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Rethinking Auto Fuel Economy Policy

Technical and Policy Suggestions for the 2016-17 Midterm Reviews

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EXECUTIVE SUMMARY

In 2012 the federal government issued regulations that require automakers to meet progressively more stringent fuel economy and greenhouse gas standards (GHG) for the 2017-2025 period. Separately, the State of California and nine other states have required automakers, during the same time period, to sell an increasing percentage of zero-emission vehicles (ZEVs).

Both the federal government and the State of California recognize that these regulatory requirements could have a significant impact not only on the environment but also on the economy as a whole. Thus, midterm reviews of the regulatory requirements will be undertaken by both the State of California (2016-2017) and the federal government (2017-2018), with an emphasis on meeting the requirements for the 2022-2025 period.

This preliminary report offers technical suggestions and policy options for consideration during the midterm reviews. The primary focus of the report is the potential macroeconomic impact of the regulatory requirements as mediated through impacts on the rate of sales of new passenger vehicles.

Public comments on this preliminary report are encouraged. A final report is planned for January 2017. In addition to revisions to this preliminary report, the final report will include quantitative modeling of the impact of the regulatory requirements on new vehicle sales, employment, and other macroeconomic indicators.

The eight findings of the preliminary report are summarized below.

1. There has been a significant decrease in fuel prices since the federal and ZEV rules were developed (from 2009 to 2012). Official government projections of fuel prices have been revised downward and remain relatively low through 2030. Regulations should be reevaluated during midterm reviews with consideration given to these lower fuel price projections, emphasizing revised consumer payback periods and impacts on new vehicle sales.
2. The midterm reviews, when they estimate impacts on new vehicle sales, should consider recent evidence concerning how consumers weigh fuel saving benefits against the higher price of a fuel efficient vehicle or a ZEV. A sensitivity-analysis approach to vehicle-sales impacts is reasonable insofar as there are uncertainties about how consumers will react to fuel efficient and zero-emission vehicles.
3. Regulatory analysts should develop a realistic baseline fleet of passenger vehicles when reanalyzing the model year 2017-2025 standards.
4. The midterm reviews should incorporate authoritative, up-to-date technical information on fuel saving technologies, including alternative fuel vehicles.
5. Methodological improvements are possible for new regulatory analyses in order to provide a more accurate and complete understanding of the macroeconomic effects of the federal and ZEV regulatory programs.
6. The midterm reviews should carefully evaluate the benefits and drawbacks of the California ZEV regulation as it interacts with the federal regulations. If the ZEV regulation is retained following this reassessment, refinements to its design and implementation should be considered in order to reduce or prevent adverse effects on new vehicle sales.
7. The midterm reviews should reanalyze the federal regulatory programs, seeking reforms that achieve energy security and environmental objectives with less risk of adverse effects on new vehicle sales.
8. The federal and California regulations may pose less of a threat to new vehicle sales if they are accompanied by complementary policies at the federal, state, and local levels of government that stimulate consumer interest in fuel efficient and zero-emission vehicles. The midterm reviews should pinpoint the most cost-effective complementary policies.

PURPOSE AND SCOPE

The federal Corporate Average Fuel Economy (CAFE) standards, combined with the more recent greenhouse-gas (GHG) standards, are the primary mechanisms through which the U.S. federal government regulates GHG emissions from the transportation sector. Beyond emissions reduction objectives, the standards are also intended to improve the nation's energy security and enhance the welfare of consumers (Consumer Federation of America, 2015).

The CAFE standard for passenger vehicles is on schedule to reach an average of 41 miles per gallon by model year 2021, as established by the National Highway Traffic and Safety Administration (NHTSA) in collaboration with the Environmental Protection Agency (EPA). The EPA also set a schedule for reducing GHG emissions from model years 2017 to 2025, culminating in a standard that is equivalent to approximately 54.5 miles per gallon in 2025.

The figure of 54.5 miles per gallon is a compliance value based on laboratory testing of vehicles. Real-world fuel economy is typically 20% smaller than the federal compliance value, so the 2025 compliance value corresponds to approximately 43 miles per gallon in typical driving conditions (Bond & Bunkley, 2013). Regulators in both Europe and the U.S. are looking into compliance reforms that would emphasize real-world fuel economy.

Separately, California decided in 2012 to substantially increase the mandate for zero-emissions vehicles (ZEVs), such as plug-in electric vehicles and hydrogen fuel-cell vehicles. By 2025, the ZEV regulation will compel the industry to sell enough ZEVs to reach approximately 15.4% of California's new passenger-vehicle fleet. Nine other states, including New York, have also adopted California's ZEV regulation.

The state of California and the federal government recognize that the 2017-2025 standards could have a significant impact on the economy as well as the environment. Consequently, the State of California has indicated that it intends to review the ZEV program in 2016-17 (California Air Resources Board [CARB], 2015). EPA and NHTSA plan to conduct a joint midterm evaluation of the federal standards—with the participation of California—and release a Technical Assessment Report by early 2018 (EPA, 2012). The report will focus specifically on the 2022 through 2025 standards. The Technical Assessment Report may cover, among other topics, technology costs and production, consumer behavior, and the role of alternative fuel vehicles. EPA and NHTSA also plan to publish a Draft Technical Assessment Report in mid-2016.

In this report, we do not provide a comprehensive analysis of midterm review issues (for a discussion of additional issues not covered in this report, see Krupnick, Linn, & McConnell, 2014). Instead, we focus primarily on the potential impact of the regulations on new vehicle sales, including consideration of complementary policies that might prevent or dampen any adverse impacts on new vehicle sales. Although impacts on new vehicle sales are not the only impact that regulators should consider, they are of particular importance in the midterm reviews for several reasons.

First, it is important to consider any adverse impacts on new vehicle sales because the automotive industry plays a central role in the health of the U.S. economy (Hilsenrath & Spector, 2015; Prusa, 2015; Motor and Equipment Manufacturers Association [MEMA], 2013; Center for Automotive Research [CAR], 2011). Based on data from the Bureau of Economic Analysis (BEA), motor vehicle manufacturing accounted for 9.6% of the gross output of the entire manufacturing sector in 2014 (with an average contribution of 10.2% over the 1997-2014 period). In addition, motor vehicle manufacturing and motor vehicle retail trade together contributed 2.7% of U.S. GDP in 2014 (with an average contribution of 3.1% over the 1997-2014 period; BEA, 2016). This first rationale is macroeconomic in nature, as the resurgence of the U.S. automotive sector played a significant role in the recovery of the U.S. economy from the Great Recession of 2007-2009 (Goolsbee & Krueger, 2015). The regional economic impacts of changes in vehicle sales will also be salient to policy makers, as the South and Midwest are more dependent on the auto sector than the West and East Coasts. The distributional impacts of vehicle sales may also influence the political sustainability of the federal programs, as the history of CAFE reveals that the program has vulnerabilities that are rooted in political conflicts—conflicts that are at least as much regional in nature as they are partisan or ideological (Luger, 2005; Graham, 2010).

Second, any regulatory impact on new vehicle sales is relevant to an appropriate societal cost-benefit analysis of the regulations, since consumer welfare is impacted. Cost-benefit analysis of the 2022-2025 CAFE rulemaking is required by presidential executive order. This second rationale is microeconomic in nature, insofar as consumers care about the attributes of their passenger vehicles. In 2011-2012 neither California nor the federal government found evidence that the regulations would exert a significant impact on new vehicle sales, and therefore did not perceive a need to address this issue in societal cost-benefit analyses at the time (CARB, 2011b; EPA, 2012; Department of Transportation [DOT], 2012).

Third, the rate of new vehicle sales affects achievement of the regulatory objectives, since the rate of new vehicle sales influences the pace of retirement of old vehicles from the fleet. Older vehicles exert a disproportionate influence on national gasoline consumption and GHG emissions because old vehicles tend to be much less fuel efficient than new vehicles. Old vehicles also emit a disproportionate share of local pollutants related to smog and soot, in part because the emissions controls (for local pollutants) tend to work less effectively as a vehicle ages (Drake, 1995; Gruenspecht, 2001; DOT, 2009).

Finally, delayed retirement of old vehicles is also linked to adverse safety outcomes for motorists. The designs of new vehicles today provide much better occupant crash protection than new vehicles designed in the 1990s (Insurance Institute for Highway Safety [IIHS], 2015a; DOT, 2009). Thus, a slower rate of new vehicle sales will hamper progress in automobile safety.

With our focus on new vehicle sales in mind, this report provides a series of recommendations for consideration in the midterm review processes. The recommendations fall into three categories: technical suggestions for regulatory analysts, regulatory reforms for consideration by federal and state regulators, and legislative policy options. The consequences of the recommendations in this report generally observes these three categories.

In preparing the report, we have: (1) reviewed the regulatory impact analyses (RIAs) and related technical documents underpinning the federal and California requirements; (2) reviewed academic and other literatures that assess the impact of CAFE and ZEV on new vehicle sales, or are relevant to such an assessment; (3) reviewed key trends in the industry, especially factors that have changed since 2009-2012 when the regulations in question were developed and finalized; (4) assessed related federal, state, and local policies that might be modified to complement the federal and California requirements; and (5) considered reforms of the federal and California requirements that are worthy of more in-depth analysis in the midterm review. We have also incorporated feedback offered by an independent Peer Review Advisory Panel comprising experts in energy, the environment, transportation, macroeconomic and microeconomic modeling, and the structure and operations of the global automotive industry.

This report is the first phase of research conducted by a team of analysts at Indiana University. Between January 2016 and January 2017, the research team will complete a second phase of research, in which we will model the impact of the federal and California requirements on new vehicle sales, employment, and related macroeconomic indicators. Our phase two report will draw from the foundations provided in the present document, public comments on this report, and continued feedback provided by our Peer Review Advisory Panel.

This report begins with an overview of the federal and ZEV standards, with information on the political history of these regulations. It then describes the structure of the industry and its importance to the U.S. economy and the recovery from the Great Recession of 2007-2009. We then review regulatory compliance procedures and previous industrial impact studies, particularly those studies that investigate macroeconomic variables such as new vehicle sales and employment. Finally, we present our specific recommendations to enrich the midterm evaluations of the California and federal standards.

PUBLIC POLICY CONTEXT

History of CAFE

The Arab oil embargo of 1973-74 led to a quadrupling of world oil prices, rapidly rising gasoline prices, and fuel shortages that caused long lines at refueling stations in the U.S. The Congress and President Gerald Ford responded with new legislation aimed at reducing America's dependence on petroleum. Enacted in 1975, the Energy Policy and Conservation Act (EPCA) authorized the U.S. DOT, through the NHTSA, to set minimum miles-per-gallon (mileage) performance standards for all new cars and light trucks sold in the U.S.

The legislation, followed by NHTSA rulemakings, contributed to a doubling of average car mileage from 13 miles per gallon (MPG) in model year 1974 to 27.5 MPG in model year 1985. Market responses to higher gasoline prices contributed to the average mileage gains from 1974 to 1985, but the stricter CAFE standards also played a significant role (Greene, 1990; Greene, 1997; Nivola & Crandall, 1995). Savings in petroleum use were significant but less than projected because sales of light trucks grew more rapidly than sales of cars during this decade (National Research Council [NRC], 2002). The federal mileage requirements for light trucks were more permissive, starting at 17.2 MPG in 1979 and rising to 19.5 MPG in 1985. Moreover, entire segments of the light-truck fleet (e.g., pickup trucks and large sport-utility vehicles) were exempt from federal mileage standards (NRC, 2002).

Market conditions changed in the late 1980s. In the face of declining fuel prices and financial concerns expressed by GM and Ford, the CAFE standards were relaxed in 1986 for cars and in 1990 for light trucks. GM and Ford apparently had product plans that would have achieved compliance with CAFE standards, but consumers, spurred by low fuel prices, demanded a disproportionate number of vehicles with low fuel economy (Luger, 2005, p. 130).

Efforts to legislate stricter CAFE standards gained momentum in 1990-1992 due to a new environmental concern: global warming from the GHGs emitted by motor vehicles (Lugar, 2005, p. 163). However, opponents of CAFE standards blocked stricter legislation in the Senate using the filibuster threat.

When President Clinton took office in January 1993, the CAFE standards for model year 1993 were virtually unchanged from 1985. While President Clinton and Vice President Al Gore had pledged tighter CAFE standards during their campaign, a bipartisan coalition in Congress preempted the administration with a series of appropriations riders that barred increases in CAFE standards. The CAFE "freeze" started in model year 1996 and persisted throughout the Clinton administration.

The politics of CAFE changed during the George W. Bush administration, in part due to a rapid rise in average retail gasoline prices from approximately \$1.50 per gallon in 2000 to more than \$3.00 per gallon in 2008 (Graham, 2010). The Bush administration decided to both tighten CAFE standards and, in response to suggestions from an independent study, reform the program to reduce safety risks (NRC, 2002). In order to discourage unsafe downsizing of vehicles but reward substitution of lightweight materials, the CAFE standard for each manufacturer was adjusted based on the size distribution of its products (German & Lutsey, 2010). Small vehicles were subject to stricter standards than large vehicles.

When Congress agreed to lift the CAFE freeze in 2002, NHTSA responded by raising light-truck CAFE standards from 20.7 MPG in model year 2005 to 22.2 MPG in 2007. NHTSA followed with a key reform of the light-truck program that adjusted each automaker's CAFE requirement according to the size distribution of its products. For model years 2008 to 2011, NHTSA tightened the light-truck standards based on footprint (the area between the four wheels) to achieve an industry-wide average of approximately 24 MPG (Graham, 2010).

When the Democrats secured a majority in Congress in January 2007, they worked with the Bush administration on a major reform of the CAFE law included in the Energy Independence and Security Act (EISA) of 2007. Support for the legislation was widespread in both parties. Many Democrats saw a strong environmental rationale—global warming—while many Republicans shared Bush's concerns about energy security. EISA (a) applied the footprint adjustment to cars as well as trucks, and (b) established a minimum performance standard of 35 MPG by 2020 for both cars and light trucks. Higher standards were authorized for model years 2021 and beyond, with the specifics to be determined by technical analyses performed by NHTSA and EPA (Graham, 2010).

Drawing on the authority given in EISA, the Obama administration tightened CAFE standards through rulemakings. A 2012 final rule sets footprint-based standards that are expected to achieve an average of 41 MPG by model year 2021 (cars and light trucks combined), and a goal of 54.5 MPG by model year 2025. The final CAFE standards for model years 2022 to 2025 will be set by a future NHTSA rulemaking, after the scheduled 2017-18 midterm review of the federal program.

California's GHG Standards for Motor Vehicles

During the Clinton and George W. Bush administrations, environmentalists and their allies in the California legislature became increasingly disenchanted with the federal government's handling of the CAFE program. Despite objections from the auto manufacturing industry and dealers, the California legislature passed in 2002 a new law, AB 1493, that placed limits on GHGs from new motor vehicles sold in California. The law calls for CARB to accomplish a sustained reduction in GHGs that is roughly equivalent to a 36 MPG CAFE requirement in model year 2016. Other states began to join the California program, as concerns about global warming were increasing.

A legal battle ensued as to whether California possessed the authority to impose its own GHG standards (Graham, 2010). Industry and the Bush administration argued that EPCA preempts any state regulation of motor vehicles related to fuel economy. California and environmentalists argued that the 1990 amendments to the Clean Air Act provide California with the power to set stricter auto emissions standards than the federal government. EPA under the Bush administration denied California the required waiver under the Clean Air Act, but a federal court ruled in 2007 that California does possess the authority under the Clean Air Act to set its own emissions standards for motor vehicles.

When the Obama administration fashioned its policies from 2009-2012, the State of California was included as a key stakeholder in the discussions with industry, labor, environmentalists, and consumer groups. The Obama administration decided to enact highly stringent CAFE standards, similar to what California had enacted for 2016 and was considering for 2017-2025. The State of California agreed to allow automakers to treat compliance with the new federal standards as compliance with the California GHG standards.

As a result of the negotiations, the seemingly complex combination of the California GHG standards, the EPA GHG standards, and the NHTSA CAFE standards began to seem like a uniform national program because the compliance obligations for vehicle manufacturers were coordinated and measured only on a national basis. Thus, at the present time, the California GHG standards do not impose any regulatory burdens on the auto industry that go beyond the federal requirements.

Federal GHG Standards for Motor Vehicles

The U.S. Supreme Court determined in 2007 that the EPA possesses the authority under the Clean Air Act to regulate GHG emissions from motor vehicles. Drawing on this authority, EPA made an endangerment finding in 2009 that the GHG emissions from mobile sources are a threat to public health and the environment. In response to a 2009 instruction from President Obama, EPA, in consultation with NHTSA, created an entirely new performance standard governing GHG emitted by new cars and light trucks. The new standards, which have been finalized through model year 2025, are essentially equivalent to NHTSA's CAFE standards except that the slightly stricter EPA performance standards also allow automakers to earn compliance credits by modifying air conditioners to reduce GHGs. The federal government has taken the position that the EPA and NHTSA programs have been harmonized as much as possible, given the existing legislative authority for the two programs.

California's ZEV Program

The State of California has played an influential and innovative role in car-emissions control for decades (Carley, Betts, & Graham, 2011). In the 1990s CARB created a ZEV program that requires each vehicle manufacturer doing business in California to sell a specified percentage of ZEVs to consumers. Although originally seen as a program to help Los Angeles and other areas address unhealthy levels of airborne smog, today the ZEV program is also considered a tool to reduce the GHG emissions linked to global warming (CARB, 2011a; CARB, 2011b; Graham, Cisney, Carley, & Rupp, 2014). The ZEV requirement was initially defined as 2% of new vehicle sales in 1998, ramping up to 5% in 2001 and 10% in 2003.

Due to technical, legal, and economic setbacks, the ZEV requirements were delayed and amended by CARB several times over the last 20 years. In their current form, as finalized in 2012, the ZEV requirements mandate approximately 15.4% of ZEVs in each automaker's fleet by 2025. Now that another nine states have decided to replicate California's ZEV requirements, it appears that approximately 30% of national vehicles sales will be covered by a ZEV program. Thus, assuming a national sales rate of 17 million vehicles per year, a 15.4% requirement in 30% of the market translates into 785,400 ZEVs in model year 2025 (for a similar calculation, see NRC, 2015b). By way of comparison, just over 114,000 new plug-in vehicles were sold nationwide in 2015 (Electric Drive Transportation Association [EDTA], 2015). Thus, there is no question that the ZEV requirements for 2018-2025 will compel vehicle manufacturers to make significant investments in ZEVs.

In this report, the term *plug-in electric vehicle* (PEV) is used to describe any vehicle that draws electricity from the electrical grid. A *battery-electric vehicle* (BEV) is a PEV that relies entirely on electricity for propulsion power (e.g., the Nissan Leaf). A *plug-in hybrid electric vehicle* (PHEV) is a PEV that draws power from both a gasoline engine and a battery pack (e.g., the Toyota Prius Plug-In). A *fuel cell vehicle* (FCV) is powered by a hydrogen fuel cell (e.g., the Hyundai Tucson SUV). PEVs and FCVs are considered the most likely propulsion systems to be used by automakers to achieve compliance with the ZEV regulation. A conventional *hybrid electric vehicle* (HEV), such as the well-known Toyota Prius, operates on both gasoline and battery power but does not have the plug-in feature.

Regulatory Systems Worldwide

The U.S. is not the only country to enact fuel economy standards or GHG standards for new vehicles. There are now nine governmental bodies around world that have enacted or proposed such standards: the U.S., Brazil, Canada, China, the European Union (EU), India, Japan, Mexico, and South Korea. The automobile production in these jurisdictions accounts for 80% of the global vehicle market (The International Council on Clean Transportation [ICCT], 2014). The regulatory programs around the world vary in structure, stringency, flexibility, drive cycle, and vehicle certification test procedures. At the present time, no other jurisdiction in the world has a regulatory program similar to the California ZEV mandate.

Comparing the fuel economy requirements in different countries is no small task. The U.S. measures fuel economy using a weighted average of testing procedures for city and highway driving conditions. The EU and China use the New European Driving Cycle (NEDC) to measure fuel economy, which similarly considers the differences in urban and extra-urban driving. Japan uses the JC08, which takes a weighted average of a cold start measurement and a hot start measurement. The United Nations Working Party on Pollution and Energy group is developing a worldwide standard—the Worldwide Harmonized Light-duty Test Cycle (WLTC)—which is intended to replace the NEDC and potentially other approaches. These fuel economy test cycles differ in several ways, including starting conditions, duration, distance, mean and maximum velocity, stop phases, and acceleration (Kühlwein, German, & Bandivadekar, 2014).

The ICCT developed a series of conversion factors that allow for the comparison of fuel economy standards among these countries. Table 1 shows a comparison of the fuel economy requirements for the U.S., the EU, Japan, and China, using the ICCT's conversions to keep all comparisons consistent with the CAFE-MPG approach. Although

Table 1. Fuel Economy Standards for Light-Duty Vehicles (MPG), Selected Countries

	US	EU	Japan	China
2017	35.4			
2018	36.5			
2019	37.7			
2020	38.9		45.9	47.7
2021	41.0	56.9		
2022	43.0			
2023	45.1			
2024	47.4			
2025	49.7	72.5-82.3*		

*This standard is being studied but has not been adopted.

Source: ICCT http://www.theicct.org/sites/default/files/info-tools/pvstds/Global_PV_data_20150803.xlsx

the U.S. standard appears to be more lenient than the European, Japanese, and Chinese standards, the U.S. auto market, as we explain below, has fewer small cars and more light trucks than the EU, Japan, and China.

All large-volume automakers sell vehicles in multiple countries, yet they are looking to make as many vehicles as possible from a single global platform. Thus, it can be expected that during product planning and production-volume decisions, automakers will consider their compliance obligations in multiple countries and regions. On the other hand, the U.S. vehicle market is so large that global automakers can afford to tailor some product offerings specifically to the U.S. market. As the industry globalizes, it is reasonable to expect that regulators will come under increasing pressure for harmonization or mutual recognition of regulatory requirements.

The New Green-Jobs Rationale for Regulatory Requirements

When they were first adopted, all four U.S. regulatory programs were promoted on either environmental or energy security grounds. In recent years, however, advocates of the four programs have begun to espouse some economic development objectives in support of the regulatory requirements. Advocates argue that new investments in green automotive technologies will create jobs and spur the economy to higher levels of production and prosperity (Oge, 2015).

The State of California currently has few facilities that produce auto parts or assemble vehicles for sale (CARB, 2011b, p. 68-9). However, California investors and start-ups (e.g., Tesla) are playing a pivotal role in the push for electrification of the transport sector. Silicon Valley is seen as a potential source of innovation in vehicle offerings that could couple ZEVs with driverless technology (Ramsey, 2016). CARB Chairman Mary Nichols, when issuing the 2012 ZEV requirements, was explicit about the economic-development rationale: “The Board’s Action will create thousands of jobs, transforming California into the advanced car capital of the world. California is now in the pole position in the race to provide next-generation ultra-clean cars to the global market” (CARB, 2012a).

At the national level, the Obama administration also portrayed the new NHTSA and EPA regulations as a strategy to help revive the domestic auto industry by stimulating companies to offer the fuel efficient cars that consumers have wanted and that will be demanded in Asia and Europe in the future (White House, 2012). The administration has also provided grants and federal loan guarantees (e.g., for domestic companies that make lithium ion batteries for PEVs or HEVs) to facilitate a more rapid transition to a greener automotive economy. In the regulatory impact analyses published in support of federal requirements, claims are made that new jobs will be created in the green-technology industry. California's regulatory impact analysis in support of the ZEV program makes a similar claim, noting that some of the leading companies that sell recharging stations for PEVs are based in California (CARB, 2011, p. 68-9).

