 50 to 99; 100 to 249; 250 to 499; 500 to 999; 1000 to 4999

Values: 2136, 1280, 543, 397, 117, 40, 12, 2, 0

## National Carrier Technology Factors

Large, national carriers have been a driver of fuel and emissions efficiency innovations in the industry. FedEx, for example, is in collaboration with environmental think tanks

to design and adopt more efficient trucks that reduce fuel use and emission rates. Likewise, UPS has gained national attention for its collaboration with services that reduce engine idling through the minimization of left hand turns.

Larger firms in the national carrier sector are better positioned to coordinate and finance efficiency improvements to the characteristics of existing vehicles and improvements to vehicle use.

Zero national carriers have registered with the California Climate Action Registry.

## National Carrier Cost Factors

National carriers generally face the same energy costs as regional carriers within California but have the advantage of fueling up in neighboring states with lower fuel costs. Depending on the carrier's route, this can amount to energy savings as much as 4 to 12%. Firms that have vertically integrated in the petroleum industry have the advantage of dedicated access to diesel fuel, but federal regulation of the industry ensures that vertical integration does not give firms a cost advantage.

National carriers may benefit less per mile in fuel efficiency gains because of its tendency to use newer, cleaner stock, the diminishing capabilities of fuel efficiency efforts already made and because national carriers run more highway miles, optimal operating conditions for heavy duty trucks.

National carriers have higher fixed costs than regional carriers due to their heavier use of management, distribution hubs, logistics technology and marketing, but face the same variable costs of maintenance and repair, fuel and tire expenses.

## National Carrier Perspectives – Trends & Uncertainty

Regardless of AB32's measures, fierce competition in the national carrier sector will continue to drive fuel and emissions efficiency through technology innovation and maximization of economies of utilization.

Due to its dominance of long haul routes, the national carrier sector is more affected by hours of service regulations and high turn rates than regional carriers.

# 9. Regional Carriers Operating In California
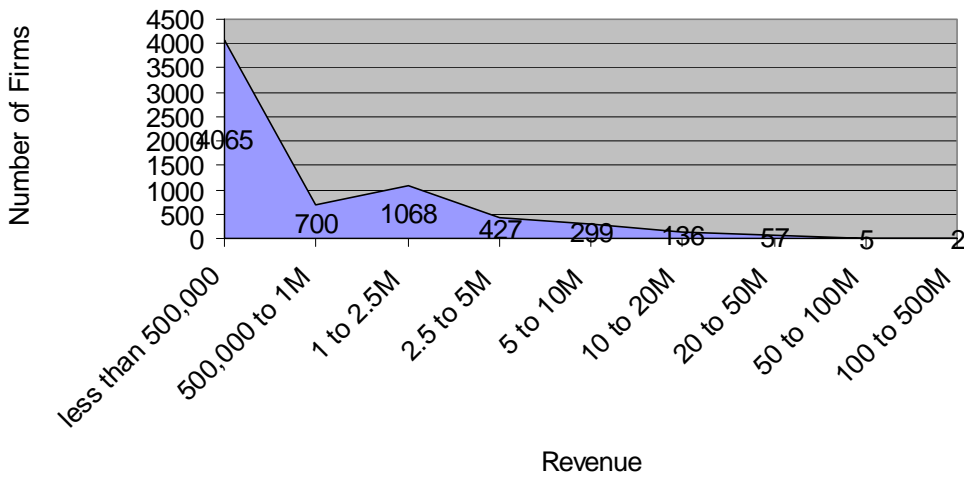
## Regional Carrier Industry Overview

The 4529 regional carriers operating in California make up 40% of the state's overall trucking industry. Similar to the characteristics of the overall industry, the regional carrier sector is comprised of a few leading firms and a large competitive fringe. Leading firms in the industry with revenues greater than $50 million include Adams Grain Company, Sunny Express and Unity Courier Services. More than 60% of the state's regional carriers earn less than half a million dollars; 90% of California's regional carriers earn less than $2.5 million. Regional carriers tend to be privately owned firms. (Figures 5 and 6)

## Regional Carrier Production Factors

Regional carriers have the same inputs and outputs of the overall industry with less of a need for sophisticated tracking logistics and management practices due to its dominance of shorter, dedicated routes. The dominance of short haul routes results in lower fuel and emissions efficiency than industry averages due to more stops per ton-mile, less highway miles and increased intercity miles in congested areas.