Thus, it is no longer appropriate to view the federal and California regulatory programs strictly through the lens of energy security and environmental protection. An objective of advancing economic development has also motivated these four programs.

THE U.S. AUTOMOTIVE INDUSTRY

In this section, we examine the role of the automotive sector in the U.S. economy. We begin with the perspective of the new-car consumer, describe the structure of the industry and the major product categories, explore the extent of the supply chain and how it is changing, pinpoint how the revival of the U.S. auto sector was a central feature of the U.S. economic recovery since 2009, and consider recent sales forecasts for the U.S. market.

Consumer Perspective

An auto manufacturer's ability to meet federal requirements and ZEV standards is contingent upon consumers purchasing its vehicles. Therefore, it is not enough for manufacturers to design and produce highly fuel efficient and zero-emission vehicles; consumers must also prefer these vehicles to less fuel efficient, more powerful models, which can be either used or new.

A small percentage of early adopters care deeply about fuel efficiency and environmental protection, but most mainstream consumers care more about other vehicle attributes (Helveston et al., 2015; NRC, 2015a; NRC, 2015b). One recent survey found that consumers rate reliability, durability, quality of workmanship, value for the money, and manufacturer's reputation as most important in their decision to purchase a vehicle. Fuel economy was listed as the 11th most valued feature—behind such features as seating comfort—even with gasoline prices at $4.02 per gallon at the time of survey distribution. The same survey revealed that a mere 5% of respondents who purchased vehicles were willing to pay a premium for environmentally friendly features. Further, those who considered but decided against purchasing a PEV expressed uncertainty with regard to their confidence in these vehicles' reliability and durability (Strategic Vision, 2013; NRC, 2015a). In addition, Egbue and Long (2012) found that their sample of potential early adopters of PEVs ranked the environmental attributes of these vehicles behind their cost and performance.

Some residents of urban centers can access alternatives to owning a passenger vehicle (e.g., carpooling, biking, walking, or taking public transportation) but such alternatives are actually losing market share to the private automobile. More than three-quarters of U.S. workers drove to work without anyone else in the vehicle in 2012, up from 64% in 1980. The amount of carpooling has declined by 50% over the same period. The number of trips supplied by public transit systems has declined from 6% in 1980 to 5% in 2012. The number of employees working at home is growing rapidly, but that trend does not necessarily curtail interest in vehicle ownership (Tavernise & Gebeloff, 2011; Shah, 2013).

Switching to a fuel other than gasoline is appealing to many consumers, but there are several barriers to the deployment of any alternative fuel vehicle (AFV). Consumers are wary of new, unproven technologies; in the face of risk and uncertainty, they will often turn to more familiar choices (Egbue & Long, 2012; NRC, 2015a; NRC, 2015b; Siddiki, Dumortier, Curley, Carley, & Krause, 2015). Fuel infrastructure is undeveloped in much of the country for electricity, hydrogen, compressed natural gas, and even diesel in some areas. The costs of AFVs are typically higher than that of conventional vehicles. Although consumers might see net savings over many years during times of high gasoline prices, current prices are too low to generate large benefits (Frades, Nigro, & Frazeli, 2015). As more AFVs are sold, more fueling stations are added, and as gasoline prices rise, demand for these vehicles should rise accordingly. However, consumer demand may not rise quickly enough to allow manufacturers to meet the federal and ZEV standards set for 2022-2025.

NRC (2015b) identified barriers specific to the adoption of PEVs. These include "limited variety and availability of PEVs; misunderstandings concerning range of PEVs; difficulties in understanding electricity consumption; calculating fuel costs, and determining charging infrastructure needs; complexities of installing home charging; difficulties in determining the 'greenness' of the vehicle; lack of information on incentives; and lack of knowledge of unique PEV benefits." Many other studies confirm these findings (e.g., Carley, Krause, Lane, & Graham, 2013; Krause, Carley, Lane, & Graham, 2013).

The real or anticipated travel behavior of the consumer can serve as a primary reason for a consumer's decision not to purchase a BEV. The average household takes approximately three trips and drives approximately 30 miles per vehicle per day, resulting in an average trip length of just under ten miles (FHWA, 2011). These trips consist of about 71% of all trips and 25% of all vehicle miles traveled.

These averages do not capture the different uses of the vehicle over its lifespan, however. For instance, although long trips (of more than 100 miles) represent less than 1% of total trips taken (and 16% of vehicle miles traveled), a consumer's desire to have the freedom to take these trips may dissuade them from purchasing limited-range BEVs (NRC, 2015b). This concern is especially weighty if a consumer anticipates that he or she will take several trips of this length each year.

While long-distance trips may present a barrier to BEV adoption, they may not be an issue for consumers with multiple vehicles or other options for long-distance travel. Additionally, the PHEV, with its ample driving range, may be more appealing than a BEV to the many buyers who seek a vehicle that can accomplish both long and short trips without refueling (Graham et al., 2014).

Helveston, et al. (2015) find that older, wealthier, and more educated consumers—especially those who own multiple vehicles and have children in the household—are less sensitive to upfront and operating costs. Higher income consumers are also less interested in HEVs or PEVs. Consumers with lower incomes demonstrate more receptivity toward PEVs but, since PEVs tend to be expensive, lower-income households typically cannot afford them. Therefore, current purchasers of PEVs are on average more educated and have substantially greater incomes than purchasers of conventional vehicles (NRC, 2015b).

Generational differences also have important implications for new vehicle sales. Auto dealers will be targeting the next generation of consumers (Gen Y) to replace lost sales from the aging Baby Boomers, implying that the preferences of Gen Y will influence the market. Similar to previous generations, Gen Y consumers list low cost, convenience, utility, and a love for driving as their top four reasons for owning a vehicle; eco-friendliness ranks sixth in a list of seven reasons, ahead only of luxury (i.e., owning a car as a symbol of wealth; Bruce et al., 2014).

Some segments of Gen Y seem to be trending away from owning a vehicle. Instead, evidence suggests they are more interested in living in urban settings and relying on alternative modes of transportation, including public transit, biking, and walking. Perhaps more importantly, the success of car-sharing services such as Uber, which are familiar to Gen Y, could transform the demand for vehicles (Litman, 2015; Gardner, 2016).

In accordance with these findings, the states with the strongest PEV markets are those with high environmental consciousness, incentives in place for purchasing and owning these vehicles, and mandates for cutting carbon emissions (NRC, 2015b). Nonetheless, consumers have been shown to be largely unaware of the financial incentives available to them. Krause et al. (2013) surveyed adult drivers in 21 large U.S. cities and found that 75% of respondents underestimated the value and advantages of PEVs, and 94.5% of respondents had no knowledge of state and local incentives for the purchase and use of these vehicles. On the other hand, Krause et al. (2013) found that consumers underestimate the price of a PEV. Many consumers may not fully value PEVs unless they are provided information on the monthly total cost of ownership of these vehicles, compared to an otherwise similar gasoline vehicle; current vehicle labels, however, do not provide this level of detail to potential car buyers (Dumortier et al., 2015).

Improved education about these incentives, and the potential application of other PEV incentives used around the world (Lane et al., 2013), could drive the market for these vehicles forward, but it is not clear which public organizations have the responsibility and resources to undertake such a large-scale public education effort. CARB, EPA, and NHTSA are primarily regulatory bodies, with limited track records in public education. The Department of Energy (DOE) has strong technical programs but much less experience in the social science aspects of promoting alternative fuel vehicles. A priority for the midterm reviews should be a resolution of the responsibility for public education in this field.

Despite all of these barriers, PEVs have been experiencing relatively rapid commercialization—a more rapid rate of growth than that seen when HEVs were first introduced. Specifically, sales of PEVs in the U.S. grew at more than twice the rate of that of HEVs when comparing their first 34 months of sales (Graham et al., 2014). Government subsidies and tax credits, coupled with relatively high gasoline prices, may have contributed to much of this early growth in sales of PEVs, however. Whether those conditions will be sustained for the next decade seems increasingly uncertain.

Structure of the U.S. Industry

The new passenger vehicle market in the United States is dominated by high-volume producers that sell globally: Toyota, Volkswagen, General Motors, Hyundai/Kia, Nissan-Renault, Ford, Fiat Chrysler, Honda, Suzuki, BMW, Daimler, Mazda, and Mitsubishi. Although the Big Three (Ford, GM, and Chrysler) were once the dominant three producers, they have been gradually losing market share for decades and were downsized during the financial crisis of 2007-9 (Goolsbee & Krueger, 2015). Today, the U.S. auto industry, defined here as companies selling vehicles in the U.S. (including their supply chains and dealers), is highly competitive with strong Japanese, Korean, and German manufacturers competing against each other and against the Big Three (CAR, 2015).

Several start-up producers of PEVs (e.g., Tesla, Atieva, Fisker Automotive, NextEV, Youxia, and Faraday Future) are beginning to introduce even more competition to the industry (Ramsey, 2015). Some of the recent start-ups have backing from Chinese companies and investors, reflecting the growing Chinese interest in electrification (Lane et al., 2013; Millward, 2015). The startups are part of a loose network of venture capitalists, suppliers of batteries and chargers, electric utilities, and environmental advocacy groups with a common goal: electrification of the transportation sector. Major companies in Silicon Valley have also indicated an interest in offering new automotive components or entirely electric, driverless vehicles with the latest information technology (Gibbs, 2014; Boston, 2015). Many of the key companies and investors in the electrification network are based in California.

The electric vehicle could be considered a “disruptive technology,” because it threatens to unseat the dominant technology of the internal combustion engine. Some disruptive technologies succeed; many others fail. Electric vehicles actually outsold gasoline vehicles in the 1920s, but innovation in the internal combustion engine, including low-cost mass production, caused the electric vehicle to lose out. A disruptive technology does not typically catch on until quality in mass production is established and widely recognized. Sometimes disruptive technologies remain a fringe offering for a long time; in other cases their pace of commercialization is astonishingly rapid (Christensen, Raynor, & McDonald, 2015).

Public subsidies and federal loan guarantees have played an important role in the recent resurgence of the Big Three, in the emergence of Tesla, and in Nissan-Renault’s leading position on BEVs (Dolan & Murphy, 2009). GM and Chrysler (including their financing arms and suppliers) emerged from structured bankruptcy proceedings in 2009 with financial backing from the U.S. Department of the Treasury (Goolsbee & Krueger, 2015). In 2009-10 Ford Motor Company and Tesla received large federal loan guarantees from the DOE to develop and offer greener automotive technologies. Nissan also received a large DOE loan guarantee to build new facilities in Smyrna, Tennessee to make lithium-ion batteries and assemble BEVs.

The California ZEV program was structured in a way that boosted the commercial fortunes of start-up EV makers. For example, Tesla, as a maker of BEVs, can sell ZEV compliance credits to large-volume vehicle manufacturers, such as Honda and Daimler, who have difficulty meeting their ZEV requirements (Webb, 2010). In 2013, each Model S that Tesla sold generated seven ZEV credits. With the average credit selling for $5,000, Tesla was earning $35,000 in extra revenue for each Model S sold (Knittel, 2014). In recent years, sales of ZEV credits have attenuated the annual financial losses reported by Tesla. In 2014 alone, Tesla was the largest seller of ZEV credits, earning $152 million or about 5% of the company’s total 2014 revenue (Edelstein, 2015b).

Previous studies have found that the adverse financial impacts of stricter CAFE standards do not affect all high-volume producers equally. Historically, a disproportionate burden has been felt by the Big Three, though this conclusion may not fully reflect the impact of the relatively new footprint-based structure of the CAFE and GHG standards (Sallee, 2011; Jacobsen, 2013).

The midterm reviews should recognize that regulatory requirements can have significant impacts on the structure of an industry. Special effort should be devoted to the design of regulatory requirements that achieve broad national goals while carefully considering the impacts those requirements will have on companies in the affected industries.

The U.S. Vehicle Market: Key Product Categories

Products in the U.S. industry are typically divided into two broad categories: cars and light trucks (cross-over vehicles, sport-utility vehicles, pickup trucks, and minivans). The distinction between a car and light truck is not always clear and the definitions are not always consistent; indeed, EPA defines some crossovers as cars for regulatory purposes (EPA, 2015). A crossover vehicle is not defined by size or mass, but typically has the ride height that many American consumers have come to enjoy (NRC, 2015a). The federal regulatory definition of a light truck—and the more permissive CAFE standards for trucks—has played a pivotal role in the evolution of the industry (Sallee, 2011).

In order to remain globally competitive, high-volume producers have gravitated to single platforms where multiple vehicles (cars and light trucks) can be produced for different regions of the world. However, the platforms must be flexible enough to tailor characteristics of the vehicles to consumer preferences in different regions. Thus, it is useful to consider some of the special features of the U.S. auto market that make it different from the comparably sized market in Europe and the larger and rapidly expanding market in Asia.

As a starting point, consider the volume and market shares of each vehicle product category in America in 2015, as shown in Table 2.

Perhaps the two most distinctive features of the U.S. passenger vehicle market are the popularity of the pickup truck and, in the last decade, the emergence of the crossover SUV coupled with the decline in interest in the large SUV.

The midterm review should recognize that regulatory requirements were not intended to alter or influence the American consumer's preferences for vehicle characteristics (e.g., number of seating positions, safety, ride height, cargo-carrying capacity, engine performance, towing capability). Accepting consumer preferences as

Table 2. Product Categories by Sales Volume and Market Share, 2015

Product Category	Total Vehicles Sold in America (2015)	Market Share in America (2015)	Example Model
Small/Compact Car	2,999,980	17.26%	Toyota Corolla/Matrix
Midsized Car	2,974,893	17.11%	Toyota Camry
Large Car	315,320	1.81%	Chevrolet Impala
Luxury Car	1,234,528	7.10%	BMW 3-series
Pickup	2,474,669	14.24%	The Ford F-Series
Crossover	5,208,360	29.96%	Honda CR-V
SUV	1,247,387	7.18%	Ford Explorer
Van	927,093	5.33%	Honda Odyssey

Source: (Ward's Auto, 2016a)

given, regulation is intended to deliver those characteristics to the consumer through innovative designs that meet fuel economy and GHG standards.

Workforce, Assembly Plants, and Supply Chains

The U.S. industry has both a unionized and nonunion sector. Organized by the United Auto Workers of America (UAW), the Big Three have business models that depend primarily on sales of light trucks assembled in the U.S. and Canada. About 75% of the passenger vehicles sold by the Big Three are trucks; the comparable figure for Japanese firms is about 50% (Bennett & Stoll, 2015). In recent years, Japanese and other foreign producers, which have few UAW-organized plants, have begun to challenge the Big Three's dominance of the light-truck market. Toyota now builds the Tundra (pickup truck) at a nonunion plant in San Antonio, Texas in order to serve the U.S. consumer market. Domestic producers of light trucks are protected by an internationally-sanctioned tariff on the importation of light trucks, though this tariff is under discussion in the ongoing trade negotiations between the EU and the U.S. (Beene, 2015b; Young, 2015).

Toyota and Honda dominate the passenger-car market, but Hyundai/Kia, Volkswagen, and the Big Three are offering a mix of new and remodeled products that challenge Japanese dominance. Daimler and BMW are major players in the market for upscale sedans and luxury cross-over vehicles, the latter being one of the most rapidly growing and profitable segments in the industry.

From 1950 to 1980, Japanese, Korean, and German automakers assembled their vehicles abroad and exported them to the U.S. for sale (Grossman, 2009). To avoid unfavorable U.S. tariffs and currency valuations and to establish a presence in the U.S., those companies have increasingly located assembly plants in North America (Kurylko, 2013). The first "transplants" were located in Marysville, Ohio (Honda-1982) and Smyrna, Tennessee (Nissan-1983),[1] but the largest plants today (in terms of vehicle production) are located in Montgomery, Alabama (Hyundai-2005), San Antonio, Texas (Toyota-2006), Greenburg, Indiana (Honda-2008), Woodstock, Ontario (Toyota-2008), West Point, Georgia (Kia-2009), Blue Springs, Mississippi (Toyota-2011) and Chattanooga, Tennessee (Volkswagen-2011). Both the Big Three and foreign automakers are also locating an increasing share of their North American production (especially small-car production) in Mexico, often in close proximity to the U.S. border. The transplant share of U.S. auto production has steadily climbed from 22% in 2000 to 31% in 2005 and 46% in 2013; it is projected to exceed 50% by 2017 (Kurylko, 2013; Goolsbee & Krueger, 2015).

In order to appreciate how regulation impacts the industry and its workers, one must look beyond the assembly plants to the supply chains for engines, parts, batteries, and other components (MEMA, 2013). GM, Ford, and Fiat Chrysler share a network of suppliers that is somewhat distinct and often organized by the UAW (Goolsbee & Krueger, 2015). When Ford publicly supported the rescue of GM and Chrysler in 2008-9, they did so because they shared a supplier base with GM and Chrysler. Had Chrysler and GM folded, the future of Ford would have been in question (Graham, 2010).

The Big Three are diversifying their supplier base within North America while also importing more parts from outside the U.S. In model year 2010, 90% of the Ford Escape's content originated in the U.S.; in model year 2015 the domestic content of the Escape was only 55%. The transplants assemble the vehicle in North America but are even more likely to import the parts from overseas. Overall, the importation of auto parts has grown from $31.7 billion in 1990 to $89 billion in 2008 and $138 billion in 2014 (Hagerty & Bennett, 2015).

Despite the widespread importation of auto parts, foreign auto brands contribute significantly to employment in the U.S. (Greimel, 2015). In 2014 the production of Japanese auto brands contributed (directly and indirectly) to 730,000 jobs in the U.S. The dealer network for Japanese brands contributed (directly and indirectly) to an additional 760,000 jobs in the U.S. The total associated employment was approximately 1.5 million. The net

[1] In 1984, GM and Toyota launched a joint automobile manufacturing venture, the New United Motor Manufacturing, Inc., in Fremont, California.

number of new jobs created in 2014 due to Japanese auto brands alone was approximately 157,000 (Prusa, 2015).

Among all automakers, over 7 million U.S. jobs are supported, directly or indirectly, by vehicle manufacturing, suppliers, and dealers. Each auto manufacturing job is linked to roughly seven jobs in other industries throughout the economy (CAR, 2015).

A different way to express the economic importance of the U.S. auto sector is to trace the impact on state and federal tax revenues. Hill, Menk, & Cregger (2015) have done so, and place auto-related state tax revenue at $110 billion in 2013, or about 13% of total state tax revenue. A lower bound on auto-related federal tax revenue is $95.5 billion, or about 3.4% of total federal revenue.

A shift from the internal combustion engine to electric propulsion would have a dramatic impact on supply chains. Lithium-ion battery technology, which is being adapted for automotive applications, is seen as crucial to the near-term promise of electrification (Sandalow, 2009). Although some U.S. suppliers have tried to enter the lithium battery business (often with subsidies and loans from the U.S. government), those efforts have not been highly successful. The battery business is increasingly dominated by large Asian companies (e.g., LG Chem of South Korea and Panasonic of Japan). The three largest-selling PEVs (by sales volume)—the Tesla Model S, the Nissan Leaf, and the Chevrolet Volt—are making use of Asian battery technology.

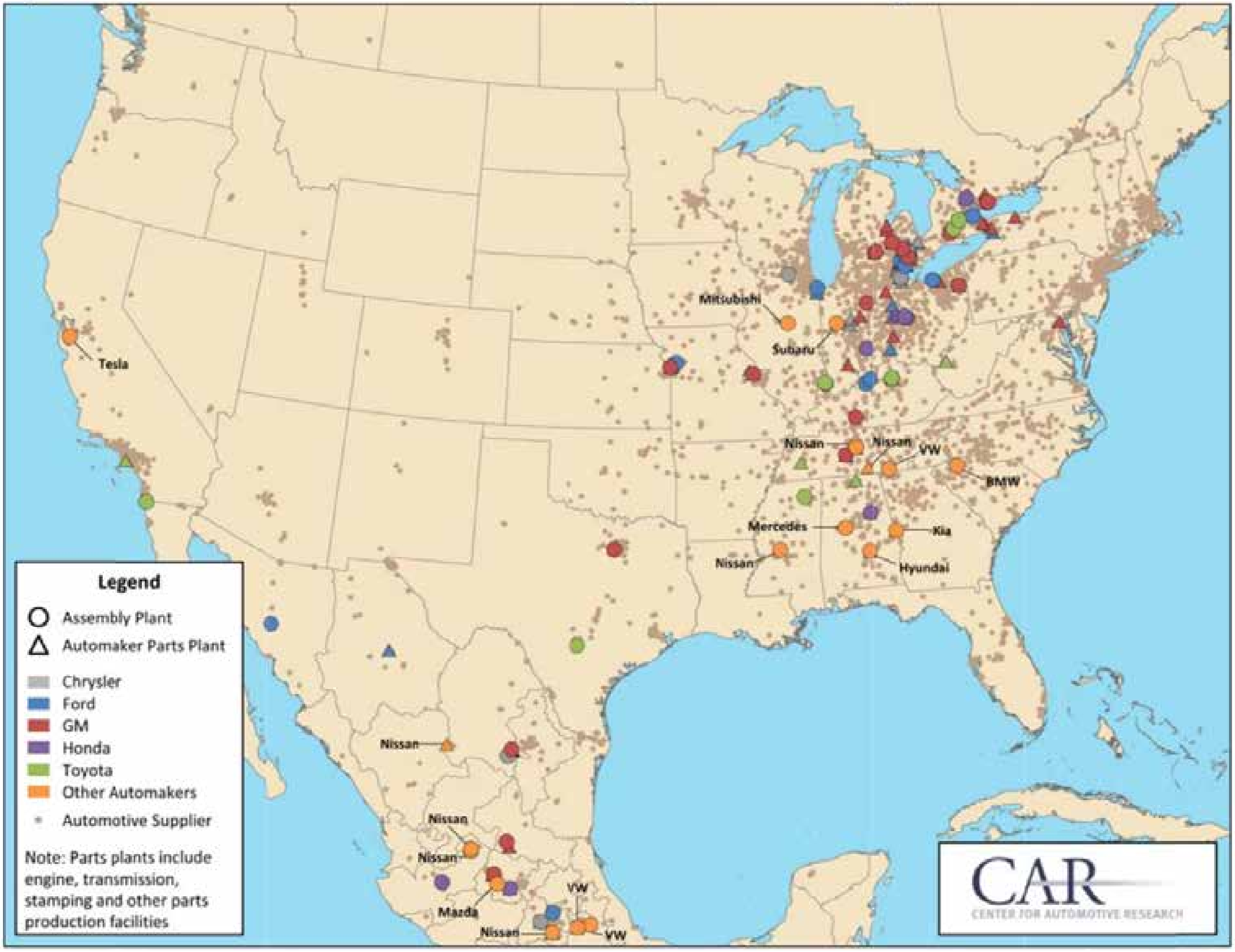
It seems reasonable to expect that, as PEV sales increase in the U.S., the vehicles, batteries, and electric drivetrains will be made in the U.S. Nissan and Tesla are already making batteries in Tennessee and Nevada, respectively. However, the history of the Prius is a cautionary tale in this regard. Toyota has long considered making the popular Prius (and presumably its batteries) in the U.S., but instead continues to import the vehicle into the U.S. from Japan. In 2010 Toyota decided against producing the Prius at its Mississippi plant and to instead build the Corolla there (Kim, 2010). There is considerable uncertainty as to what electrification would do to U.S. auto employment, especially in the supply chain (Wright, 2016).

Even a more modest change in materials use, such as the shift from steel to aluminum, has ramifications for the entire supply chain. Greater use of aluminum increases employment in aluminum production, but it does not necessarily cause a net increase in U.S. employment. Fewer U.S. workers would be needed to produce steel. Moreover, the entire supply chains of aluminum and steel must be considered. The key input to aluminum production is bauxite, which is mined outside of the U.S. Two of the key inputs to steel production, iron ore and coal, are mined primarily by U.S. firms and workers. Thus, the shift from steel to aluminum may create some green aluminum jobs, but other jobs may be lost, and the net employment impacts require careful analysis.

The geographical distribution of gains and losses also require consideration. The auto parts industry, which is the sector responsible for the largest share of manufacturing employment in the U.S. (935,900 in 2014), is not spread equally around the country (Bureau of Labor Statistics [BLS], 2015). A large majority (more than 70%) of auto parts manufacturing employment is concentrated in ten states: Michigan, Ohio, Indiana, Tennessee, Kentucky, Illinois, Alabama, Texas, North Carolina, and South Carolina (CAR, 2015). When combined with the assembly plants, which tend to be located in these same states, it is readily apparent why the health of the auto industry is of greater concern in the South and Midwest than it is on the East and West coasts (Goolsbee & Krueger, 2015). A shift from the internal combustion engine to electric propulsion may change the geographic distribution of employment in the supply chain (See Figure 1).

A key exception to this point is the vast auto dealer network (710,000 employees at latest count), which must have national reach in order to maximize sales to consumers (CAR, 2015). Vehicle manufacturers technically sell their products to dealers, who then have the responsibility of selling them to retail customers or companies. In contrast to Europe, where a large fraction of sales are made to companies or fleet buyers, the U.S. market is dominated by the unaffiliated retail buyer who strives to meet the needs and preferences of his or her household and often buys the car on credit.

Figure 1. North American Automaker and Automotive Supplier Production Facility Locations



Source: (CAR, 2015)

As the midterm reviews consider the impact of regulatory requirements on the employment of workers in the U.S., as required by presidential executive order, it is crucial to consider the entire supply chain and dealers as well as assembly plants. If the U.S. auto industry had assembly plants but no parts businesses, the amount of employment in the auto industry would be much smaller than it is today. In addition, the fact that dealers may have multiple operations representing more than one automaker complicates the task of examining the impacts dealers will face from changes in car sales.

The Auto-Sector Recovery, 2009-2015

The U.S. economic recovery from the Great Recession (2007-2009) has been painfully slow, indeed the slowest recovery on record, but one of the positive developments has been the revival of the U.S. auto industry (Seefeldt & Graham, 2013). The five-year auto recovery accounted for 25% of the rise of manufacturing industrial production in the U.S. from 2009 to 2014, more than twice the average share in the four previous U.S. recoveries (Goolsbee & Krueger, 2015). One estimate is that the auto recovery was related to about 10% of the overall recovery of U.S. GDP in 2014 (Young, 2014).

Annual sales of new passenger vehicles (cars and light trucks) in the U.S. averaged 16 million from 1998 to 2007. That sales rate collapsed to 10.4 million in 2009, reflecting the combined impact of accelerating underemployment, declining incomes, falling consumer confidence, defaults on home mortgages, and lack of consumer access to affordable car loans.

Since 2009 the auto recovery has been significant. After six straight years of sales growth, the industry, boosted by low interest rates, is now (2015) selling more than 17 million new passenger vehicles, an annualized record for the U.S. Virtually all of the high-volume automakers have been reporting increasing revenue and profit in the post-recession period. Although the profit margins for investments in the auto sector are less than in other sectors, the recent period of profitability has allowed the Big Three to offer multiple years of bonuses to their workers and to make some new plant investments in North America. Foreign automakers have also announced new plant investments in the U.S. In total, about $70 billion in company-announced investments in new, expanded, or retooled investments in North America have been made from 2010 to 2014. About two-thirds of those investments are in the U.S. (CAR, 2015).

As a result, auto-related employment in the U.S.—both at assembly plants and at facilities that make engines, components, and parts— has rebounded significantly. In September 2005, direct auto-related employment in the U.S. was measured at 1,089,800, falling sharply to a trough of 653,400 in September 2009. It has grown each year since 2009, and was recorded at 935,900 in September 2015 (BLS, 2015).

Despite the recovery, automakers vary considerably in their access to the technology and capital necessary to implement major changes in vehicle propulsion systems. Fiat Chrysler is carrying the largest debt load among the high-volume producers and faces significant compliance challenges (Vellequette, 2015). One of the possible reasons that Fiat Chrysler is publicly looking for a merger partner is that it may lack the capital necessary to make aggressive investments in response to both the federal and California regulatory requirements. Even if companies do not merge, they may form alliances to share technological expertise. Toyota and Mazda are sharing information on advanced diesel and gasoline engines while GM and Honda are sharing information on fuel-cell vehicles (Roco, 2015).

The midterm review should recognize that the U.S. economic recovery from the Great Recession has been assisted by a healthy auto sector. Given the interdependence of some manufacturers on a common supplier base, regulatory damage to one firm can have ripple effects on other firms and the structure of the industry (Goolsbee & Krueger, 2015). The demise of one firm is not necessarily a crucial regulatory consideration, but industrial restructuring through regulation requires careful consideration.

Forecasts of Vehicle Sales

Most forecasts of new vehicle sales in the U.S. call for modest growth or stability between now and 2018. CAR (2015) projects 17.6 million units sold in 2018. The key (and uncertain) determinants are the rate of growth in household income and wealth and the path of interest rates, which have been quite low by historical standards. The Federal Reserve Board is actively considering policies that could put interest rates on a gradual upward path (Hilsenrath & Spector, 2015). Higher interest rates generally curb the car-buying power of consumers, since over 80% of consumers purchase new cars with loans (DeBord & Rudegeair, 2014). The negative statistical association between changes in interest rates and changes in new passenger-vehicle sales is well established (Copeland et al., 2015).

REGULATORY COMPLIANCE AND CREDIT TRADING PROCEDURES

In order to appreciate the complexity of the regulatory system faced by automakers, it is useful to review how manufacturer compliance with the standards is determined and the penalties for noncompliance. The programs also provide some flexibility for manufacturers, and the terms of those provisions are explored briefly below.

NHTSA's CAFE Program

Congress has specified that CAFE standards be set at the "maximum feasible level," taking into account technological feasibility, economic practicability, the effects of other standards on fuel economy (e.g., safety or smog standards), and the need to conserve energy. The CAFE standards for individual manufacturers are specified in two product categories: passenger cars and light trucks. A manufacturer's standard is determined by computing the sales-weighted average, specifically the harmonic mean, of the mileage targets for individual vehicles in a manufacturer's fleet. The requirements for individual vehicles vary based on their size (footprint): Vehicles with larger footprints have lower minimum fuel economy targets than do vehicles with smaller footprints.

To assess manufacturer compliance with CAFE standards, the average fuel economy of vehicles distributed for sale by a manufacturer is compared with the manufacturer's CAFE standard. A manufacturer's passenger car fleet is compliant if the aggregate fuel economy of this fleet is at or above the stated standard. A separate compliance determination is made for the manufacturer's light trucks. Most large-volume manufacturers sell both cars and light trucks, so they have two CAFE compliance standards to meet.

The CAFE regulatory program is credit based, such that each manufacturer has a credit account that can be debited or filled based on its compliance in a given model year. Any time a manufacturer exceeds compliance targets it earns a certain number of credits. Manufacturers can address under-compliance by using credits accumulated in previous model years or by paying a civil penalty set at $55 per MPG. With respect to credits, manufacturers can (i) carry excess credits earned in a given year forward up to five consecutive years following the model year in which these credits were earned ("carry forward provision"); (ii) carry credits backward up to three consecutive years prior to the model year in which credits were earned ("carry backward provision"); (iii) transfer excess credits earned for one vehicle product category to account for deficits in another; or (iv) purchase credits from other manufacturers that have excess credits.

EPA's GHG Standard

Similar to the CAFE program, EPA's vehicle emission standards for GHGs are set according to vehicle footprint, wherein larger footprint vehicles have more permissive GHG emissions targets than smaller footprint vehicles. Also, like the CAFE program, the EPA's program relies on a credit banking system.

Manufacturers under-/over-complying with GHG emissions standards can carry credits forward or backward to account for compliance shortfalls, or trade credits with other manufacturers. The incorporation of certain types of vehicle technologies or vehicle design features earns manufacturers extra credits. For example, manufacturers earn credits for including efficient air conditioning systems that reduce refrigerant leakage and rely on alternative refrigerants with lower global warming potential. Manufacturers also earn credits for solar panels and engine start-stop technology as well as for improvements in vehicle aerodynamics. When the benefits of the vehicle technology/design features are not reflected in emissions testing procedures, the credits awarded to the manufacturer are termed "off-cycle" credits.

Further, under EPA's program, manufacturers earn extra credit for certain types of vehicles. In 2017, each BEV and FCV distributed for sale by a manufacturer will count as two vehicles. By 2021, the multiplier will be decreased to 1.5. PHEVs will be multiplied by 1.6 in 2017 and 1.3 in 2021. The presence of such credits can be seen as an effort to coordinate federal regulatory policy with the California ZEV program.

BEVs and FCVs sold between 2017-2021 will be counted as emitting zero grams CO_2 equivalent per mile, including upstream emission and on-road emission. For subsequent model years up to 2025, the EPA will allow manufacturers who sell 300,000 BEVs or FCVs between 2019-2021 to count up to 600,000 of these types of vehicles as zero-CO_2 emitting vehicles, beyond which manufacturers will need to report on upstream emissions. The agency will allow all other manufacturers to count up to 200,000 vehicles as zero-CO_2 emitting during this time period.

EPA and NHTSA have not been able to harmonize the compliance incentives for BEVs, PHEVs, and FCVs. NHTSA does not offer any credit multipliers for such vehicles, as it does not believe it has the legal authority to do so.

When the EPA launched the new GHG program, it did not assign zero credit balances to all vehicle manufacturers. It recognized that some manufacturers (e.g., Toyota) had accumulated significant GHG credits from 2009-2011 and allowed those credits to be transferred to the start of the EPA program. In other words, Toyota was posted in 2013 with 86 million EPA credits at the start of the 2012 model year, credits that can be used until the 2021 model year (when they expire) (Nelson, 2013a).

Manufacturers need to ensure, if they plan to use credits under the NHTSA program, that they also have sufficient credits under the EPA program. While some German manufacturers have a history of paying fines under the CAFE program, the Big Three have feared that they might be liable for civil damages in stockholder lawsuits if they paid fines (Kleit, 2004). In any event, paying fines as a compliance technique will not work in the future because it is not a viable option under the EPA program. The EPA can stop a company from selling vehicles if it does not meet the standard or have credits to cover any deficit (Leard & McConnell, 2015).

The EPA credit program was also designed to help start-up PEV manufacturers. New PEV manufacturers are permitted to accumulate credits each year relative to their sales volume. Those credits can then be sold to other vehicle manufacturers who are confronting an EPA compliance deficit (Crain Communications, 2014).

The ZEV Regulation

A "ZEV state" is one that has adopted California's entire "Advanced Clean Cars Program," including requirements for control of smog, soot, and global warming gases and regulation to encourage greater numbers of ZEVs. The ZEV regulation requires that manufacturers selling vehicles in a state earn a certain number of "ZEV credits," which corresponds to a percentage of the total number of passenger cars and light-duty vehicles distributed for sale in the state. The ZEV regulation currently applies to large and intermediate volume manufacturers. Currently, large volume manufacturers are defined as those that sell more than 60,000 vehicles per model year in California. Intermediate volume manufacturers are defined as those that sell 4,501 to 60,000 vehicles per model year. Starting in 2018, any manufacturer that produces more than 20,000 vehicles per year will qualify as a large-volume manufacturer.

A ZEV is a vehicle that does not produce tailpipe emissions during operation. Operationally, the ZEV must be a BEV or FCV (CARB, 2013). Currently, under the ZEV regulation, CARB grants credits for these vehicles as well as for others that operate as extremely low polluting technologies. BEVs and FCVs are referred to as pure ZEVs. Other types of vehicles that receive ZEV credits include those categorized as Transitional ZEVs, Partial ZEVs, and Advanced Technology Partial ZEVs. Table 3 lists the types of vehicles that are included in each ZEV category. The number of credits awarded for any particular kind of ZEV currently depends on characteristics like vehicle type, how far the vehicle can travel on a zero-emission fuel source, and a vehicle's fast refueling capability.

Fast refueling capability is the ability to refuel to 95% capacity within 10-15 minutes, depending on a vehicle's zero emission fuel range (i.e., similar to the rate of traditional gasoline or diesel fueled vehicles). A provision specific to fast refueling allows manufacturers to earn additional credits beyond the baseline credits based on demonstrated fast refueling capability. Currently, manufacturers can earn credit for up to 25 vehicles based on performing 25 fast refueling events on just one vehicle. The fast refueling credit will be eliminated altogether in model year 2018.

While the ZEV program does currently allow manufacturers to earn credits for transitional ZEVs, advanced technology partial ZEVs, and partial ZEVs, the awarded credit is lower for these vehicles than for pure ZEVs. Further, manufacturers can only fulfill a limited fraction of their requirements with non-pure ZEV vehicles. Table 3 also shows the range of credits that can be earned for different types of vehicles in model years 2012-2017 and 2018-2025. Note that no credits are provided for HEVs or partial ZEVs starting in model year 2018.

CARB publishes formulae that determine how credits vary based on the design of a ZEV and how credits translate to compliance percentages. For each model year, CARB sets a Total ZEV Percentage Requirement and a Minimum ZEV Floor Requirement. The Minimum ZEV Floor Requirement specifies the percentage of credits that must be earned with pure ZEVs alone. The Total ZEV Percentage requirement can be met with a combination of pure ZEVs and other allowed technologies. Table 4 shows the minimum ZEV floor and total ZEV percentage requirements for model years 2018-2025 for large volume manufacturers.

Beyond 2025, ZEV requirements are expected to become increasingly stringent to help California accomplish its goal of reducing statewide greenhouse gas emissions to 80% below 1990 levels. In support of this goal, California

Table 3. Credit Ranges by ZEV Vehicle Type

ZEV Vehicle Type	Definition	Vehicle Type	Credits Model Years 2012-2017	Credits Model Years 2018-2025
ZEV	Zero Emission Vehicle	Battery electric vehicle, hydrogen fuel cell vehicle	1-9 depending on range and fast-refuel	1-4 depending on range
TZEV	Transitional Zero Emission Vehicle	Plug-in hybrid or extended range electric vehicle, hydrogen internal combustion engine vehicle	1-3 depending on technology	0.4-1.3 depending on range
PZEV	Partial Zero Emission Vehicle	Extremely clean conventional vehicle	0.2	-
AT PZEV	Advanced Technology Partial Zero Emission Vehicle	Natural gas vehicle, hybrid electric vehicle	> 0.2-3 depending on technology	-

Source: Adapted from Center for Climate and Energy Solutions http://www.c2es.org/us-states-regions/policy-maps/zev-program

Table 4. ZEV Requirements by Model Year

Model Year	Total ZEV Percentage Requirement (%)	Minimum ZEV Floor Requirement (%)
2018	4.5	2.0
2019	7.0	4.0
2020	9.5	6.0
2021	12.0	8.0
2022	14.5	10.0
2023	17.0	12.0
2024	19.5	14.0
2025	22.0	16.0

Source: CARB, 2012b. http://www.arb.ca.gov/regact/2012/zev2012/fro2rev.pdf

Governor Jerry Brown recently issued a target of having ZEVs comprise 100% of new vehicle sales in 2050 as part of a non-binding agreement with several U.S. states, Quebec, and several European countries (Siders, 2015).

Intermediate volume manufacturers are granted some leniency in achieving ZEV requirements through model year 2017 because they generally have less revenue and capacity to engage in research and development than do large volume manufacturers (CARB, 2014). Through model year 2017, intermediate volume manufacturers are allowed to meet ZEV requirements entirely with PZEVs. Starting in 2018, they will also be allowed to meet requirements solely through TZEVs.

Manufacturers that over-comply with ZEV requirements (i.e., earn more ZEV credits than required in a given year) can bank those credits for future use to accommodate compliance shortfalls or sell excess credits to other manufacturers. Conversely, under-complying manufacturers must pay a fine or purchase credits from manufacturers with excess credits. Starting in 2018, manufacturers will be required to make up a ZEV credit deficit within one year (CARB, 2014). While small-volume manufacturers—those producing 4,500 or fewer units per year—are not currently regulated under the ZEV program, they may earn, bank, market, and trade credits for the ZEVs and TZEVs they produce and deliver for sale (CARB, 2012a, p. 3).

Under the federal Clean Air Act, states are allowed to opt in to California's ZEV program and nine are currently recognized as ZEV states: New Jersey (2004), Connecticut (2004), Vermont (2005), New York (2005), Maine (2005), Rhode Island (2005), Massachusetts (2005), Oregon (2006), and Maryland (2007). States that opt to follow the California standards must adopt them in their entirety (even as they are amended by CARB) in order to maintain consistency and thereby simplify the compliance burdens on automakers.

Currently, manufacturers can apply the credits they earn for the sale of pure ZEVs in one ZEV state to count toward meeting regulatory requirements in any other ZEV state (CARB, 2011). This credit transfer allowance is referred to as the "travel provision," but it is set to end in 2017. By eliminating the travel provision for pure ZEVs, CARB is compelling a minimum number of BEV sales in each of the ZEV states (CARB, 2012c). The travel provision for FCVs has been indefinitely extended to allow ZEV states ample time to develop infrastructure to support these vehicles and to implement policies that will facilitate their adoption and use. Currently, there is not adequate hydrogen refueling infrastructure in any state to support widespread use of FCVs (Fleming, 2015b).

CARB also offers automakers additional flexibility through the "Optional Section 177 State Compliance Path" (Optional Path). This compliance path provides automakers the flexibility of meeting their ZEV obligation in three regional pools: California, other western states, and eastern states. The western pool includes all states west of the Mississippi River, excluding California. The eastern pool includes all ZEV states east of the Mississippi River. Thus, if a manufacturer's sales are short in Massachusetts, the company can compensate with a surplus of sales in another eastern ZEV state (e.g., New York). Credits transferred between states in the same regional pool transfer at full value. Credits transferred across regional pools do so at a reduced value. The Optional Path also reduces TZEV requirements in 2015-18 model year and pure ZEV requirements in 2018-2020 model year for non-California ZEV states. Manufacturers choosing the Optional Path are subject to increased pure ZEV sales quotas in 2016-17 model year in non-California ZEV states.

REVIEW OF PREVIOUS INDUSTRIAL IMPACT STUDIES

Although the federal and California regulations are likely to have a significant impact on the automotive industry, we found remarkably few studies that examined these industrial impacts. Our search for studies included both government reports and the academic and think-tank literatures. The following screening criteria were employed: the authors addressed (1) the 2017-2025 federal and/or California standards and (2) the impact of the standards on new vehicle sales and/or employment. The seven studies we found are reviewed briefly below.

NHTSA (DOT, 2012) and EPA (2012) provide the official regulatory impact analyses in support of the federal CAFE and GHG standards, respectively, for model years 2017-2025. Both reports include a detailed engineering-economic analysis of compliance technologies, including their costs and fuel-consumption benefits, but differ in their commitment to the likely employment effects. On the one hand, the NHTSA analysis provides alternative scenarios in which the quantitative impact of the standards on new vehicle sales is either positive or negative, depending upon the reaction of consumers to higher vehicle prices and the estimated savings in fuel expenditures. Employment impacts are positive or negative, depending on the scenario. On the other hand, EPA (2012) includes a qualitative discussion of possible impacts on new vehicle sales but no quantitative modeling. A consumer payback analysis is performed. This analysis shows that consumers will reap sufficient fuel savings to pay for the higher vehicle prices in a short period of time. Some positive employment impacts are quantified in sub-sectors that produce green automotive technology.

The official regulatory impact analysis in support of the California ZEV standards for model years 2018-2025 examines only economic impacts in California and does not address the nine ZEV states or the national economy (CARB, 2011). Similar to EPA (2012), CARB (2011b) provides a qualitative discussion of possible impacts on new vehicle sales but no quantitative modeling. Results from a consumer payback analysis show that fuel savings from at least one type of BEV will be sufficient to cover the higher price of the vehicle over the lifetime of the vehicle. Positive employment impacts are quantified for the State of California (e.g., in firms that produce recharging stations for plug-in vehicles).

We also reviewed economic impact analyses produced by four think tanks. Although most of the studies focus on the 2012-2016 and 2017-2025 standards, there is some variation in the MPG targets underlying the estimates. For example, CAR (2011) studies the impacts of the 2017-2025 standard under assumption of 47, 51, 56, and 62 MPG in 2025; Wagner, Nusinovich, & Plaza-Jennings (2012) study the impact of meeting the standards for model year 2017-2025; and Busch, Laitner, McCulloch, & Stosic (2012) assume a fuel economy of 54.5 MPG by 2025.

Busch et al. (2012) from the Blue-Green Alliance do not model vehicle-sales impacts but they do produce estimates of employment impacts. They combine technology cost estimates from the federal regulatory impact analyses with social accounting matrices that are taken from the Minnesota IMPLAN Group to estimate the macroeconomic effects of the federal standards using the Dynamic Energy Efficiency Policy Evaluation Routine (DEEPER) model. The model used in the analysis has 14 economic sectors and one household sector. Busch et al. (2012) assume that fuel savings are distributed across the economy in proportion to 2010 consumption, that 80% of the additional spending on technology required to meet the standard will go to the parts and supplies sector (and 20% to vehicles), and that the government's administrative costs will be $30 million per year in real 2010 dollars. They find that CAFE will create approximately 320,000 jobs by 2025 and 570,000 by 2030. A breakdown by sector reveals employment gains for every sector except oil refining and oil and gas extraction; the largest gain is in the business and personal services sector. They further find that net real (2010 $) wages and GDP increase by $49 billion and $75 billion, respectively, by 2030. Finally, they estimate the employment impacts of an increase in the domestic content of cars to 75% and find that direct auto-manufacturing jobs would increase by 3,300 by 2025 and 4,100 by 2030. Total number of jobs created by this increase in content is 10,000 by 2025 and 13,000 by 2030 in their estimate.

CAR (2011) prepared its study prior to the completion of the joint federal rulemaking, but the range of rulemaking options it examines includes the 54.5 MPG standard that was finalized by NHTSA/EPA. CAR begins its analysis with the technology-cost estimates from the National Research Council (2010), to which it makes several adjustments. CAR assumes a greater reduction in vehicle mass compared to the NRC (2010), and also includes cost estimates for PEVs, on the assumption that some PEV production will be necessary to comply with the federal standards. CAR then estimates the mix of technologies that is able to achieve four different levels of CAFE standards relative to a baseline of model year 2008: 47, 51, 56, and 62 MPG. The average per-vehicle cost of achieving each of the CAFE standards is determined based on the combined weighted cost of implementing that technology mix. CAR then estimates the fuel cost savings of each technology mix at two alternative gasoline prices ($3.50 and $6.00), and the authors net the fuel savings from the increased cost per vehicle. CAR determines economic impacts by first estimating the price elasticity of motor vehicle expenditure (% change in expenditure due to a 1% increase in price) and uses this estimate to determine the impact of the increased net price on vehicle demand.[2] The change in vehicle sales is translated into U.S. vehicle production and employment using a sourcing ratio of 60% and an automotive labor-market productivity of 12.26. All rulemaking scenarios analyzed by CAR produce a decline in vehicle sales and employment except one: a standard of 36 miles per gallon where the price of fuel is pegged at $6 per gallon.