**Figure 5: 2006 National Carrier Distribution of Firm Size by Revenue**

Number of Firms (y-axis): 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500

Values: 4065, 700, 1068, 427, 299, 136, 57, 5, 2

Revenue categories (x-axis): less than 500,000; 500,000 to 1M; 1 to 2.5M; 2.5 to 5M; 5 to 10M; 10 to 20M; 20 to 50M; 50 to 100M; 100 to 500M

Revenue

**Figure 6: National Carrier Distribution by Employee Size**

Number of Firms (y-axis): 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000

Values: 4354, 748, 782, 564, 201, 97, 27, 3, 1

Employee Size (x-axis): 1 to 4; 5 to 9; 10 to 19; 20 to 49; 50 to 99; 100 to 249; 250 to 499; 500 to 999; 1000 to 4999

Employee Size
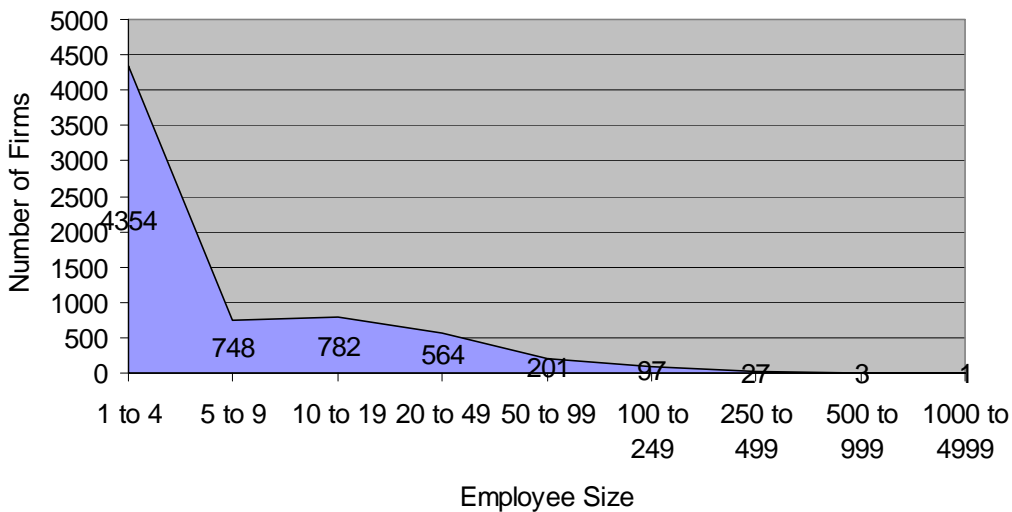
## Regional Carrier Technology

Due to purchasing patterns in the overall industry, regional carriers have been historically slower to adopt cleaner technologies than national carriers. Regional

carriers are positioned to gain the most from fuel efficiency measures as older stock is replaced and because of the room for efficiency improvement in intercity transport.

Only one regional carrier is registered with the California Climate Action Registry:  Bill Signs Trucking of San Diego.  Bill Signs Trucking is the the industry's sole firm on the Climate Action Registry.

## Regional Carrier Cost Factors

Regional carriers face energy, fixed and variable costs standard to the industry. Regional carriers do not share national carrier advantages of fueling up at lower costs outside the state with the exception of those firms operating routes near state boarders.

## Regional Carrier Perspectives – Trends & Uncertainty

As a sector, regional carriers face less competition from the industry's rail, pipeline, domestic water and air freight competitors due to the flexibility trucks have in carrying more specified routes.

Between firms, regional carriers are price competitive due to the number of firms operating in the industry.

## 10. Conclusion:  Prognosis for Policy

The success of the state's trucking industry is an indicator and result of California's economic well-being.  Participation of the industry's firms in meeting the goals of AB32 can greatly reduce greenhouse gas emissions in significant and needed ways. Fortunately, trucking is well positioned to implement AB32's measures due to innovative fuel and emission efficient technologies currently available to the industry. In addition to the incentives AB32 provides in reducing emissions, the industry's competitive environment creates considerable internal motivation to improve fuel and emissions efficiency as a means of profit maximization.   Gains made in fuel and emissions efficiency have the benefit of cost savings to firms and the industry as a whole.  If AB32 regulation results in higher prices to trucking consumers, the make-up

of the industry dictates that costs will not simply be passed through to customers; any resulting price increases will not likely rise above commensurate cost increases to trucking firms. Due to the history of environmental regulation in the industry, trucking firms have been more receptive to such policy initiatives and have more support networks in place to implement AB32's provisions than industries unaccustomed to regulation.

The trucking industry has many strategies relating to all its inputs to facilitate compliance with AB32. The network characteristics of the industry make regional collaborations with California's neighboring economies ideal. In particular, West Coast collaborations to standardized biofuel blending with diesel fuel would minimize emission leakage. Additional collaboration with industry groups, such as the California Trucking Association, and industry leaders would help facilitate implementation of AB32 measures.

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