Wagner et al. (2012) from the National Automobile Dealers Association (NADA) calculate the share of consumers who meet the minimum debt-to-income (DTI) ratio required to finance the purchase of the cheapest new vehicle available on the market before and after the stricter CAFE standards.[3] Drawing on technological costs from the federal RIAs, they assume that the cheapest new vehicle will increase in price by between $2,937 and $12,349 (in 2010 $) after complying with the new CAFE standards. They further assume that a consumer will only receive a loan if her DTI is less than 40%. The main finding is that compliance with the new CAFE standards will lead to a significant drop in new vehicle sales because a large number of consumers fail to meet minimum DTI requirements. The cheapest new vehicle will cost approximately $15,700 under CAFE, and this price would reduce the number of people with qualifying DTI by approximately 5.8 to 6.8 million. The study's worst case scenario of a $12,349 price increase would cause approximately 27.7 million consumers to drop out of the market.

Baum and Lauria (2010) do not model vehicle sales impacts but do supply employment estimates. They rely on the technological cost estimates produced by The Panning Edge to estimate macroeconomic impacts using the Regional Economic Model Inc. They report that every packet of 100,000 traditional U.S.-made vehicles is associated with 17,000 jobs; this estimate is made after making adjustments for increased labor productivity and reduced U.S. content. They then assume that employment is proportional to the cost of manufacturing the vehicle, which they further assume is approximately 80% of the listed price. From this calculation they conclude that an energy-saving technology that adds $500 to the cost of each vehicle is associated with 2.5% of the 17,000 jobs mentioned above.

This body of literature suffers from several major limitations that can be corrected in future work. First, none of the studies incorporate the California ZEV program in conjunction with the federal standards. The impact on industry is understated due to the omission of the ZEV program. Second, the studies make conceptually different assumptions about employment impacts: some assume that regulatory costs reduce employment because the resulting price increases reduce vehicle sales and vehicle-related employment; others assume that regulatory costs increase employment because regulatory costs are related to increased employment in the green technology sector. The different assumptions need to be reconciled. Third, the studies provide relatively little information on regional and state-level employment impacts, particularly the studies that link employment impacts to changes in

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[2] CAR (2011) estimates the price elasticity of motor vehicle expenditure (% change in expenditure due to a 1% increase in price) to be -1.92 in the short run and -0.58 in the long run. These point estimates are converted to arc-elasticities using data for the period 1994-2009. The arc price-elasticity is estimated to be -0.39 and arc income elasticity is 1.2.

[3] The cheapest vehicle in the "before" period (2011) is the Chevrolet Aveo, which costs approximately $12,750 including incentives, taxes, and fees. Each consumer is assumed to make a $1000 down payment and thus requires a loan of $11,750 with a term of 72 months and an interest rate of 4%; this calculation mplies a monthly payment of $183.

the volume of vehicle sales. Fourth, none of the studies had access to NRC's (2015a) update of the costs and fuel-consumption benefits of alternative technologies. Fifth, the studies were performed before the collapse of global oil prices and the downward forecasts for fuel prices between now and 2025. Finally, the studies are inconsistent as to their baseline assumptions (i.e., how the industry—sales and employment—would have fared without the stricter federal and state requirements) and in some cases the baseline assumptions are not transparent. We elaborate on several of these points in our recommendations for the midterm reviews.

Given the limitations of the literature, we recommend that agency analysts look carefully at how implementation of the 2017-2025 regulatory requirements will impact passenger vehicle sales, employment, and other macroeconomic indicators. Our Phase 2 report, due January 2017, will supply some quantitative modeling of these issues. The remainder of this report makes more specific recommendations on technical issues and policy options that are relevant to impacts on vehicle sales and employment and thus worth considering in the midterm reviews.

RECOMMENDATIONS FOR MIDTERM REGULATORY REVIEWS

1. There has been a significant decrease in fuel prices since the federal and ZEV rules were developed from 2009 to 2012. Official government projections of fuel prices have been revised downward and remain relatively low through 2030. Regulations should be reevaluated during midterm reviews with these lower fuel price projections, emphasizing revised consumer payback periods and impacts on new vehicle sales.

The GHG and CAFE standards for model years 2017 to 2025 are projected to reduce gasoline consumption by 4 billion barrels of oil over the entire lifetimes of the vehicles. Applying a 3% discount rate, this reduction results in estimated monetary savings ranging from $459 billion (2010 baseline fleet) to $471 billion (2008 baseline fleet). The monetary benefits derived from reduced fuel consumption represent 80% of the combined benefits of the federal 2017-2025 standards; environmental and energy-security benefits account for most of the remaining 20%.

To arrive at the estimated monetary savings, NHTSA and EPA used gasoline price projections based on the early release of the 2012 Annual Energy Outlook (AEO) of the Energy Information Administration (EIA). The projection path included the following prices per gallon of gasoline: $3.53 in 2015, $3.76 in 2020, $4.04 in 2030, and $4.57 in 2050. In its 2011 RIA, CARB made similar assumptions for gasoline prices ($4.06 for 2020, $4.02 for 2025, and $4.17 for 2030). The AEO 2012 forecasts only extended as far as 2035. The agencies, however, considered fuel savings over the entire lifetime of the vehicles and, as a result, required fuel price projections as far as 2060 (i.e., some vehicles last 25 years or more). The projected fuel prices for the period 2035 to 2060 were obtained by inflating the 2035 figures by an average annual rate of 0.8.[4]

The monetary savings estimated by the agencies do not include federal and state fuel taxes as these taxes are viewed as income transfers. However, when considering the savings experienced by consumers, fuel taxes were incorporated in the analysis.

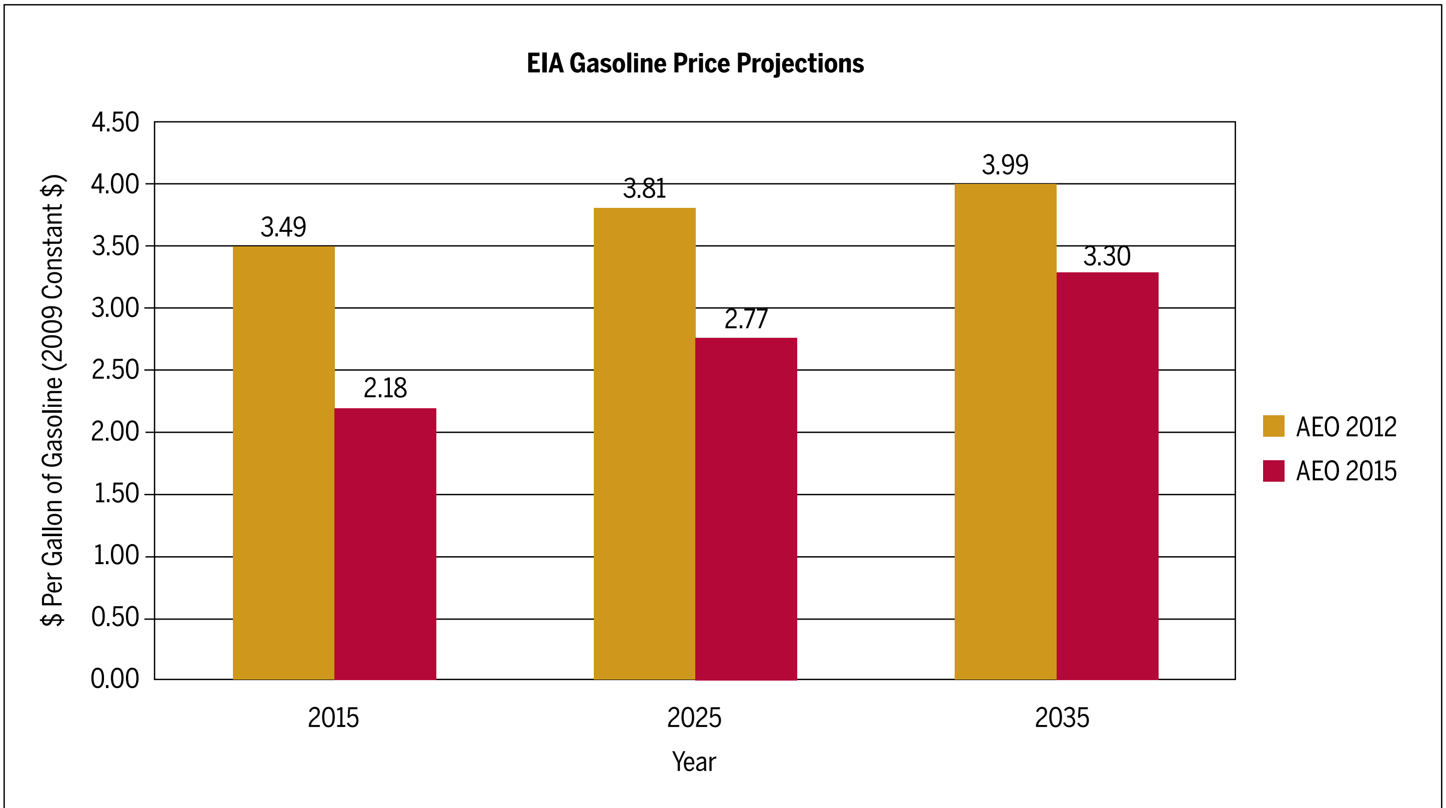
Since the development of the final 2017-2025 federal and ZEV rules, the world oil market has undergone significant changes. The rate of growth in global demand for oil has tapered as the growth of the Chinese economy has slowed and as economic difficulties have plagued the economies of the EU and other regions. On the supply side, the success of unconventional technologies has boosted U.S. and Canadian oil production (Luskin & Warren. 2015). Iraq has resumed its production, Iran may expand production, and both Russia and Saudi Arabia have chosen to defend market share rather than reduce production (International Energy Agency [IEA], 2015; Gold, 2015; Faucon, 2015; Kantchev & Summer, 2015; Said, Spindle, & Faucon, 2015; Sheppard & Raval, 2015).

The subsequent drop in gasoline prices in the U.S. has been significant, with the national average price in 2015 being $2.31 (EIA, 2015c). EIA forecasts the average national price of fuel at $2.74 in 2020 and $3.20 in 2030. Figure 2 illustrates gasoline price projections from AEO 2012, which are the projections used by the agencies in setting the regulations, and AEO 2015 (calculated in constant 2009 dollars). The difference between the AEO 2012 forecast for 2015 and the observed price was $1.31 per gallon. Differences of similar magnitudes are estimated for 2025 ($1.04) and to a lesser extent for 2035 ($0.69). The price path based on the AEO 2015 projections deviates substantially from the 2012 AEO reference case projections and, if applied to the analysis conducted by the agencies, would result in a downward revision of the estimated benefits of the rules.

The large degree of uncertainty regarding long-run oil and gasoline prices is acknowledged by EIA (2015a, 2015b). Each year EIA reports both a reference case and low and high gas-price scenarios. For 2020 those projections are $2.56, $2.18, and $3.88, in 2009 constant dollars, respectively. We encourage agency analysts to compute

[4]This is the inflation rate projected during the period 2017 to 2035.

Figure 2. Gasoline Price Forecasts Based on AEO 2012 and AEO 2015



Notes: The 2015 figure of $2.18 is obtained from the 2015 Short Term Energy Forecast (not the 2015 Annual Energy Outlook). All prices are calculated in 2009 constant dollars. Source: EIA (2012), EIA (2015b); calculations made by the authors.

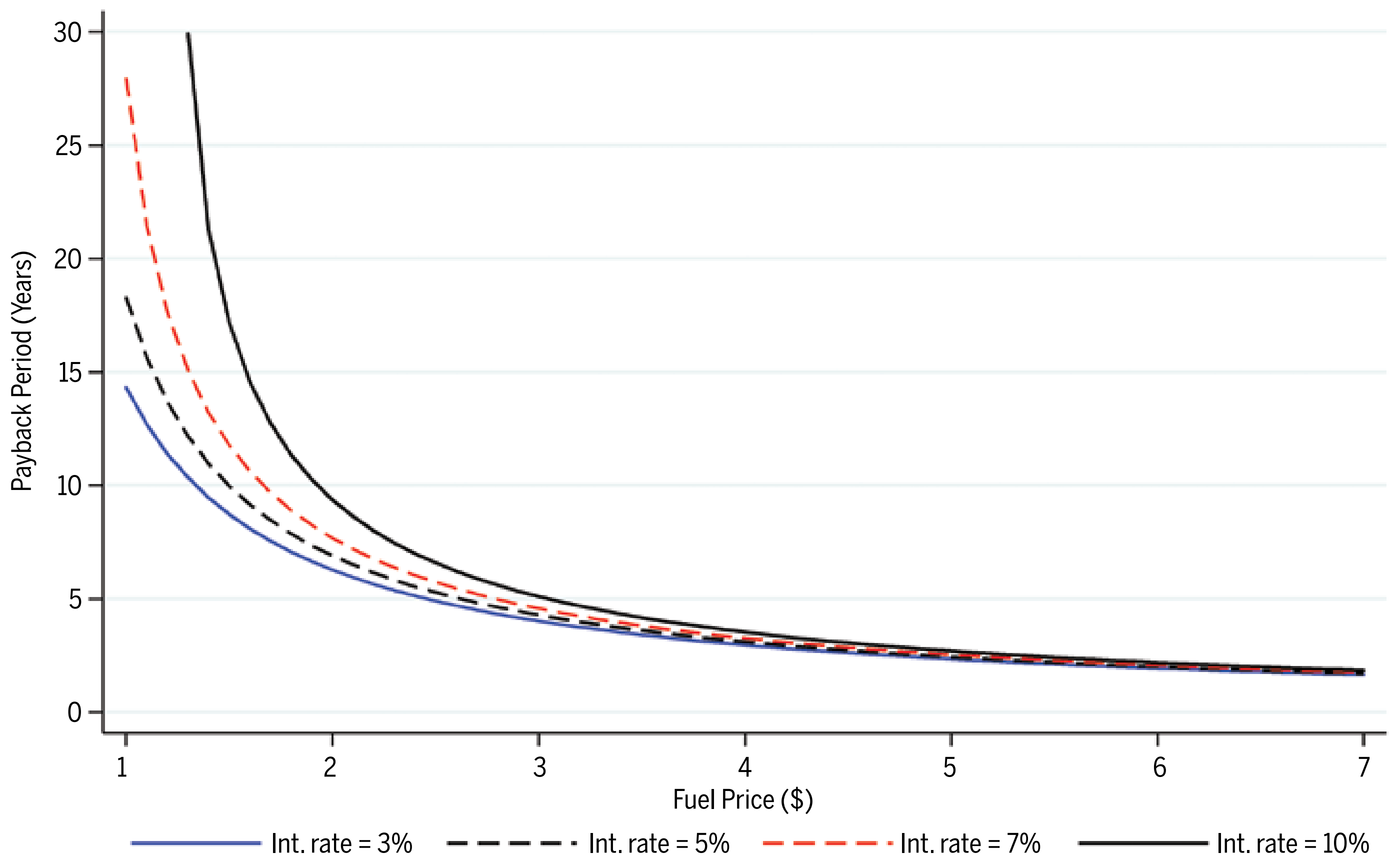
consumer payback periods based on all three scenarios for gasoline prices in 2020-2025, using the most recent EIA forecasts.

With regard to the commercial future of PEVs, the difference between fuel prices and electricity prices also needs to be considered. DOE's eGallon tool was developed to make this comparison easy for consumers (Leistikow, 2013). The tool uses the most recent data on gasoline and electricity prices to compare how much money consumers will pay for energy during a trip of the same length. On January 18, 2016, DOE reported the average cost of gasoline in the U.S. as $2.00 per gallon; the price of electricity, in DOE's "eGallon" format, was $1.16 per gallon. The advantage for electricity was much larger in California ($2.84 per gallon of gasoline vs. $1.36 per eGallon) than it was in Massachusetts ($1.97 per gallon for gasoline vs. $1.67 per eGallon). Looking forward, agencies need to consider the projected pathways for both electricity and gasoline prices, especially in the ZEV states.

In order to illustrate the powerful impact of lower fuel prices on the appeal of fuel-efficient vehicles and PEVs, we calculate consumer payback periods for a range of fuel prices and four discount rates. The results from this analysis are presented in Figures 3, 4, and 5 for incremental price impacts of $2,000, $5,000, and $10,000, respectively. The lower price corresponds roughly to extensive modification of a gasoline-powered vehicle, the mid-range prices correspond roughly to an HEV or an advanced diesel engine, and the higher price corresponds roughly to a future PEV. In assessing the consumer payback periods, it may be useful to consider the rough rule of thumb that a typical new vehicle purchaser expects payback for a fuel-economy investment in three to five years (CAR, 2011; Greene, Evans, & Hiestand, 2013; NRC, 2015a).

The results show that consumer payback periods are lengthened substantially at low fuel prices. For example, Figure 3 shows that a $2,000 investment in fuel economy is defensible at $4 per gallon; the payback period is

Figure 3. Consumer Payback (in Years) Analysis for a 55 MPG Vehicle with an Incremental Price of $2,000



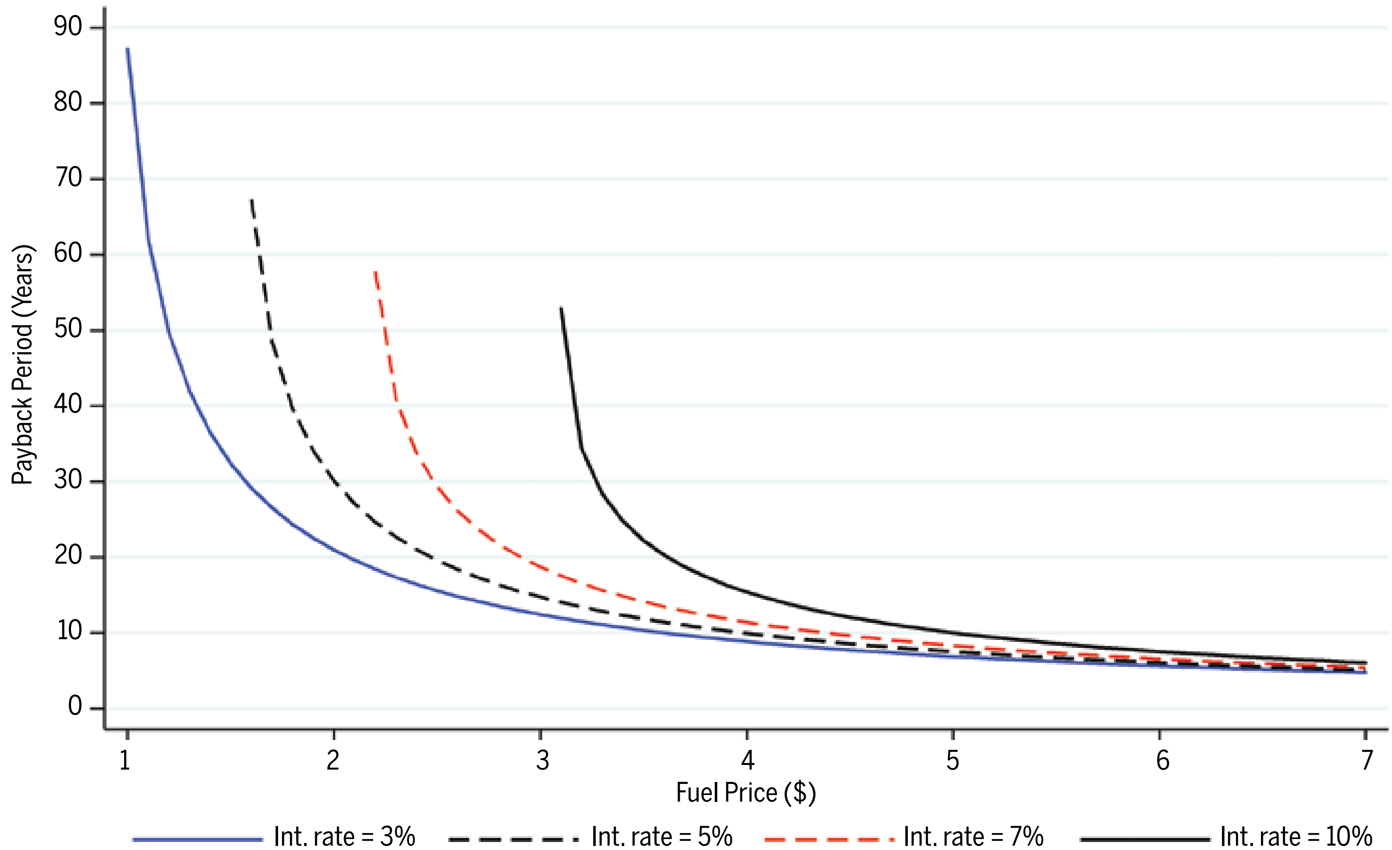
Notes: Reported is the payback period (in years) required to recoup the $2,000 incremental cost of buying a fuel efficient vehicle under various assumptions about interest rates and fuel price. We assume the consumer drives 12,500 miles per year, that the inefficient car gets 35 MPG, and that the efficient vehicle gets 55 MPG. We further assume that on-road fuel economy is 80% of the stated fuel economy and that the incremental resale value of the efficient vehicle is 10% of the incremental cost. The analysis assumes that all parameter values are constant over the life of the vehicle, which implies that fuel savings are constant across time.

less than 5 years regardless of the discount rate. The investment is far less attractive when fuel price is $2 per gallon, especially at higher interest rates. Similarly, Figure 4 shows that the payback period for a price premium of $5,000 is not attractive at fuel prices under $7 per gallon. Finally, Figure 5 shows that, at a price premium of $10,000, a PEV might pay for itself after 12 years of driving, assuming gasoline costs $4 per gallon and a 5% discount rate. At $2 per gallon, it takes almost 40 years of driving for the investment to pay off. We explore below (under Recommendation #2) recent evidence about how consumers think through these issues when purchasing a new car or truck.

Lower fuel prices may also influence a series of other analytical parameters in the RIAs (see Appendix A). Here we offer another example of a variable, the rebound effect, that needs to be reconsidered in a low fuel-price environment.

A significant literature has addressed the “rebound effect,” that is, the behavioral phenomenon whereby drivers of fuel efficient vehicles tend to increase their vehicle miles traveled due to the lower fuel cost per mile of travel.

Figure 4. Consumer Payback (in Years) Analysis for a 55 MPG Vehicle with an Incremental Price of $5,000

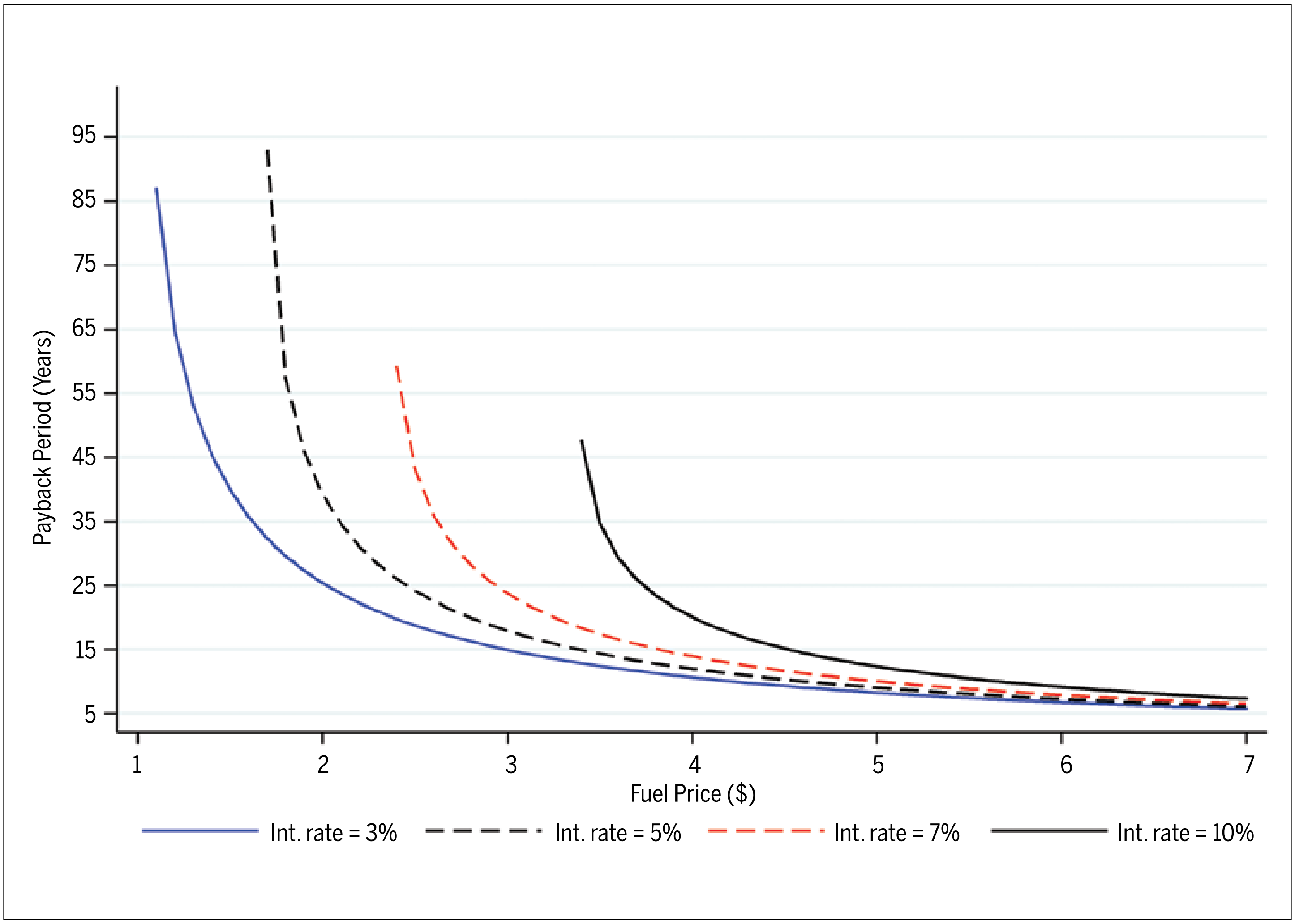


Notes: Reported is the payback period (in years) required to recoup the $5,000 incremental cost of buying a fuel efficient vehicle under various assumptions about interest rates and fuel price. We assume the consumer drives 12,500 miles per year, that the inefficient car gets 35 MPG, and that the efficient vehicle gets 55 MPG. We further assume that on-road fuel economy is 80% of the stated fuel economy and that both vehicles have the same resale value. The analysis assumes that all parameter values are constant over the life of the vehicle, which implies that fuel savings are constant across time.

The federal agencies conducted a thorough review of the literature and assumed a rebound rate of 10%, which at the time the RIAs were published (2012) captured the consensus among the peer reviewed literature. However, recent work has found a declining rebound effect over time.

Hymel and Small (2015) use data from 1966-2009 and find that consumers respond more to fuel price increases than decreases. As a result, they report a greater rebound effect in years when fuel prices are rising. Furthermore, they find that the rebound effect declines in magnitude as household income rises. This income effect, while surprising, can be justified based on the fact that, as income levels increase, the driver's time plays a predominant role in the variable cost of travel and decreases the role of fuel prices. In another recent study, Gillingham, Jenn, & Azevedo (2015) report a short run gasoline price elasticity of driving of 10% for drivers in Pennsylvania, with substantial heterogeneity demonstrated among drivers. Drivers of low fuel economy vehicles exhibit high rates of gasoline price elasticities of driving, while drivers of fuel efficient vehicles demonstrate inelastic behaviors.

Figure 5. Consumer Payback (in Years) Analysis for a PEV with an Incremental Price of $10,000



Notes: Reported is the payback period (in years) required to recoup the $10,000 incremental cost of buying a PEV under various assumptions about interest rates and fuel price. We assume the consumer drives 12,500 miles per year, that the inefficient car gets 35 MPG, and that the efficient vehicle gets 105 MPG (the equivalent of a BEV100 [35KWh]). We further assume that on-road fuel economy is 80% of the stated fuel economy and the incremental resale value of the efficient vehicle is -10% of the incremental cost. The analysis assumes that all parameter values are constant over the life of the vehicle, which implies that fuel savings are constant across time.

During the midterm reviews, analysts should examine carefully how lower fuel prices could influence each of the variables in the consumer payback analyses. Emphasis should be given to how low fuel prices influence, directly and indirectly, consumer payback periods and new vehicle sales.

2. **The midterm reviews, when they estimate impacts on new vehicle sales, should consider recent evidence concerning how consumers weigh fuel-saving benefits against the higher price of a fuel efficient vehicle or a PEV. A sensitivity-analysis approach to vehicle-sales impacts is reasonable insofar as there are uncertainties about how consumers will react to fuel efficient and zero-emission vehicles.**

As summarized by NRC (2015a, p. 312), federal regulators argued in 2012 that the 2025 standards will be a good investment for consumers. While the 2025 standard was estimated to increase the average price of a new vehicle by about $1,800, the consumer was estimated to save $5,700 - $7,400 over the long lifetime of the vehicle (typically 10-20 years), depending on whether a 3% or 7% annual discount rate is applied to future fuel savings (DOT, 2012). The investment appears to be so attractive that the 2025 standards might increase vehicle sales (NRC, 2015a, p. 312).

However, the above comparison is not necessarily persuasive because the vehicle-sales impacts of federal regulatory standards depend on how consumers value fuel savings in the automotive market. Valuation of fuel savings is also central to assessing the impact of ZEV requirements on vehicle sales. During the midterm reviews, regulatory analysts can draw from a larger literature on consumer valuation than was available in the 2009-2012 period.

When consumers purchase a new vehicle, they do not plan on keeping the vehicle for its entire 10- to 20-year lifetime (the average vehicle life is 14 years and rising). Most consumers own the vehicle for less than seven years (many for only 3 or 4 years), and then trade it in for a new vehicle or sell it in the used-car market (CAR, 2011; NRC, 2015a). Recent surveys suggest that consumers focus primarily on fuel savings accrued during the three years after purchase (Greene et al., 2013). Savings that accrue beyond the third year may not have a significant influence on the purchasing decision.

Some consumers consider the likely resale value of a new vehicle, and there is evidence that, other things equal, a vehicle with good fuel economy commands a higher price in the used-car market than a vehicle with poor fuel economy (Sallee, West, & Fan, 2015; Busse, Knittel, & Zettelmeyer, 2012; Busse, Knittel, & Zettelmeyer, 2013). The premium for fuel economy in the used car market is greater when fuel prices are high than when fuel prices are low (Gilmore & Lave, 2013), and some PEVs have very low resale value (Woodyard, 2015). As an example, resale values for the Nissan LEAF fell from 43.5%, to 36.5%, to 25.3% in each of the first three years of the vehicle's life, respectively (NADA, 2015). By way of comparison, the average gasoline car retains about 35% of its value after five years of use (Gorzelany, 2013). The poor resale values of some PEVs may help explain why a majority of new PEVs are sold through leasing arrangements. A leasing arrangement puts the onus of resale on the dealer rather than the consumer.

A consumer's perception of future fuel prices may also deviate from the forecasts of federal agencies. Recent evidence suggests that consumers, when they make vehicle purchasing decisions, do not forecast—as EIA does—that fuel prices will rise gradually after the vehicle is purchased. Instead, consumer beliefs about future fuel prices, absent any recent price shocks, are similar to a no-change forecast (Anderson, Kellogg, Sallee, & Curtin, 2011; Anderson, Kellogg, & Sallee, 2013).[6] In other words, from the perspective of consumers, the observed fuel prices in the period immediately prior to the purchasing decision are assumed to persist for the foreseeable future.

In addition, the time preferences of consumers may be more present-oriented (impatient) than captured by the Office of Management and Budget's recommended annual discount rates of 3% or 7%. Some older and more recent studies find consumer discount rates for fuel savings in excess of 10% per year (e.g., see Dreyfus & Viscusi, 1995; Gallagher & Muehlegger, 2011).

The larger academic literature on energy economics sheds further light on consumer valuation issues. The term "energy gap" is used to describe the situation where consumers and/or firms fail to adopt energy saving technology, despite the fact that doing so would lower energy expenditures by more than the cost of adopting

[5] Possible explanations for the low resale value of the Leaf include the absence of a federal or state tax credit, consumer concern about battery reliability, recharging difficulties, and a possible perception that plug-in vehicle technology is improving rapidly over time.

[6] The findings of Anderson et al. (2013) support the no-change forecast during normal economic conditions. However, during the 2008 financial crisis they report a deviation from the no-change forecast where consumers predict that prices will rebound. In light of that finding, the authors caution against adopting a no change forecast scenario in periods of severe price shocks.

the energy-efficient technology (Greene, 2010). This topic has received a significant amount of attention in the academic literature.

The most recent and more empirically sound studies suggest that there is little evidence in support of the energy gap's existence (Sallee, 2011; Allcott & Greenstone, 2012; Allcott, 2013). Specifically, Allcott & Greenstone (2012) identify four strands of empirical literature that have attempted to determine the existence of the energy gap. Some studies relate to autos; others concern non-auto energy investments.

The first strand, which covers engineering studies, estimates the net present value of a set of possible energy efficient investments. This strand of the literature generally finds evidence of a substantial or even extremely large gap (Granade et al., 2009; Greene, German, & Delucci, 2009; Greene, 2011; Rosenfeld et al., 1993). NRC (2015a) provides a useful summary of this literature as it applies to automobile fuel economy.

Second, there is a strand of literature that evaluates the impact of federal and state energy conservation policies (e.g., the Weatherization Assistance Program [Schweitzer, 2005]). These studies estimate the average return for the set of consumers who adopt an energy efficient technology, but often fail to calculate the present discounted value of the energy savings. Overall, these studies find that weatherization reduces energy consumption and thus provides consumers with savings. However, they generally require payback periods in excess of ten years, which suggest that failure to adopt these energy efficient goods might actually be a rational choice. In other words, evidence from this literature does not sufficiently establish the existence of a gap.

The third strand of the literature evaluates the cost effectiveness of energy conservation programs implemented by utility companies. The energy gap is said to exist if the cost of implementing the program is lower than the savings produced by the program. The results from this strand of the literature suggest that the gap is very small if it exists at all (Arimura, Shanjun, Newell, & Palmer, 2012).

The final strand considers the trade-off between durable goods that differ in their energy efficiency only. The idea is that any changes in the fuel cost of a car should be capitalized in its market price. Therefore, the energy gap exists if, relative to a fuel inefficient car, the market price of a fuel efficient car increases by less than the increase in the present discounted value of fuel costs. The evidence from this strand of the literature favors the conclusion that the gap either doesn't exist or is very small (Allcott & Greenstone, 2012). For example, two studies find no evidence of a gap (Busse et al., 2013; Sallee, West, & Fan, 2015) while another two studies find evidence of a small gap (Allcott, 2013; Allcott & Wozny, 2014).

Each of these analytic strategies face interpretation issues. The first three strategies ignore the non-fuel economy unobserved utility cost associated with choosing a fuel-efficient car. For example, fuel efficient vehicles tend to be smaller and have less power. To the extent that people value power and size, this implies that the present discounted value of fuel savings and resale value must be large enough to cover the incremental upfront cost and the utility loss associated with diminished power and/or smaller vehicle size. The fourth strategy described above represents an important advancement in the literature in that it controls for the utility costs. However, because the recent estimates are based on variation in fuel prices, their application to CAFE standards requires the (unverified yet plausible) assumption that consumers respond to increases in fuel economy the same way they respond to changes in fuel prices.

The possibility of utility losses from fuel-saving automotive technologies needs to be taken seriously. As regulators have imposed stricter fuel-economy standards on automakers, industry surveys have found that the perceived quality of new vehicles has suffered. Michelle Krebs of Edmunds.com has commented that "...automakers are tweaking their engines and transmissions to maximize fuel economy, but their experiments have taken their toll in terms of driving experience, and quality ratings are suffering as a result" (Woodyard, 2011).

For example, automakers have added turbochargers to smaller engines in order to boost fuel economy and performance. Consumers Union reports that some motorists who are unsatisfied with the acceleration capability of the turbocharged engine push down the pedal strongly, thereby dampening the fuel economy of the vehicle.

Thus, consumers may be frustrated by either poor acceleration or real-world fuel economy that is less than was advertised by the vehicle manufacturer (Truett, 2013).

All-aluminum pickup trucks save fuel but also have their downsides. Aluminum is more prone to contamination than steel in the painting process. Consumers report more paint problems and corrosion with aluminum. Ford Motor Company is addressing such issues through new production processes and consumer advisories but it should not be assumed that the only downside of aluminum is its higher production cost (Travers, 2015).

In summary, in order to assess the impact of regulations on new vehicle sales, the best available evidence on consumer valuation of fuel savings and other vehicle attributes should be evaluated. If more than one approach to consumer valuation seems plausible, then a sensitivity analysis of different approaches is reasonable. This is the analytic strategy pursued by NHTSA in 2012 and we believe it should be retained but refined in the midterm reviews, using the new evidence on consumer valuation of fuel savings.

3. **Regulatory analysts should develop a realistic baseline fleet of passenger vehicles when reanalyzing the model year 2017-2025 standards.**

When estimating the impact of model year 2017-2025 standards on new vehicle sales, agencies need a realistic baseline fleet of vehicles to use for comparison purposes. The baseline is the fleet of vehicles that would be sold to consumers if CAFE/GHG standards were frozen at their 2016 levels. The characteristics of those vehicles (price, fuel economy, and other attributes) can then be compared to the characteristics of the vehicles subject to the model year 2017-2025 standards (price, fuel economy, and other attributes). If the regulated vehicles are more attractive to consumers, then the volume of new vehicle sales should increase; if they are less attractive, new vehicle sales should decline.

In the final rulemaking for model years 2017-2025, EPA/DOT started with a simulated fleet of 2016 vehicles as improved by the 2011-2016 standards (i.e., fuel-economy certification data for the 2010 fleet was used as a baseline and then fuel-saving technologies were applied until the simulated 2016 fleet was in compliance with the 2016 standards). Other vehicle attributes such as performance (e.g., horsepower and acceleration capability) and safety (e.g., number of airbag systems in the vehicle) were held constant from 2010 to 2016.

Both NHTSA (DOT, 2012) and NRC (2015a, p. 320, p. 363) have pointed out that it is not realistic to assume that, in the absence of stricter standards for 2017-2025, fuel-expending improvements such as increased performance and enhanced safety would not have been implemented by automakers. A robust body of historical data does show that, as technological advances proceed, automakers deliver more performance, acceleration capability, and fuel economy to consumers (EPA, 2015). Without pressure from regulation or high fuel prices, innovation tends to be channeled to performance and acceleration capability instead of fuel economy (Knittel, 2011). Those improvements in performance and safety, if foregone by the stricter 2017-2025 standards, represent an "opportunity cost" of the stricter standards that should be analyzed (NRC, 2015a, p. 327). However, it is difficult to know exactly what those characteristics would have been and how consumers would have valued them.

A tractable approach to addressing this issue, which we recommend, is to assign a fuel economy penalty in the baseline 2017-2025 fleet for the projected improvements in performance and safety that producers would deliver in response to consumer and regulatory demands. For example, in 2002 NRC recommended that NHTSA assign a 3.5% weight penalty in the baseline fleet for future safety and smog-related emissions requirements (NRC, 2002, p. 66, p. 76, p. 112). NHTSA has found that some safety systems do add to the weight of the vehicle (Tarbet, 2004). The extra vehicle weight can then be assigned a fuel economy penalty using standard methods. Likewise, it would be reasonable to assume a 1% or 2% annual gain in horsepower in the baseline fleet to meet consumer demand, and an associated fuel economy penalty for the added horsepower (EPA, 2015).

The consequence of the fuel economy penalties is that a more extensive and costly set of fuel economy technologies are necessary to bring the baseline fleet into compliance with the 2017-2025 standards. The cost of those additional technologies (with deductions for the fuel savings) are then incorporated into the analysis of vehicle prices and impacts on new vehicle sales and employment.

An advantage of this approach is that the agencies can maintain their preferred analytic assumption that safety and performance will not be affected by the regulatory requirements. All that changes are vehicle price and fuel economy, and those characteristics can readily be linked to new vehicle sales with established methods and data. This approach is also consistent with recent empirical work demonstrating that consumers are willing to pay more for increases in performance than for a proportional increase in fuel economy (Klier & Linn, 2012; Bandivadekar et al., 2008; NRC, 2015a).

For CARB's updated consumer payback analysis, the baseline fleet of vehicles should reflect the gains in fuel economy projected to result from the 2017-2021 federal CAFE standards. For 2022-2025, CARB can incorporate the EPA standards, since NHTSA has not yet finalized standards for 2022-2025.

The size distribution of the passenger vehicles in the baseline fleet also needs to be reconsidered. From 2009 to 2012, when the federal government and CARB were developing new regulatory requirements for model years 2017 to 2025, the automotive marketplace appeared to be increasingly receptive to more fuel-efficient vehicles and PEVs. From 2000 to 2012 the average fuel price (nominal) climbed from roughly $1.00 per gallon to almost $4.00 per gallon. The small-car market share was on the rise (from 15.2% in 2000 to 19.6% in 2012). The market shares of large SUVs and pickup trucks were declining. Additionally, both HEVs and diesels were capturing larger market shares. Not surprisingly, NHTSA (2012) assumed a gradual shift in market share from light trucks to cars from 2017 to 2025.

In the three years since the regulations were finalized, the patterns of consumer purchasing decisions in the automotive marketplace have begun to change significantly. The small-car market share has declined for three years in a row. The pick-up truck share is no longer on the decline. The SUV market share is rising, driven by crossover sales. The market shares of HEVs and diesels are beginning to decline. Furthermore, after five years of significant growth (2010-2014), the absolute number (as well as share) of PEVs sold in the U.S. declined in 2015, despite numerous federal and state incentives (EDTA, 2015).

Only a few years ago, market analysts were projecting a 60-40 split, cars over trucks. Now analysts are projecting 60% truck sales for the foreseeable future. In late 2015, monthly counts revealed 59% light truck sales in the U.S. (Bennett & Stoll, 2015). Table 5 illustrates this trend in market shares from 2009 to 2015.

A recent study of consumers who traded in their HEV or PEV found significant differences in their 2015 decisions compared to 2014 and 2013. The percentage of the consumers who traded in for a new SUV was 22 percent in 2015 compared to 18.8% and 11.9% in 2014 and 2013, respectively. Loyalty rates for HEV and PEV owners fell below 50% in 2015 for the first time (Edmunds.com, 2015).

Thus, there is an emerging body of real-world evidence that consumers are not particularly inclined to purchase the fuel efficient and zero-emission vehicles that automakers are offering pursuant to regulation. Such evidence lends credence to the hypothesis that stricter federal and ZEV requirements could have an adverse impact on new vehicle sales.

Table 5. Market Share of Passenger Cars vs. Light Trucks

	2009	2010	2011	2012	2013	2014	2015
Passenger Cars	52%	49%	48%	50%	49%	47%	43%
Light Trucks	48%	51%	52%	50%	51%	53%	57%

Source: (Ward's Auto, 2016b)

4. The midterm reviews should incorporate authoritative, up-to-date technical information on fuel-saving technologies, including alternative fuel vehicles.

Since 2012, substantial real-world experience has been acquired with fuel-saving technologies, including alternative fuel vehicles such as the advanced diesel engine and HEVs. Here we draw on this experience to inform the midterm reviews. We do not address some alternative fuels (cellulosic ethanol, natural gas, and propane) that seem unlikely candidates for rapid expansion between now and 2025 due to financial and infrastructure barriers.

Refinements to the Gasoline Engine

Since the CAFE program was revived in model year 2004, manufacturers have made steady progress in producing and selling more fuel efficient vehicles with higher average fuel economy. Passenger vehicle fuel economy has increased 26% (or 5 MPG) over this period, to an industry average of 24.3 MPG in model year 2014 (approximately 27.9 MPG for cars, 20.4 MPG for light trucks). Roughly half the gains have been attributed to better technology, as opposed to consumer shifts to more fuel efficient products (Khanna & Linn, 2013). The gains in model years 2014 and 2015 (preliminary data) have slowed, as consumers have increasingly purchased vehicles with lower average fuel economy (e.g., crossovers, pick-up trucks, and other SUVs), virtually nullifying the effects of better technology (EPA, 2015; University of Michigan Transportation Research Institute [UMTRI], 2015).

In the last five years, the bulk of the technology-based gains in fuel economy have been accomplished through refinements to gasoline-powered vehicles. Those refinements include variable valve timing, multi-valve engines, gasoline direct injection, turbochargers, 6+ speed transmissions, and continuously variable transmissions. Only a small portion of the gain in average fuel economy is attributable to new propulsion systems (i.e., HEVs, diesels, and PEVs; EPA, 2015).

There is much debate about the extent to which the 2025 standards can be met through continued refinements to gasoline-powered vehicles as opposed to increased investments in alternative fuel vehicles. On the one hand, some suppliers project that automakers will be able to achieve the 2025 federal EPA and NHTSA standards through a wide variety of refinements to the gasoline engine, without investing in alternative propulsion systems (Sedgwick, 2014). On the other hand, several leaders of vehicle manufacturers have indicated publicly that significant sales of PEVs and/or FCVs will be necessary to comply with the federal standards in model year 2025 (Rechtin, 2012; Beene, 2015a).

The average rate of fuel economy improvement since model year 2004 has been 0.5 MPG per year. If that rate of improvement is replicated for the next decade, the 2025 target of 54.5 MPG will not be achieved. An additional 10 years at +0.5 MPG per year would elevate the industry average from 24.3 MPG to only 29.3 MPG. Another indication of the difficult path ahead is that only 3% of the model year 2015 vehicle production could meet the 2025 NHTSA goal for fuel economy and the 2025 EPA standard for GHG emissions. Those few vehicles are predominantly PEVs and FCVs (EPA, 2015). One academic analysis envisions 50% hybridization by 2025 (Lutsey & Sperling, 2009).

A recent authoritative report from the National Research Council (NRC, 2015a) examined a wide range of fuel-saving technologies—some already in use, others in development—that could be used by manufacturers to help achieve the 2025 standards. That report finds that large gains in fuel economy are feasible through additional refinements to the gasoline engine, though new fuel-saving technologies will add to the price of new passenger vehicles, with uncertain ramifications for consumer acceptance and new vehicle sales. NRC (2015a) did not estimate compliance costs or impacts on new vehicle sales. But, NRC (2015a, p. 275) did find, for a mid-sized car, that the cumulative technology costs for the 2025 standard could be 11 to 56% greater than NHTSA's 2012 estimate. NRC (2015a) did not account for any of the compliance flexibilities in the CAFE and EPA programs.

The EPA and NHTSA RIAs of 2012 concluded that industry would meet the 2025 standards primarily through refinements to the gasoline engine, without making widespread use of alternative propulsion systems such as diesels, conventional hybrids, and plug-in electric vehicles. The midterm review should revisit this question in light of the NRC (2015a) report, the growth in the rate of sales of light trucks, a more realistic baseline fleet of vehicles, the presence of the ZEV regulation, and new evidence about consumer attitudes toward fuel economy and available technologies.

Substituting Lightweight Materials

Since 2012, an important development in vehicle fuel economy has been the greater-than-anticipated contribution of mass reduction to fuel economy gains. Specifically, manufacturers are reducing mass by substituting lighter-weight materials. Downsizing of vehicles is less attractive, in part because the federal programs impose stricter mileage and GHG control requirements on vehicles with smaller footprints.

In addition to the direct fuel-consumption benefit of a vehicle with lighter materials, a secondary benefit occurs because engineers can reduce the size of the needed powertrain, braking systems, and crash management structures (NRC, 2015a, p. 107). Taking account of both the direct and secondary benefits, each 10% drop in vehicle weight can achieve a 5.7 to 7.4% drop in fuel consumption at a cost of approximately $700 per vehicle. Larger weight reductions require disproportionately larger costs, such as $1,600+ per vehicle for a 20% mass reduction (NRC, 2015a, p. 113).

The NRC (2015a, p. 264) fuel-saving estimates for a 20% weight reduction are approximately 20% larger than NHTSA assumed in 2012. If this estimate holds up in the midterm review, weight reduction will look more attractive to consumers and manufacturers than NHTSA and EPA envisioned in 2012.

Ford Motor Company is already making much greater use of aluminum (rather than steel) in its largest-selling vehicle: the F-series pickup truck. The 2015 F-150 is fitted with aluminum instead of steel for every panel except the firewall, resulting in a 700 pound loss of weight compared to the steel-based 2014 F-150. In effect, the new truck has a high-strength steel frame coupled with an aluminum body. For this rugged-vehicle application, the aluminum is strengthened with extra thickness and heat-treating after it is formed. EPA reports that Ford's 2015 F-150, due to weight reduction, a smaller engine, and other fuel-saving features, is already near compliance with the 2025 EPA truck target for GHG emissions and is rated overall at 22 MPG (Williams, 2015b).

Ford's decision has triggered an aggressive competitive response from steelmakers. Advanced high-strength, light-weight steels (AHSS) are being marketed that cost less and have fewer lifecycle GHG emissions than aluminum. AHSSs have been incorporated into the 2015 Chevrolet Colorado, the 2015 Ford Edge, and the 2015 Nissan Murano (American Iron and Steel Institute [AISI], 2015).

Given recent developments, the midterm reviews must address some issues with lightweight materials that were not considered adequately in the 2012 RIAs. These issues include not only lifecycle GHG emissions, since an older study touted the advantages of aluminum (Ungureanu, Das, & Jawahir, 2007), but also new concerns regarding occupant safety and repair costs.

First, the IIHS tested both the four door F-150 SuperCrew and the smaller SuperCab version in a battery of crash tests (IIHS, 2015a; Valdes-Dapena, 2015). Both Ford trucks performed well in normal frontal and side-impact tests. However, the smaller version did not perform well in IIHS's new overlap frontal crash test. About one-quarter of serious and fatal injuries in real-world frontal crashes are caused by "small overlap" frontal impacts, such as collisions with trees and utility poles. IIHS noted that Ford added additional structures to the F-150 SuperCrew that prevented passenger compartment intrusion in the test. The SuperCab version, without the additional structures, experienced crushing of the passenger compartment and a risk of foot and leg injuries. The good safety performance of the SuperCrew version in the overlap test suggests that the issue may be addressable with special design features.

Second, IIHS also tested the new 2015 F-150 in low-speed crash tests. The results show more vehicle damage and 26% greater repair cost than steel-based models (IIHS, 2015b; Valdes-Dapena, 2015). The concern is that property-damage insurance premiums could rise due to aluminum substitution. Ford counters that the early real-world experience with the 2015 F-150 shows lower repair expenses than experienced with the 2014 F-150 (Williams, 2015a; Hirsch, 2015).

In summary, advances in lightweight materials are helping automakers comply with federal requirements. The midterm reviews need to address the relative cost of materials, safety, repair costs, and lifecycle GHG emissions. The most recent data on consumer reactions to aluminum vs. steel should also be examined.

Advanced Diesel Technology

A major difference between Europe and the U.S. is the penetration of the diesel engine into the passenger vehicle market. Diesels account for 53% of new passenger vehicle sales in Europe compared to 2.75% in the U.S. (Clark, 2015). Tax and regulatory policies contribute to the difference (Cames & Helmers, 2013). Europe imposes higher taxes on gasoline than diesel fuel while the U.S. favors gasoline over diesel in tax rates. The emission-control regulations for smog and soot from diesels have historically been stricter in the U.S. (especially in California) than in Europe, which has facilitated the expansion of the diesel market in Europe and restrained diesel penetration in the U.S.

As concerns about GHG have become at least as important as fuel efficiency per se, the case for expanded use of diesel technology has weakened somewhat. Diesel fuel produces 15% more CO_2 emissions per gallon than gasoline (NRC, 2015a). Thus, even though diesel engines can achieve 30% higher mileage ratings than gasoline engines and help comply with NHTSA's fuel-economy requirements, the diesel engine offers only about a 20% advantage in carbon emissions compared to a gasoline engine. As a result, shifting from a gasoline to a diesel engine may not, by itself, be sufficient to bring a light-duty passenger vehicle into compliance with EPA's 2025 GHG requirements.

The cost premium on a diesel engine is substantial. For a mid-sized sedan, the manufacturing cost premium for a base engine is approximately $3,300 to $3,600 per vehicle (NRC, 2015a), or at least $4,600 (with a 1.5 retail markup). For applications to large pickup trucks and SUVs, the cost premium (without retail markup) will exceed $5,000. The Ford F-250 Super Duty (diesel), for example, has an $8,500 price premium over the gasoline version, plus substantially higher maintenance expenses. However, the Ford diesel reportedly lasts 100,000-200,000 miles longer than the gasoline engine and delivers superior torque and towing capability (Ford Truck Enthusiasts, 2014).

The price of diesel fuel is also higher than the price of motor gasoline. The price spread is typically about 10%, but the spread fluctuates and vanished temporarily in May of 2015 (Diesel Technology Forum, 2015b). EIA forecasts that the spread will be 11% in 2016 ($2.67/$2.36) and 12% ($3.49/$2.95) in 2025 (EIA, 2015b). The persistence of the unfavorable price spread for diesel is primarily due to tax policy, as the long-run marginal cost of refining oil into diesel fuel is generally less than gasoline.

Some recent news reports about the Volkswagen diesel scandal have suggested that VW's mistakes may jeopardize the commercial future of all light-duty diesel technology in the U.S. and Europe (Clark, 2015). This pessimistic scenario seems unlikely since other German manufacturers (BMW and Daimler), using different emissions-control technology (e.g., selective-catalytic reduction with a urea liquid added to the fuel), have had success with their diesel-powered sedans in the U.S. and Europe. Moreover, the number of light-duty diesel models offered in the U.S. is expected to rise from 39 in 2015 to 54 in 2016. Those manufacturers include not just VW and Audi but also BMW, GM, Ford, Chrysler, Daimler, Nissan, Porsche, and Range Rover (Diesel Technology Forum, 2015a; Colias, 2015b). Thus, advanced diesel technology is a promising federal compliance technology for vehicle manufacturers, but the price premium for the consumer will be significant. Moreover, the large investment in a diesel strategy will not help companies comply with the ZEV mandate and will help less with EPA's requirements than with NHTSA's fuel economy requirements.

The midterm review should give careful consideration to dieselization as a federal compliance strategy for 2022-2025. Some of the tax and regulatory policies that disadvantage diesel may merit reconsideration.

Conventional Hybrid Technology

Exemplified by the Toyota Prius, the HEV has two propulsion systems: a gasoline engine and battery-generated power. Hybrid models vary in how the two propulsion systems are integrated, but they all reduce fuel consumption in three ways: capturing for reuse some of the energy lost during braking, reducing idling, and enabling engine downsizing (NRC, 2015a, p. 130). Mild hybrids are distinct from full hybrids because they embody only some of the fuel-saving features of a full hybrid (e.g., a mild hybrid may have only a stop/start system).

A full hybrid can deliver 30+% gains in fuel economy and corresponding declines in GHG emissions. For example, the Hyundai Sonata hybrid delivers 51.5 MPG compared to 36.6 MPG for its gasoline counterpart; the Toyota Camry LE hybrid delivers 57.4 MPG compared to 38.2 MPG for the Camry (NRC, 2015a, 132). Since full hybrids often have other features that differ from gasoline comparators, it is sometimes difficult to isolate the fuel-economy gain that is attributable to hybridization per se.

HEVs are costly because they require two propulsion systems instead of one. For a mid-sized car, full hybridization may entail $2,000 to $2,700 in direct manufacturing costs, or an extra cost to the consumer of at least $3,000 (assuming retail markup of 1.5). For applications to large pickup trucks and SUVs, the cost penalty for full hybridization is likely much larger. Much of the incremental cost of hybridization is attributable to the cost of batteries (NRC, 2015b).

Due to the commercial success of the Toyota Prius (the #1 selling car in California in both 2012 and 2013), a reputable forecaster projected ten years ago that full hybrids might capture 7% of U.S. market share by 2015 (Shamit, 2008). Those forecasts were overly optimistic, as HEVs accounted for less than 3% of sales in 2015. Hybrid sales grew steadily from 2000 to 2008, were hurt by the Great Recession in 2009-2010, but surged to their peak in 2013 (547,095). Despite a growing car market, hybrid sales declined in both 2014 and 2015 (DOT, 2015). Survey researchers find that hybrids are favored by many respondents in "intent to purchase" studies, but many of those respondents do not follow through and purchase an HEV (Popiel, 2011).

For a company like Toyota, which has a strong edge in HEV technology, one might think offering hybrid engines on a wide range of Toyota products would be a fruitful federal compliance strategy. Indeed, Toyota has expanded its offerings of HEVs significantly over the last several model years.

Following Toyota's lead, the number of HEVs offered industry wide has grown from 24 in 2009 to 47 in 2014. However, the growth in HEV market share over the same period has been slower, from 2.4% to 3.0%, and the HEV share actually declined in 2015 (Libby, 2015).

A variety of explanations have been offered for the unexpectedly slow growth of the HEV market share. Each of the following explanations has some supporting evidence or is considered plausible by industry experts:

1. An increased payback period has curtailed consumer incentive to purchase an HEV. This is due to:
    a. the significant price premiums for HEVs compared to comparably-sized gasoline vehicles;
    b. declining gasoline prices;
    c. the removal of state and federal tax credits for HEVs (e.g., a federal income tax credit of $3,400 for HEVs expired at the end of 2010; Diamond, 2009; Chandra, Gulati, & Kandlikar, 2010; Beresteanu & Li, 2011; Gallagher & Muehlegger, 2011);
2. The removal of HOV lane access, which had helped boost HEV sales in California and other congested areas, has depressed demand for HEVs (Sewell, Mather, & Bloomekatz, 2011; Healey, 2011);
3. Greener versions of gasoline-powered vehicles (e.g., Ford's Ecoboost engine) are seen by some consumers as more cost-effective than an HEV;
4. The growth in public subsidies and social marketing for PEVs has channeled environmentally conscious consumers away from HEVs to PEVs.

From a performance perspective, HEVs tend to have faster acceleration times from 0 to 30 miles per hour but slower times from 0 to 60 miles per hour compared to gasoline engines (NRC, 2015a, p. 154). In terms of reliability, the batteries in the Toyota Prius have been highly reliable but some cautious consumers may have doubts about battery reliability. Thus, there may be some perceptions of hybrid performance or reliability that deter some buyers.

Proponents of the HEV argue that Toyota's new version of the Prius, due in most showrooms by early 2016, will be crucial in determining the near-term commercial success of HEVs (McCormick, 2015). Consumers may be shying away from the old version of the Prius because they know that the new version will be out soon.

Toyota's experience with the 2016 RAV4 Hybrid (a crossover) will also be instructive. It is rated at 34 MPG-city, 31 MPG-highway, 33 MPG-overall compared to the gasoline version's ratings of 22 MPG-city, 29 MPG-highway, 26 MPG-overall. The RAV4 Hybrid also delivers more horsepower and torque than the gasoline version. Toyota has priced the RAV4 Hybrid only $700 above the gasoline version, causing one prominent car reviewer to describe the vehicle as a "No Brainer Gas Saver." Yet Toyota remains cautious, predicting that only 10-15% of RAV4 buyers will select the hybrid (Woodyard, 2016).

Overall, the midterm reviews should explore carefully consumer reactions to the conventional hybrid, and whether it can serve as an effective bridge to PEVs. However, the presence of the ZEV mandate may deter investments in HEVs since CARB determined that they no longer contribute to compliance with the ZEV mandate. EPA is offering compliance incentives for hybrid trucks, but CARB is discouraging hybrid trucks in its ZEV program.

5. Methodological improvements are possible for new regulatory analyses in order to provide a more accurate and complete understanding of the macroeconomic effects of the federal and ZEV regulatory programs.

Previous RIAs prepared by the EPA and NHTSA are marked by three important methodological limitations. First, the approaches taken to model the macroeconomic impacts of the standard are overly simplistic and do not capture dynamics within the economy. Second, the modeling analyses employed in these studies only track vehicle production decisions and do not additionally account for other important energy sector ramifications. Third, these studies present national level estimates of sales and employment impacts but do not additionally disaggregate these results to the regional or state levels. Each limitation is discussed in more detail below.

An enhanced methodological approach should account for two major processes. The first is the technological component, in which auto manufacturers respond to federal and state mandates by altering their vehicle technologies as well as the mix of vehicles that they offer to consumers. Contingent on consumers' demand elasticities as well as a variety of other parameters that specify consumers' behavior, one can generate estimates of total vehicles sold and the total cost of these vehicles over a set time frame. The second process is the macroeconomic component, in which one can track the effects of changes in vehicle prices and sales through the economy. For example, one may measure the effects on U.S. gross domestic product, or employment, wages, or output in specific economic sectors.

These processes are generally modeled as separate steps due to the methodological capabilities and limitations of most models. The separate steps then need to be linked.

The two processes lend themselves well to bottom-up and top-down models, respectively. A bottom-up model is a techno-economic model—also referred to as a "process-oriented model"—that simulates market dynamics due to technological or policy scenarios. These models are often based on cost minimization and they tend to provide significant detail across different energy technologies. A top-down model, on the other hand, tracks market supply and demand over time and across different economic sectors. Different top-down modeling techniques include input-output models, computable general equilibrium (CGE) models, and econometric models.

Previous studies of CAFE have used a combination of these types of models, or alternative simplified modeling approaches.[7] Regulatory impact analyses of the CAFE standards, such as those prepared by the EPA and NHTSA, focus the majority of their efforts on bottom-up modeling, and then use simplified calculations to derive potential employment impacts that correspond to changes in sales and the costs of vehicles. The EPA, for example, uses the Optimization Model for reducing Emissions of Greenhouse Gases for Automobiles (OMEGA), a bottom-up model of the transportation sector, to simulate those vehicle packages that different manufacturers will use to comply with regulatory requirements. From this model, they extract estimates of the upfront cost of vehicles that will be sold to comply with the standard, and compare the upfront costs to the present value of fuel savings over the primary ownership of the vehicle. The net cost, passed through to vehicle prices, is converted to an estimate of total vehicles sold based on a demand elasticity. This kind of analysis has been conducted by the EPA in previous rulemakings. However, in setting the 2017-2025 standards, the EPA did not estimate changes in car sales. The agency is in the process of finalizing a vehicle choice model that, when linked with the results of the OMEGA model, will generate car sales estimates. Furthermore, in the absence of estimates about car sales, the EPA relies solely on the cost effect to determine the employment impacts of the regulation. That is, the agency estimates the overall cost of compliance, and then applies a ratio of workers per $1 million spent in the automobile sector, weighted by the percentage of vehicles that are produced in the U.S. relative to those sold domestically, to determine the employment effects.

In a similar process, NHTSA uses the Volpe model—also referred to as the CAFE Compliance and Effects Modeling System—to estimate vehicle costs. Like the OMEGA model, the Volpe model assembles vehicle options from which manufacturers may choose in a constrained cost-minimization, bottom-up model. They take the derived sales estimates and divide by the average number of vehicles that an employee produces in a year, as they assume this calculation can serve as a measure of "job years." They then multiply this estimate by the same ratio of domestic production to domestic sales as used in the EPA analysis. Both the NHTSA and EPA employment estimates only apply to the auto industry, and do not extend to other sectors of the economy through "ripple effects."

This basic overview of the methodological approaches used in the RIAs highlights the observation that the regulatory agencies used simplified assumptions to derive employment impact estimates. It is important to note, however, that the main objective of these studies was to provide a benefit-cost analysis of the rulemaking, not produce estimates of macroeconomic impacts. Yet, as argued earlier in this report, an assessment of the effects of CAFE and other transportation regulations on the U.S. economy is fundamental to our understanding of how these regulations will perform. Through the use of simplified assumptions about the manner in which vehicles sales will affect employment, and without considering these effects through a dynamic modeling structure, these previous studies may have produced unrealistic estimates. Top-down models that can account for interactions among different economic sectors and long-term supply and demand balances, to list just two possible advantages, could be used to produce a more detailed understanding of the impacts of these regulations on the U.S. economy. Of course, each top-down model has its own set of limitations, as is well documented in the EPA regulatory impact analysis, and these limitations must be weighed carefully.

The second methodological limitation of previous regulatory impact analyses pertains to the level of information contained in the bottom-up models. An extraordinary feature of the OMEGA and Volpe models is the degree of technological detail on the vehicle options from which the model may select. The OMEGA model, for example, includes a few hundred vehicle options, with variations in vehicle class, vehicle type, engine size, valve train configuration, and valves per cylinder. This detail, however, comes at a cost, where the focus is exclusively on technological alternatives among vehicles, whereas other features are omitted. Examples of such omitted features include the treatment of the electricity sector and other non-transportation related energy sector categories.

The CAFE regulation has implications for the electricity sector, in that at least a small portion of CAFE-compliant vehicles will be PEVs. The proportion of PEVs may become larger or smaller, depending on how regulators design

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[7] For an overview of the methodological approaches and parameter assumptions used in other studies, refer to the appendix.

compliance incentives and public subsidies. The need to include an electricity sector in the bottom-up models is even more pronounced in light of the ZEV standard. The production and consumption of PEVs could have important implications for electricity consumption and electricity prices, as well as for GDP and employment. The OMEGA and Volpe models also do not account for consumer demand endogenously for either vehicles or electricity, which means that estimation of both micro and macroeconomic impacts may be misspecified.

The third limitation of previous modeling efforts—not limited to the RIAs but also including the majority of other grey literature, save a study by Bezdek and Wendling (2005)—is the lack of consideration of regional or state impacts. Sub-national analysis is important for understanding the effects of CAFE and other transportation regulations, since both automobile production and consumption is not the same across the entire U.S. Manufacturing centers and supply chain companies are geographically oriented. Furthermore, the electricity mix and electricity prices vary by state and geographic region, which will have important implications for the diffusion of PEVs. Given that the ZEV mandate is a state level policy, albeit clustered in specific regions, it is particularly necessary that the models used to evaluate this regulation provide either state or regional level granularity.

6. **The midterm reviews should carefully evaluate the benefits and drawbacks of the California ZEV regulation as it interacts with the federal regulations. If the ZEV regulation is retained following this reassessment, refinements to its design and implementation should be considered in order to reduce or prevent adverse effects on new vehicle sales.**

The simultaneous presence of two federal programs and the California ZEV program creates the potential for regulatory interaction and unintended consequences (Goulder & Stavins, 2011). The ZEV regulation was not incorporated into the 2012 uniform national program designed by the Obama administration. CARB's 2011 RIA was undertaken as if the federal programs did not exist. In addition, the 2012 EPA and NHTSA RIAs were conducted as if the ZEV program did not exist.

ZEV and CAFE

To illustrate the importance of regulatory interaction, we prepared a consumer payback analysis for a BEV at an interest rate of 5% and alternative assumptions about fuel price and fuel economy of a gasoline-powered car. Based on industry experience and recent survey evidence, a consumer payback period of only 3 to 5 years is considered unattractive for the typical retail car purchaser (Greene et al., 2013; CAR, 2011).

The results illustrated in Figure 6 show that the attractiveness of the consumer payback from a BEV purchase declines as gasoline-powered cars become more fuel efficient. This conclusion is evident in the upward and rightward shift of the payback curves as the fuel economy of gasoline vehicles increase from 30 MPG to 55 MPG in Figure 6.[8] In other words, for a given interest rate and fuel price, the payback period for a BEV increases as fuel economy of gasoline cars increase, *all else equal*. This insight suggests that the increased fuel economy mandated by the federal standards is likely to undermine the commercial success of BEVs, complicating implementation of the ZEV program and threatening a loss of new vehicle sales due to the ZEV requirements.

Further, the potential interactions between the federal and ZEV programs need to be analyzed because the presence of the ZEV program can have major implications for manufacturer compliance strategies, federal credit-trading markets, and attainment of environmental benefits (Leard & McConnell, 2015; NRC, 2015a; NRC, 2015b).

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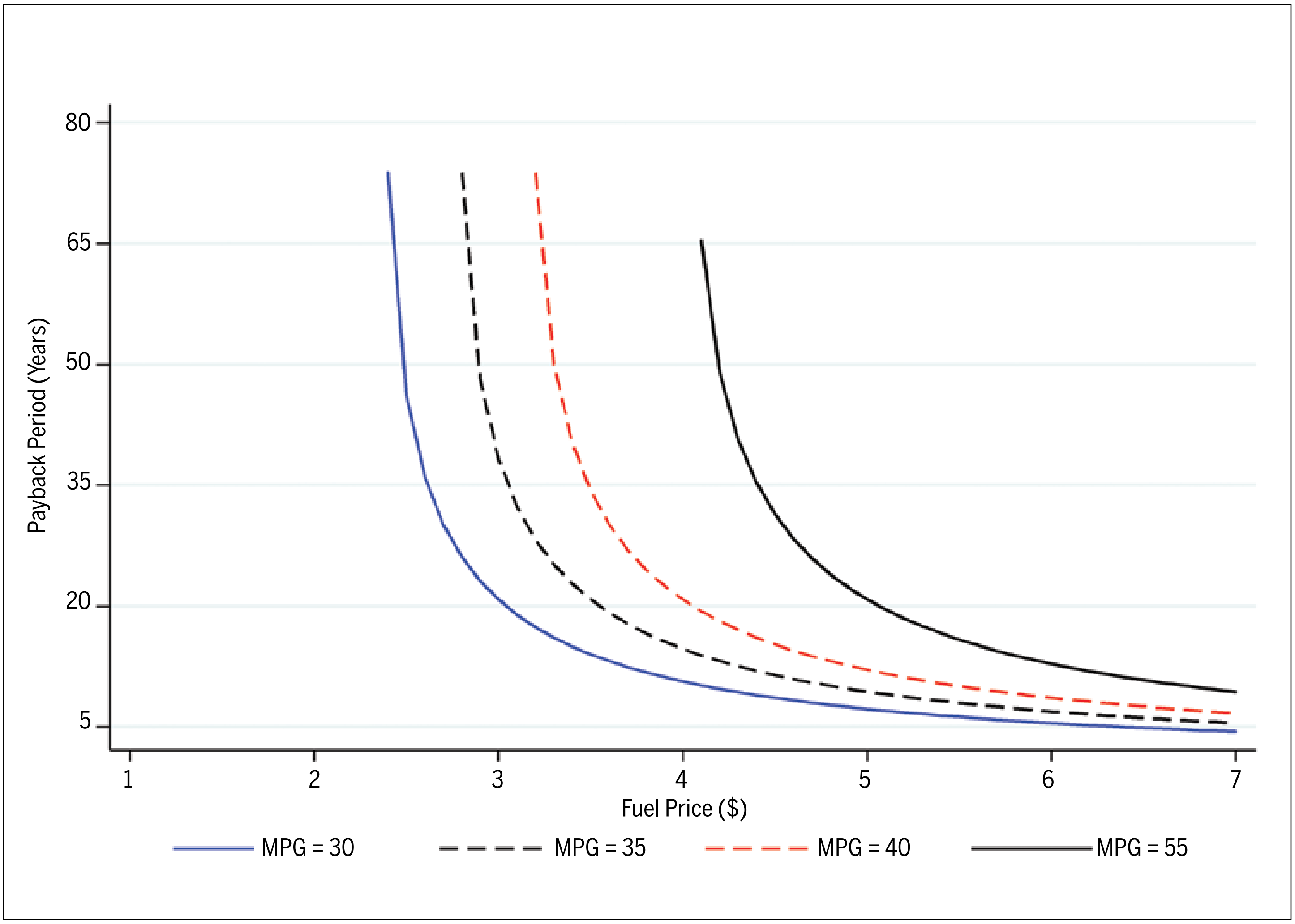
[8] Lower interest rates reduce the payback period while higher interest rates increase the payback period. However, additional analyses, not presented here, show that the relationship illustrated in Figure 6 holds true at interest rates of 3, 7, and 10%. The price premium of the BEV is set at $11,551 (see Table 5.7 of CARB [2011]) except for the 55 MPG car where the premium is set at $9,751 (=$11,551-$1,800). This $1,800 adjustment reflects the incremental cost of achieving 55 MPG by 2025 (DOT, 2012).

Figure 6. Payback Analysis (In Years) for a BEV with a 100-Mile Range Compared to Four Gasoline Vehicles



Notes: Reported is the payback period (in years) required to recoup the incremental cost of buying a battery-electric vehicle (BEV) at an interest rate of 5% and under various assumptions about fuel price. The BEV is compared to a traditional gasoline powered vehicle that gets 30, 35, 40 and 55 MPG, respectively. We assume that the consumer drives 12,500 miles per year, that the BEV has a range of 100 miles on a full charge of 35 KWh, and that electricity costs $0.15/KWh. We assume that the price premium is $11,551 for each of the gasoline cars except for the car that achieves 55 MPG where we assume a price premium of $9,751. The difference in resale value between the BEV and traditional vehicle is assumed to be zero. The analysis assumes that all parameter values are constant over the life of the vehicle, which implies that fuel savings are constant across time.

Manufacturer compliance with the ZEV regulation moves a company closer to meeting federal CAFE and GHG targets. Under the EPA program, vehicles that satisfy ZEV requirements not only count toward compliance with GHG standards, but they do so at a multiplied rate until 2021. The EPA, however, did not justify these compliance multipliers with cost-benefit analysis in its 2012 RIA.

Some critics argue that the overlap in compliance accounting limits improvements in the fuel economy of conventional vehicles (ICCT, 2012; NRC, 2015b). The NRC (2015b) states, “The vehicles that manufacturers sell to comply with the ZEV Mandate will form a part of their compliance with the CAFE/GHG standards, meaning that they will need fewer fuel economy improvements from their conventional vehicles than would have been required without the ZEV Mandate” (p. 354). Others argue that the overlap between regulatory programs might lead to a decrease in the size of the agency-sponsored credit markets, thereby reducing the cost-effectiveness of policy (Leard & McConnell, 2015).

ZEV and Local Pollution

Although the ZEV regulation is intended to reduce pollution, it is questionable whether it will have such an effect due to the presence of the federal regulations and their corporate averaging provisions (CARB, 2014). Lifecycle comparisons of PEVs do suggest environmental advantages over gasoline vehicles, as long as the carbon-intensity of power production is low (Tessum, Hill, & Marshall, 2014; NRC, 2015b). However, the averaging provisions in federal programs make it difficult for the ZEV program to make an environmental contribution.

Even CARB (2014) has acknowledged that "fleet average requirements ensure that air quality benefits do not suffer as a result of an automaker producing fewer ZEVs" (p. 17).This comment was made in reference to the positioning of the ZEV program within California's Advanced Clean Car Program, which sets fleet average emission standards commensurate with EPA standards, and CARB's proposed modifications to the ZEV program that would relax requirements for intermediate-volume manufacturers. Further, a careful modeling exercise of California's policy demonstrated that CARB's GHG program for motor vehicles in AB 1493 (2002) does not necessarily result in significant environmental benefits since vehicle manufacturers can count the vehicles produced for California in their compliance calculations for the EPA and NHTSA programs (Goulder, Jacobsen, & Van Benthem, 2012). As long as the federal program is binding on a vehicle manufacturer, each ZEV produced for California will permit the manufacturer to produce another inefficient car elsewhere in the country. The ZEV program should be subject to a modeling exercise similar to what Goulder et al. (2012) applied to the California GHG standards.

The best case for continuation of the ZEV program might be control of local smog in the congested cities of ZEV states. The Los Angeles region and San Joaquin Valley are both classified as "extreme nonattainment areas" by EPA due to excessive smog levels (CARB, 2012d). However, the CARB and EPA standards for control of smog and soot from new vehicles have become so stringent that the environmental advantages of a ZEV are not nearly as large as they were when the ZEV program was launched in the 1990s (EPA, 2014). Moreover, some degree of local pollution will also occur at the electric power plant (e.g., nitrogen dioxide emissions from a power plant fueled by natural gas) when the ZEV is plugged into the electrical grid, and the net effect on pollution may depend on whether and how the electricity sector is regulated for emissions (Linn & McConnell, 2013). During the midterm reviews, CARB and EPA should determine whether there are any significant local air quality benefits from the ZEV regulation, taking into account the new tailpipe standards for conventional air pollutants enacted by CARB in 2012 and EPA in 2014 and the corporate averaging provisions in the CARB and EPA regulations (CARB, 2014). The induced power plant emissions should also be considered.

CARB (2012) has already acknowledged that the rationale for the ZEV program has shifted to GHG control as well as local air quality management. It does not matter where GHGs are emitted since they have the same effect on global climate regardless of emission location. The midterm reviews should also determine whether the ZEV program will accomplish any GHG control beyond what is accomplished by the federal programs.

Reconsidering the EPA Waiver

If the midterm reviews conclude that the ZEV program does not provide significant environmental benefits or has costs greater than benefits, stemming in part from interaction with federal regulatory programs, then EPA should withdraw the ZEV waiver provided to California under the Clean Air Act. Since that action would be unprecedented, it would likely face complex litigation. A more definitive approach would have Congress pass correcting legislation. Removal of the ZEV program would simplify the compliance obligations of vehicle manufacturers and remove any risk of an adverse national impact of the ZEV regulation on new vehicle sales.

National ZEV Program

If the midterm reviews conclude that continuation of a ZEV mandate is appropriate, then the inquiry should shift to whether the mandate should apply only to California and the other ZEV states or whether a national ZEV program under EPA authority would be preferable. A national program would provide more compliance flexibility to vehicle manufacturers, since a ZEV sale in Atlanta would have equal value to a ZEV sale in San Francisco in compliance calculations. Under the current ZEV mandate, vehicle manufacturers earn no compliance credit for ZEVs sold outside of California and the other nine ZEV states. If a national ZEV program is considered, the precise levels of stringency need to be determined based on careful technology assessments and cost-benefit analysis, including consideration of the federal incentives for PEVs and FCVs that are already in place (e.g., the $7,500 federal income tax credit for qualified PEVs and the compliance incentives for BEVs, PHEVs, and FCVs in the 2012 EPA GHG rule). The interaction of federal and state incentives for ZEVs with the state and federal regulatory requirements need to be analyzed carefully (McConnell & Turrentine, 2010; Congressional Budget Office [CBO], 2012; Linn & McConnell, 2013).

A key argument against a national ZEV program is that the environmental damages from use of gasoline and electricity are not uniform across the country. One study estimates that the average rate of environmental damages from electricity use are much lower in California than in the nation as a whole. Moreover, gasoline use in California is more environmentally damaging than it is in the rest of the country. Consequently, the environmental case for PEVs is much stronger in California than it is in most other states (Holland, Mansur, Muller, & Yates, 2015).

Reforms of the ZEV Program

If the midterm reviews conclude a California ZEV regulation should be pursued instead of a national ZEV program, there are some burden-reducing refinements to the ZEV regulation that are worthy of consideration. Since consumers are likely to pay for burdens applied to all vehicle manufacturers through pass-throughs in vehicle prices, burden-reduction efforts should reduce the risk of adverse impacts on vehicle sales.

First, CARB could slow the ramp-up of the percentage ZEV requirements, offering more time for the price of battery technology to decline and for ZEV states to prepare their communities for an influx of PEVs. CARB has taken similar steps in the past, when it was apparent that market conditions could not support rapid commercialization of PEVs.

Second, current credit accounting flexibility could be retained for several additional model years. The credit travel provision, which allows manufacturers to apply compliance credits earned for BEVs in one ZEV state to all other ZEV states, expires at the end of model year 2017. The elimination of the travel provision will essentially mean that manufacturers will be compelled to rapidly increase their production and sale of BEVs in all ten states. However, as we explain below, many states—including some ZEV states—remain ill-equipped to accommodate electrification of their passenger vehicles.

CARB's regional credit pooling arrangement is a useful innovation and would be even more useful in burden reduction if it was designed with fewer restrictions. For example, instead of requiring manufacturers to comply with ZEV requirements in each of the nine ZEV states, CARB could apply variable percentage requirements for future model years in the western and eastern regions based on the extent of regional progress in community readiness for PEVs and FCVs. The western region might have a more ambitious requirement than the eastern region until eastern states make progress on readiness. CARB currently does not permit overcompliance in California to be used by a manufacturer to compensate for shortfalls in the eastern and western regions. Insofar as GHG control is the primary rationale for future ZEV requirements, more flexibility should be provided in the regional pooling arrangements. Some of the additional flexibility can be provided by CARB; other forms of flexibility may require legislation.

A third regulatory reform option is to increase the number of credits awarded for TZEVs or increase the fraction of TZEVs that large manufacturers can count toward compliance with ZEV requirements. PHEVs, even those with a short all-electric range, are a more promising and cost-effective strategy for GHG emissions control and oil savings than BEVs (Michalek et al., 2011). Major manufacturers have requested this allowance, citing some advantages to the consumer of PHEVs over BEVs. At the same time, there are growing concerns that consumer demand for BEVs is not approaching the supply mandated under the ZEV regulation (Shelton, 2015).

Manufacturers already report incurring losses on BEV sales, stemming from high production costs and price discounts offered to encourage their sale. In 2013, the Chrysler Group conceded publicly a loss of $10,000 on each sale of a new Fiat 500e (Woodyard, 2013).

A fourth prospect for regulatory reform is to reset ZEV regulatory requirements according to electricity miles instead of production quotas by vehicle type. PHEVs tend to be driven more than BEVs, in part because PHEVs have fewer range restrictions. Manufacturers argue that electricity miles is a reasonable alternative to the current system, as it would credit vehicles based on their actual real-world performance (Nelson, 2015).

More generally, the California policy preferences for BEVs over PHEVs should be reconsidered (Michalek et al., 2011; Peterson & Michalek, 2013). The cash rebate in California for a BEV ($2,500) is larger than for a PHEV ($1,500). Even California's HOV-lane access has been adjusted to favor BEVs. An unlimited number of carpool lane stickers were made available to owners of BEVs or FCVs; only 40,000 (recently increased to 85,000) stickers were made available to PHEV owners (Berman, 2012; CARB, 2016). The stickers for PHEVs have reached the limit, which discourages sales of PHEVs. Furthermore, some PHEVs with short electric range (e.g., the Toyota Plug-In Prius) are not even eligible for the car-pool lanes in California. A midterm reassessment of the PHEV's role in ZEV implementation should be a priority.

The reforms suggested up to this point would limit adverse impacts of the ZEV regulation on the vehicle manufacturing industry and consumers. Attention must also be given to regulatory implementation strategies and consumer incentives to encourage the uptake of ZEVs.

Community Readiness for ZEVs

The success of the ZEV regulation can be enhanced—and any adverse effect on new vehicle sales lessened—by implementing measures that improve the readiness of communities for PEVs and FCVs (Sierzchula, Bakker, Maat, & van Wee, 2014; Graham et al., 2014; Clinton, Brown, Davidson, & Steinberg, 2015). Currently, some states and cities are much better prepared for PEVs than other cities (Carley et al., 2013), and the better prepared cities are not necessarily located in ZEV states (Clark-Sutton et al., 2016). The city of Atlanta, Georgia, for example, has highly progressive PEV policies and one of the highest penetration rates of PEVs among U.S. cities, primarily due to sales of the Nissan Leaf, but Georgia is not a ZEV state (Ramsey, 2014). A systematic analysis of ZEV readiness in the 31 largest U.S. cities found no strong evidence that PEV-ready cities are more likely to be located in a ZEV state (Clark-Sutton et al., 2016).[9]

Even the best prepared states and cities have a long road ahead to achieve a high degree of PEV readiness. The rate of PEV sales in California (3%) is much higher than the national average (0.5%), in part reflecting the extensive efforts made in California to pave the way for PEVs. Nonetheless, a contractor to the State of California determined recently that 102,000 to 190,000 charging points would be needed to support California's goal of one million plug-in vehicles by 2020 (National Renewable Energy Laboratory [NREL], 2014). As of August 2015, a total of 7,687 electric vehicle charging outlets were available for public use in the U.S. (California Energy Commission [CEC], 2015; DOE, 2015). New England states are only beginning to work on readiness and, not surprisingly, PEV sales rates in New England (0.6%) are only slightly above the national average.

A wide range of federal, state, and local policies could be implemented in order to enhance community readiness for PEVs (NRC, 2015b). Uniform standards, certification, and training throughout the industry are considered crucial to large-scale uptake of PEVs (Brown, Pyke, & Steenhof, 2010). NRC (2015b) found that progress on each of these fronts is inadequate. If public subsidies are expanded, subsidies of batteries—and especially sustained R&D for enhanced batteries—are more cost-effective than subsidies of public recharging (Peterson & Michalek, 2013; NRC, 2015b).

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[9] The EV readiness index is based on measures such as financial and nonfinancial incentives, favorable electricity pricing schemes, public charging networks, and inner-city parking incentives.

The challenges for FCVs are much greater than for PEVs because only recently has it become apparent that some automakers may choose to offer FCVs instead of EVs to meet the ZEV mandate prior to 2025, and the infrastructure requirements for FCVs are significant (Fleming, 2015). The midterm reviews should use the NRC (2015a) report as a blueprint for community readiness, and commission a similar report from NRC on readiness for FCVs. Further, until states demonstrate readiness for ZEVs, as defined by NRC (2015b) and NREL (2014), the travel provision should be retained.

Consumer Receptivity to PEVs

It is critical to consider consumer receptivity to PEVs in light of their costs (Helveston et al., 2015; Dumortier et al., 2015; Siddiki et al., 2015). If vehicle manufacturers price PEVs using standard costing and retail markup procedures, then the cost of a PEV to the consumer is likely to be substantial—much more than a conventional hybrid, an advanced diesel, or a greener version of the internal combustion engine. Exactly how much more costly it will be is uncertain because (a) lithium ion battery packs are the single largest source of cost, (b) the cost of manufacturing those battery packs is closely-held, proprietary information, and (c) the cost of battery packs is declining and is projected to decline significantly over the next decade (Baker, Haewon, & Keisler, 2010; Weiss et al., 2012; Orcutt, 2015).

Nonetheless, we start with some cost figures from the NHTSA 2012 RIA that are similar to figures in CARB (2011, ES-4). We then offer additional insight based on NRC (2015b). We focus on PEVs rather than FCVs because, despite recent technical breakthroughs, FCVs are significantly more expensive than PEVs. We focus on BEVs rather than PHEVs because BEVs are estimated to be slightly less expensive than PHEVs and they receive full credit under the ZEV program.

NHTSA (2012) estimated that a small BEV would cost $14,581 more than a baseline 2010 gasoline powered car. NRC (2010) warned that steep drops in the cost of producing lithium ion batteries are not likely. Nonetheless, by 2025 that additional cost was projected by NHTSA to decline to $7,899. An additional consumer cost of $1,000—equipment plus installation—should probably be added for a 240 volt home charger, which reduces the time for a full charge from 12-18 hours with a standard 110 volt outlet to 4-6 hours. That technology allows the BEV owner to obtain a full charge overnight and then drive up to 70-100 miles the next day without recharging (NRC, 2015b).

Not much has been released publicly about the degree to which the cost of producing lithium ion batteries has declined in the last year or two. One study reviewed all of the publicly available information and concluded that the costs of battery packs have been declining by 14% per year from 2007 to 2014 and thus the BEV may already be approaching cost competitiveness with the gasoline engine (Nykvist & Nilsson, 2015). NRC (2015b), after reviewing much of the same cost information and analyzing recent pricing and production decisions, came to a different conclusion; NRC (2015b) determined that NHTSA's forecast for 2025 remains valid.

Currently, the purchaser of a qualified BEV is eligible for a $7,500 federal income tax credit. NRC (2015b) emphasizes that the decline of battery production costs is occurring only gradually and probably not fast enough, given the planned phase out of the federal income tax credits for PEVs. The federal tax credit for the cost of the 240 volt charger has already expired and was not renewed. The $7,500 tax credit begins to phase out after a manufacturer produces 200,000 PEVs. Nissan, Tesla, and General Motors are likely to be the first manufacturers to reach that threshold, and probably will do so before 2025. In 2015 Tesla was the largest seller of PEVs in the U.S. (25,700 units sold) and the company's new Model X is only beginning to be delivered to consumers.

In summary, a small BEV in 2025 may face an $8,000 price premium and few financial incentives from the government to offset the premium. Based on this line of reasoning, NRC (2015b) concludes that the cost of plug-in vehicles will remain a significant barrier to purchase in 2025. NRC (2015b) recommends that Congress consider an enlargement of the manufacturer quotas or some extension of the federal income tax credit.

Given that Congress has not acted on the Obama administration's request to liberalize the federal tax credit (i.e., enlarge it to $10,000 and require the dealers to make the rebate at the point of sale), has not extended the credit for HEVs, and has allowed some subsidies and credits for ethanol to expire (ethanol can be seen as a competitor of electrification), the chances that Congress would authorize an extension of the federal tax credit for PEVs are quite uncertain. Nonetheless, the NRC (2015b) suggestion is worthy of consideration in the midterm reviews.

7. The midterm reviews should reanalyze the federal regulatory programs, seeking reforms that achieve energy security and environmental objectives but with less risk of adverse effects on new vehicle sales.

If it is determined that the current federal regulatory requirements will reduce new vehicle sales significantly, it is appropriate to consider reforms of the federal regulatory requirements that might prevent or attenuate the projected loss of new vehicle sales. Those reforms should be constructed in ways that respect, as much as possible, the federal regulatory objectives.

The CAFE Schedule

As currently designed, the stringency of the CAFE and EPA requirements ramp up significantly from model years 2022 to 2025, especially for light trucks. The consumer payback from those ramp-ups is unlikely to be attractive (in part due to low fuel prices), suggesting that adverse impacts on new vehicle sales are plausible.

One option would be to stretch out those ramp-ups from 2025 to 2030 or 2035, allowing additional time for the cost of fuel-saving technologies to decline, as NRC (2015a; 2015b) predicts will occur, and for fuel prices to rise, as EIA projects will occur from 2025 to 2030 and thereafter. Although the extension will slow the rate of decline in gasoline consumption and GHG emissions from new vehicles, an equivalent or greater magnitude of environmental benefits might be obtainable by enacting policies that accelerate the rate of retirement of older vehicles from the light-duty fleet (see Recommendation #8).

Safety Valve or Fuel Price Trigger

A second option would be to amend the federal programs to include a safety valve, such as those that are commonly used for cap and trade programs or for state renewable portfolio standards (i.e., alternative compliance payments). In other words, if the cost of compliance is shown to exceed a certain level, then CAFE requirements would be capped, lessened, or delayed. A safety valve amendment would likely require legislation.

With executive power, regulators could link the pace of the regulatory ramp-up to EIA forecasts of fuel prices for model years 2022-2025. EIA will publish forecasts of 2025 fuel prices annually between now and 2025, drawing from the best available information on global oil markets and other factors that influence fuel prices in the U.S. NHTSA and EPA should not adjust regulatory requirements annually, since manufacturers need sufficient lead time (four to six years for a new model) and regulatory certainty to adjust their product plans for new regulatory requirements. However, EPA and NHTSA could design, in the midterm review process, a planned linkage between fuel forecasts for 2025 and the 2022-2025 regulatory requirements.

Here we present a hypothetical illustration of how fuel-price forecasts might be linked to regulatory requirements. If EIA's fuel-price forecasts for 2025 rise significantly above $4 per gallon by 2020, then the federal requirements for model years 2022 to 2025 could remain as currently scheduled. If those fuel-price forecasts for 2025 are less than $3/gallon, then the ramp-up should be slowed considerably, possibly stretched out to 2035. If fuel-price forecasts for 2025 land between $3 and $4/gallon, then a stretch-out to 2030 might be appropriate.

The midterm reviews should consider carefully the merits of a safety valve versus a fuel-price trigger. If the trigger is preferred, it can be discrete or continuous in nature, in which a continuous approach would remove any rigidities near a fuel-price cut-point while a discrete approach would be easier to explain to policy makers and the public.

Off-Cycle Measures

A third option is for EPA and NHTSA to take a more systematic, consistent, and flexible approach to off-cycle measures that automakers can use to reduce vehicle fuel consumption and GHG emissions. Compliance is currently measured by laboratory (dynamometer) tests that focus on engine operations and air emissions (Roland, 2009). However, there are many valid ways for vehicle manufacturers to enhance vehicle fuel economy and reduce GHG emissions that are not measured in the specified laboratory compliance tests. Examples include better air conditioners, active grille shutters to modify airflow and improve aerodynamics, vehicle stop/start systems, electric heat pumps, solar panels, high-efficiency external lighting, solar reflective glass/glazing, solar reflective paint, active seat ventilation, and active transmission warm-up (Nelson, 2013b).

Under current law, NHTSA is apparently not permitted to consider off-cycle measures under the CAFE program while EPA is permitted to consider them. In the midterm review, NHTSA and DOT could recommend legislative language to permit systematic, consistent, and flexible use of off-cycle measures by both NHTSA and DOT.

The current EPA process has permitted some off-cycle measures (EPA, 2015). EPA has a predetermined list of permissible off-cycle measures, but the list is limited and is associated with conservative (i.e., low) credit values for compliance. Measures that are not on EPA's list—or measures that deserve values larger than EPA's conservative default values—must be validated in 5 cycle testing that includes high speeds, hard acceleration, and cold temperatures. Alternative methodologies are permitted if manufacturers believe 5 cycle testing is not appropriate, but the multiple criteria applied to alternative methodologies are formidable.

EPA and NHTSA should work together annually to update a comprehensive list of permissible off-cycle measures, each with a best-estimate value (rather than a low conservative value). Manufacturers and the public should be offered an opportunity to participate in the creation and validation of the annual list of off-cycle measures and credit values. Manufacturers should also be permitted to propose measures—or compliance credit values—based on alternative methodologies that are evidence-based and have been approved by an expert third-party review process. Those proposals should have a presumption of validity in a public comment and agency deliberative process. This more flexible approach to off-cycle measures, implemented jointly by NHTSA and EPA, would stimulate innovation in the industry and foster more cost-effective compliance with federal regulatory requirements.

Credit Trading

Fourth, there are inconsistencies in the design of the credit trading programs at NHTSA and EPA that should be harmonized. The banking periods for credits are not aligned, and NHTSA places restrictions on trading between the light-truck and passenger-car fleets. A case can be made that the two credit programs should be merged into one program, a reform that would require legislation from Congress (Leard & McConnell, 2015).

Compliance Incentives for ZEVs

Finally, if the ZEV program is to be retained, and if the credit accounting consequences resulting from the interaction between the ZEV program and the federal programs are deemed acceptable, then the federal program should be re-engineered so that the compliance incentives for BEVs, FCVs, and PHEVs remain in place during the period when the federal programs will be most challenging for vehicle manufacturers (i.e., model years 2022-2025). The timetables for the compliance multipliers in the current EPA rule were based on the overly optimistic assumption that PEV sales would ramp up significantly, putting 1 million PEVs on the road by 2015 (Rascoe & Seetharaman, 2013). As a result, the compliance incentives for PEVs begin to decline after model year 2017 and disappear in model year 2022.

It has proven much more difficult to commercialize PEVs than regulators envisioned (Graham et al., 2014; NRC, 2015b; Shepardson, 2016). As such, instead of expiring in 2022, the incentives for PEVs in the federal program might be retained until 2025. The crediting preference for BEVs over PHEVs should also be reconsidered

(Michalek et al., 2011), in part because consumer interest in PHEVs may be easier to muster (largely because their driving range is typically comparable in length to a gasoline vehicle; Graham et al., 2014). Furthermore, PHEVs may serve as a practical bridge to BEVs, much like HEVs have served as a useful bridge to PEVs (Axsen & Kurani, 2008; Colias, 2015a).

Finally, the midterm reviews should consider a legislative recommendation that authorizes NHTSA and EPA to promulgate consistent ZEV incentives for model years 2022 to 2025.

8. The federal and California regulations might pose less of a threat to new vehicle sales if they were accompanied by complementary policies at the federal, state, and local levels of government that stimulated consumer interest in fuel efficient and zero-emission vehicles. The midterm reviews should pinpoint the most cost-effective complementary policies.

As currently designed, the federal and California regulations compel vehicle manufacturers to produce large volumes of fuel efficient vehicles and PEVs in 2022-2025 whose price/attribute combinations may be less attractive to consumers than many vehicles readily available in the used-car market. Some consumers may choose to retain their existing vehicle for a longer period of time or buy a used car rather than purchase the new vehicles that satisfy regulatory requirements (Gruenspecht, 2000; NRC, 2015a).

In order to avoid a potential adverse effect on new vehicle sales, policy makers at all levels of government could enact complementary policies that encourage consumers to purchase and use fuel-efficient vehicles and ZEVs. We engage this line of thinking with caution because multiple policy instruments do not necessarily produce better results than a single instrument, especially given the complex interactions induced by multiple instruments (Morrow, Gallagher, Collantes, & Lee, 2010).

Some of the complementary policies would help sales of all fuel-efficient vehicles; others would primarily encourage sales of PEVs and/or FCVs. Drawing on the available literature, we describe a range of policies that are worthy of consideration, recognizing that further analysis would need to be conducted on each of them. Our review is not comprehensive, as we do not discuss some prominent options that we regard as less promising, such as a national feebate system for new vehicles (Greene, Patterson, Singh, & Li, 2005; Gillingham, 2013). Additionally, we accept a basic tenet of political economy: subsidies are more attractive to politicians than taxes (Sallee, 2011).

Provide better information to consumers

If the concern is that some consumers undervalue fuel economy, the most straightforward solution is to provide information to consumers that combats the undervaluation. There is plenty of evidence that many consumers do not make fuel-saving calculations and misunderstand the implications of MPG ratings (Kurani & Turrentine, 2007; Larrick & Soll, 2008).

EPA has taken a step in this direction by modifying the fuel-economy label to emphasize how much fuel and money will be saved by a consumer over a five-year period, if they choose a vehicle with above-average fuel economy. DOE has developed the eGallon tool to assist consumers in making a comparison between the price of fuel and the price of electricity (Leistikow, 2013). However, neither innovation has been subject to a large-scale randomized trial with sufficient subjects to detect effectiveness with a high degree of statistical precision. The only randomized trial in the literature on this subject finds no evidence that the revised EPA label is effective. Instead, that trial suggests that greater use of total cost of ownership information is helpful to some consumers (Dumortier et al., 2015).

A priority for the federal government is a serious commitment to behavioral research that clarifies which consumers are undervaluing fuel economy and how information programs can be targeted to meet their needs. Targeting is generally a superior strategy than raising the CAFE standards for all consumers, since many consumers may not be undervaluing fuel economy (Allcott & Greenstone, 2012; Allcott, Mullainathan & Tarbinsky, 2014).

Enact a carbon tax or raise the tax on gasoline

A substantial body of economic and policy literature dating back to the 1980s has highlighted the virtues of a carbon tax or higher gasoline tax, either as a substitute or complement to federal CAFE requirements and/or to ZEV requirements (White, 1981; Crandall, Gruenspecht, Keeler, & Lave, 1986; Crandall, 1992; Nivola & Crandall, 1995; Gerard & Lave, 2003; Kleit, 2004; Austin & Dinan, 2005; Knittel, 2012; Karplus, Paltsey, Babiker, & Reilly, 2013; Jacobsen, 2013). Some analysts suggest that use of a gasoline tax alone is more efficient than any combination of CAFE standards and a gasoline tax (Anderson, Parry, Sallee, & Fischer, 2011), while others seek to combine CAFE standards with a higher gasoline tax or carbon tax (McConnell, 2013).

An important advantage of such price instruments is that they work to reduce gasoline consumption and GHG emissions in the entire 250-million fleet of vehicles on the road while simultaneously encouraging consumers to purchase a more fuel-efficient vehicle. Higher gasoline taxes also help sales of ZEVs, since the spread between electricity prices and gasoline prices is widened, thereby underscoring the financial advantage of a ZEV compared to a gasoline-powered vehicle.

The political feasibility of a higher federal gasoline tax is questionable. Since it would take a large increase in the fuel tax ($1.00 per gallon or more) to have a significant impact on gasoline consumption and GHG emissions, it is hard to imagine a higher fuel tax replacing CAFE for the foreseeable future (Klier & Linn, 2010). The recent multi-year highway funding package passed by Congress was enacted without any serious consideration of a higher gasoline tax. Some states have enacted increases in gasoline taxes for revenue purposes but the small size of those increases is not relevant for the present aims.

A carbon tax seems even more remote in terms of political feasibility, since the idea has received little attention in Congress since the Obama administration's "cap and trade" proposal was blocked in the Senate in 2009-10. The range of carbon taxes that are commonly suggested ($10-60 per ton of CO_2) would not have a large impact on gasoline prices (Morrow, Lee, Gallagher, & Collantes, 2010). A gallon of gasoline burned produces 8,887 grams of CO_2 (NRC, 2015, p. 160). By means of a back of the envelope calculation, a carbon tax of $10/ton of CO_2 would translate into a $0.09/gallon increase in the price of gasoline. At the same time, additional considerations regarding the share of biofuels used in gasoline (which would remained untaxed in a carbon tax setting) as well as the behavioral response of consumers driving less in response to a carbon tax, pushing down retail fuel prices, might weaken the pass through of a carbon tax into fuel prices even more. In fact, the EIA in the AEO (2014) estimates that a $10 carbon tax would increase motor gasoline prices by only $0.08 in 2015 (the first year the tax would be implemented). Thus, even a $60/ton carbon tax would raise gasoline prices by a maximum of $0.53 per gallon (excluding the caveats mentioned previously). The failed cap-and-trade proposal in the 2009-2010 Congress would have reached only $26 per ton in 2019 (Sallee, 2011). Such a modest pricing impact explains why some experts believe that a carbon tax would do little to reduce GHG emissions from the transportation sector (Morrow, Lee, Gallagher, & Collantes, 2010).

Nonetheless, we suggest that tax instruments be given serious consideration in the forthcoming midterm reviews. Such instruments can help compensate for some of the key weaknesses of current federal and state regulatory requirements while stimulating more consumer interest in the purchase and use of green vehicles.

Retain and expand consumer subsidies for green vehicles

If CAFE and ZEV requirements are to be ramped up quickly despite the low fuel-price environment, a potential adverse effect on new vehicle sales can be minimized or avoided by providing public subsidies for the purchase of green vehicles. Perhaps the signature illustration of such a policy now exists in Norway, where 20-25% of new vehicle sales (late 2015) are PEVs (Hovland, 2015; Kane 2015). Subsidies may need to be quite large to entice U.S. consumers (Helveston et al., 2015).

The Norwegian subsidy policy for PEVs is actually a complex combination of policies that evolved over the last 10-15 years (Jolly, 2015). Elements of the policy include an exemption from the Value Added Tax (VAT) and other taxes on vehicle sales, free public parking spaces in the city, free use of toll roads and ferry connections, free access to bus and HOV lanes, a 50% lower tax on company cars, a 50% lower annual motor vehicle tax, and free recharging of batteries at publicly-funded charging stations.

Although the Norwegian policy has succeeded in promoting PEV sales, a recent evaluation of the policy points to some perverse effects (e.g., encouragement of families to purchase a second car and to refrain from walking, biking, and using public transit). Moreover, the same study estimates that the subsidy package costs roughly $13,500 per ton of CO_2 avoided, a figure that is cost ineffective compared to other feasible investments in carbon control (Holtsmark & Skonhoft, 2014). There are also some reports that policymakers in Norway are planning to phase out subsidies, in part because they are not fiscally sustainable (Hovland, 2015; Kane, 2015).

The U.S. also has some significant subsidies for PEVs and FCVs, but it is not clear whether those subsidies are increasing or decreasing over time. As mentioned earlier, the purchaser of a qualified PEV or FCV is eligible for a federal income tax credit up to $7,500. However, a federal tax credit for the cost of installing a home recharging station expired in 2011 and has not been renewed by Congress.

At the state level, some legislatures are enlarging cash incentives for PEVs and FCVs, some are reducing or rescinding them, and some are beginning to tax PEVs on the grounds that they do not contribute to road-repair funding. California has the longest history of a significant cash rebate for EVs, but the available funding has been constrained, the size of the rebate has fluctuated, and the rebate is no longer provided to some high-income households that are likely to consider a PEV (Hirsch, 2011; Clean Vehicle Rebate Project [CVRP], 2012; Edelstein, 2015a). Massachusetts and Connecticut recently enacted new cash rebates for EVs, but Illinois and Georgia have eliminated their cash rebates (DeMorro, 2015a; DeMorro, 2015b; Sawyers, 2015; LaReau, 2015). Ten states have passed legislation to impose fees for registration of alternatively fueled vehicles (PEVs and HEVs). Fees for PEVs specifically range from $50 to $200. In nine of the states, these are annual fees added to regular vehicle registration fees (National Conference of State Legislatures, 2016). States can aid the success of the ZEV regulation by shifting their policies in ways that encourage, rather than discourage, PEV purchase and use (Graham et al., 2014).

A different type of incentive is access to HOV lanes. In congested urban areas such as many cities in California and Washington, DC, a vehicle's access to HOV lanes can be a significant purchase incentive (Tal & Nicholas, 2014). The policy trend has been to disallow owners of HEVs from using HOV lanes but allow owners of qualified PEVs to use them. Perhaps not surprisingly, the Toyota Prius (the best known HEV) is no longer the #1 selling passenger vehicle in California. Recently, there has been debate as to whether PHEVs should be allowed in HOV lanes or whether the privilege should be restricted to BEVs and FCVs. Highway managers need to ensure that HOV lanes do not become congested.

The midterm reviews would be an appropriate time to reconsider which public subsidies of vehicles should continue and, if so, what their terms and limits should be. Public subsidies and regulatory requirements need to be coordinated (McConnell & Turrentine, 2010). The current public subsidies seem targeted primarily to BEVs and FCVs, which is compatible with the ZEV mandate. However, HEVs are a more cost-effective path to GHG control than ZEVs, yet subsidies and incentives for HEVs have been terminated (Kromer & Heywood, 2008; Samaras & Meisterling, 2008; Kammen, Arons, Lemoine, & Hummel, 2009; Michalek et al., 2011; Traut, Hendrickson, Klampfl, Liu, & Michalek, 2012). The current subsidies do little to help implementation of the footprint-based CAFE program, since they offer no encouragement to consumers who are considering a high-mileage pickup truck, a high-mileage hybrid crossover, or a high-mileage diesel-powered sedan (Sallee, 2011). Coordinating public subsidies with the federal programs should be a priority in the midterm reviews.

Overall, if regulators insist that automakers produce large volumes of fuel-efficient vehicles and PEVs in a low fuel-price environment, a system of public subsidies—at least for the period until fuel prices rise significantly—may be a practical response that avoids or minimizes a deleterious decline in new vehicle sales (for similar reasoning, see McConnell and Turrentine, 2010).

Enact "cash-for-clunker" programs to accelerate the retirement of old, inefficient vehicles

The U.S. passenger fleet has more than 250 million vehicles (57% cars; 43% light trucks; DOT, 2009). Changing the environmental profile of the existing fleet is a very slow process if the focus is on the design of new vehicles. In a good year, only 17 million passenger cars and light trucks are sold in the U.S. The average age of passenger vehicles in the U.S. has been steadily increasing and many vehicles are used longer than 15 years.

The current federal regulatory requirements are designed to achieve rapid improvements in fuel economy from new 2022 to 2025 models that will already average more than 40 MPG in model year 2021. Meanwhile, there will be tens of millions of old vehicles (10 years or older) operated with low MPG ratings and pollutant emissions that are far in excess of the average vehicle sold in model year 2021. Instead of the exclusive focus on new vehicles from 2022 to 2025, the midterm reviews may consider policies to accelerate the retirement of older vehicles from the fleet.

So-called "cash for clunker" programs seek to accomplish this objective by offering cash incentives to consumers who agree to retire their old vehicle and replace it with a new vehicle. The result might be a higher rate of new vehicle sales as well as lower rates of gasoline consumption and GHG emissions. Side benefits of such policies may include enhanced safety, reduced emissions of pollutants related to smog and soot, and a tangible benefit for limited-income households that depend on older vehicles for their work and personal transportation.

The cash-for-clunkers idea originated in France in the 1980s, as the government sought to reduce pollution and boost the fortunes of the French-owned automotive companies and their workers (Wald, 2009). The idea spread rapidly to Germany, Italy, Spain, the UK, and Ireland (Schoenfeld & Walker, 2009; Dial, 2011). Both the U.S. and selected European countries experimented with cash-for-clunker programs in the 2005-2010 period, primarily to stimulate the strongly depressed levels of new vehicle sales. Many U.S. states currently have such programs, though they vary in their design. Some of the programs have no focus on environmental gain, while others focus on older vehicles with poor environmental performance.

Evaluations of cash-for-clunker programs have yielded mixed results, both with respect to stimulus effects and environmental impacts. The programs increase new vehicle sales temporarily, but sales are much lower when the incentive is removed (Knittel, 2009; Gayer & Parker, 2013). It appears that the cash incentive influences precisely when the owner of an old vehicle decides to purchase a new one, but the earlier purchase may be less than a year ahead of when it would have been otherwise (Mian and Sufi, 2012). The stimulus effect is minimal or negative if new vehicle purchases are restricted to greener vehicles, since overall spending on vehicles may fall or not increase (Hoekstra, Puller, & West, 2014). The programs do not necessarily benefit low-income households, as higher-income households are more likely to take advantage of the opportunity, and the programs may raise prices on older used cars, those often purchased by income-constrained households (Gayer & Parker, 2013; Woodyard, 2009; Sawyers, 2009a; Sawyers, 2009b). Programs that do not regulate the environmental profile of the new vehicle may have adverse effects on the environment, as the cash incentive may cause the consumer to buy a larger (and more polluting) vehicle than they would have without the cash incentive, as that was the perverse experience in Germany (Klößner & Pfeifer, 2015).

Programs that require cash rebates to be used for green vehicles, such as the U.S. Cars Allowance Program (CAP), do report environmentally positive results (DOT, 2009). The CAP, which triggered the replacement of 680,000 old vehicles with new vehicles, induced an acceleration of the new vehicle purchase by an average of 2.87 years. Those vehicles were typically driven 10,000 to 12,500 miles per year. The average EPA mileage rating of the new vehicles was 9.2 MPG higher than the average rating of the retired vehicles (24.9 versus 15.7 MPG). As a result, CAP was associated with significant reductions in fuel consumption, GHG emissions, and criteria pollutants that are linked to formation of smog and soot (DOT, 2009).

Other studies find smaller but still substantial differences in the mileage ratings: 2.5 to 5.0 MPG higher ratings for the new vehicle compared to the retired vehicle, in part because the retirements are often SUVs and pickup trucks while the new vehicles are often small cars (Hoekstra et al., 2014; Curtin, 2009; Kellogg & Mitchell, 2009).

The cost-effectiveness of the pollution reductions from CAP are questioned relative to the social cost of carbon or carbon prices (Li, Linn, & Spiller, 2013; Knittel, 2009), but properly designed cash-for-clunker programs may still be much more cost-effective at the margin than the ZEV mandate or the 2025 federal standards. The midterm reviews should explore such a comparison.

APPENDIX A:
REGULATORY IMPACT ANALYSES MODEL PARAMETERS

In their RIAs, NHTSA, EPA, and CARB document several economic parameters that were used as inputs in their consumer-payback modeling efforts. The assumptions they made about those parameters affected, among other things, the estimated effects the regulations would have on consumer benefits and payback periods, new vehicles sales, and the overall benefits of the regulations. In our report, we have discussed some of those input parameters extensively (i.e., technology costs, gasoline prices, and rebound effect). In this Appendix, we present additional parameters that were used by the agencies in the RIAs.

Price Elasticity for Automobiles

The agencies assume a price elasticity of demand for automobiles equal to -1. That figure implies that a 1% increase in the price of an automobile will decrease sales by 1%, all else equal. The assumption used by the agencies is that automobile manufacturers will be able to pass on the increase in cost of production, due to implementation of fuel efficient technologies, to consumers.

Automobile Insurance Cost

NHTSA and EPA use data from the National Bureau of Economic Analysis to calculate the average price of a new passenger car in 2010 at $24,572 and that of a new light truck at $31,721. Considering those two estimates, the agencies calculated the average price of a new vehicle in 2010 to be $27,953. The latter is the figure based on which insurance costs were calculated. The agencies assumed that costs of collision and comprehensive insurance for the first five years in the life of a new vehicle, expressed in percentage terms of the price of the vehicle, decline based on the following schedule: 1.86% for year 1, 1.82% for year 2, 1.75% for year 3, 1.64% for year 4, and 1.50% for year 5. In aggregate, the overall cost of insurance for the first five years of the vehicle's life is 8.5% of the original price. The CARB RIA assumes an insurance premium of 6.6%.

Automobile Loan Cost

NHTSA and EPA assumed that 70% of consumers finance their automobile purchases through a loan at an average rate of 5.16% for a period of 48 months. The relevant interest rate used by CARB was slightly higher at 5.35%. The literature on automobile purchases suggests that some consumers use their credit cards to make car payments (Busse et al., 2013). If that is the case, then the financing interest rate one would need to consider to estimate the actual cost of purchasing a new car is the interest rates consumers pay on their credit cards.

Vehicle Resale/Residual Value

NHTSA assumes that the average resale value of a vehicle five years into its lifetime is 35% of its original price. The present value of this percentage using a 3% discount rate yields an effective residual value of 30.64%. The equivalent figure used in the EPA RIA is 23% (assuming a 7% discount rate), while the CARB RIA assumes a resale value of 39% (using a 5% discount rate).

Average Period of Automobile Ownership

EPA and NHTSA considered the full lifetime of cars to be 30 years and trucks to be 37 years, while CARB considered the median lifetime of a passenger car in California to be 14 years. For vehicles of a given model year, EPA and NHTSA calculate the probability that vehicles remain in service after the year they are sold. The resulting "survival rate" is used to calculate the number of vehicles in service at a specific time period. This is the first step in estimating fuel consumption. The next step requires an estimate of Vehicle Miles Traveled (VMT). The latter is produced by using the Federal Highway Administration's 2009 National Household Travel Survey

(2011). The VMT projections made by the agencies align closely with the AEO 2012 early release projections and are illustrated in Table 6. From the perspective of the consumer, average auto ownership of new car buyers is estimated to be only 2-5 years, significantly lower than the total lifetime of a vehicle considered by the agencies.

Automobile Sales Tax

NHTSA and EPA use a national weighted average sales tax of 5.46% in their regulatory impact assessments, computed by weighting the most recent automobile sales tax by state (as of when the assessments were performed) by census population by state. Census population was used as the weighting parameter instead of new vehicle sales by state, though the latter was preferable, due to data availability limitations. As a proxy for new vehicles sales, NHTSA used new vehicle registrations by state. The tax rate resulting from the registration-based proxy of new vehicle sales was negligibly different from that produced using census population. The California sales tax used in the CARB RIA is 7.25%.

Fuel Efficiency Rebound Rate

Both NHTSA and EPA estimate the rebound rate associated with increased fuel efficiency at 10%, though the agencies use different ranges in their sensitivity analyses. NHTSA uses a range of 5-20% for sensitivity testing, whereas EPA uses a range of 0-20%. CARB assumes a declining rebound rate based on the following schedule: 6% in 2012, 5% in 2020, and 3% in 2030.

On Road Fuel Economy Gap

Both NHTSA and EPA assume a 20% fuel economy gap for liquid fuel and a 30% gap for vehicles with an electric drivetrain.

Discount Rate Applied to Future Fuel Savings

NHTSA and EPA conduct their regulatory impact assessments assuming 3% and 7% discount rates on future fuel savings. These are the standard social discount rates federal agencies apply in their regulatory impact assessments, as recommended by the Office of Management and Budget (OMB). The OMB sets standard discount rates for regulatory impact assessments in light of substantial variation in the literature on the appropriate valuations of such, particularly across regulatory domains. The CARB uses a 5% discount rate for future fuel savings in its regulatory impact analysis.

Table 6. Survival Weighted Per-Vehicle Reference VMT used in the Agencies' Analyses

	MY 2021		MY 2025	
	Cars	**Light Trucks**	**Cars**	**Light Trucks**
EPA	204,161	218,399	209,037	223,688
NHTSA	206,768	218,812	211,795	223,865

Source: EPA and DOT (2012)

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