

## VEHICLE ELECTRIFICATION POLICY STUDY

# Task 2 Report: **METRICS**

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## EXECUTIVE SUMMARY

ICCT's Vehicle Electrification Policy Study seeks to evaluate policies that can achieve motor vehicle emission reductions beyond those attainable with traditional tailpipe pollution controls. The study is focused on "pure" electric vehicles—battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs), and combinations thereof—and on the efforts of governments to encourage their adoption. The pending modification of the California Zero Emission Vehicle (ZEV) program, due to be considered by the Air Resources Board in October 2011 in conjunction with the LEV III criteria pollutant and greenhouse gas regulations, is a central concern of the study.

This study identifies and promotes policies that support vehicle electrification, focusing on the California ZEV program. The ICCT study is organized around five tasks, with the results of each task presented in a separate policy report. This document reports ICCT analysis and findings regarding Task 2, metrics to measure manufacturer compliance with ZEV requirements.

The California ZEV program requires that large volume manufacturers produce and offer for sale in California a specified number of ZEVs. The existing ZEV program requirements are primarily expressed in terms of the number of vehicles that must be offered for sale, with adjustments for different types of vehicles.

The ZEV program supports three broad statewide policy goals:

- Reduce criteria pollutant and greenhouse gas emissions,
- Reduce gasoline and diesel fuel demand, and
- Maintain leadership in environmental technology policy and foster job growth.

ARB staff have defined two major technology development objectives for the ZEV regulation:

- Launch ZEV markets to commercial scale by 2025, and
- Encourage a diversified spectrum of ZEV applications in the light-duty vehicle sector.

This framing of the issue, under which the role of the ZEV program is to advance technology to the point where meaningful numbers of ZEVs can be deployed, is appropriate. Only then will significant emission and petroleum reductions be achieved.

ARB staff have previously identified several metrics (also known as "credit factors") under consideration. The ICCT team and other observers have identified other metrics of possible interest. Although California is the only jurisdiction that has a regulatory ZEV production mandate, metrics are used in other jurisdictions to determine eligibility for subsidies and, in some cases, to determine the amount of subsidy received. Thus, they are functionally similar to the ZEV credit metrics,

which determine the amount of ZEV credit earned by each vehicle. ARB staff have recently released a proposal in November 2010 outlining their recommended metric approach based on range.<sup>1</sup>

Any metric rewards a particular attribute or characteristic and, thus, incentivizes a particular outcome. The outcomes encouraged by ZEV program metrics fall into three general categories: marketability, diversity of platforms and technologies, and emission reductions.

At today's early stage of ZEV development, substantial uncertainty exists as to what mix of vehicle features and performance characteristics will have the greatest appeal to consumers. Given this uncertainty and the broad range of experimentation now taking place, ICCT believes that metrics should allow manufacturers the flexibility to design, manufacture, and market vehicles that will meet ZEV goals and customer needs rather than encourage a specific technology or design.

This policy does not imply that the program should simply treat all electric vehicles the same. Because increased performance comes at increased cost, not all of which is likely to be recoverable through increased vehicle price, an approach that treats all vehicles the same provides a de facto incentive for manufacturers to produce the cheapest, least capable vehicles. Thus, the basic underlying objective is to define metrics that compensate manufacturers for higher cost/higher function solutions so that the ZEV program encourages rather than discourages manufacturers to pursue a variety of approaches.

ICCT recommends the use of range and footprint as metrics to determine manufacturer compliance. Range is a fundamental measure of vehicle functionality. The range metric should be based on real-world driving conditions. Using only a range metric would incentivize the production of small vehicles, which can travel farther on a given amount of stored energy. Therefore, in light of the desire to encourage diverse applications, it is useful to include a size (footprint) component in the vehicle scoring metric as well. One concern is that a footprint factor, by providing additional credit for larger vehicles, could lower incentives to downsize the vehicle fleet to reduce petroleum consumption and greenhouse gas (GHG) emissions. On balance, ICCT believes that the advantages to be gained by application of a moderate footprint factor in this limited and specific circumstance outweigh the potential disadvantages of incentivizing increased size.

Range and footprint can be used in a variety of ways to calculate ZEV credit. The method chosen will affect both the overall credit awarded to a particular vehicle as well as the relative credit of that vehicle versus other configurations.

The first consideration is the relative weight attached to the range factor versus the footprint factor. Because range is the primary determinant of vehicle

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<sup>1</sup> [www.arb.ca.gov/msprog/zevprog/2010zevreg/11\\_16\\_10pres.pdf](http://www.arb.ca.gov/msprog/zevprog/2010zevreg/11_16_10pres.pdf)

functionality, and in recognition of the desire to not overincentivize increased vehicle size, ICCT recommends that the scoring system primarily rely on range. Turning next to the overall credit value, the average credit earned per vehicle determines the number of vehicles produced in response to a given percentage mandate. To provide a firmer link between the nominal percentage requirement and the resulting number of vehicles, ICCT recommends that the credit calculation be structured such that the average vehicle receives 1 credit; more specifically, ICCT recommends that the “1-credit” vehicle should be a small vehicle with a label range of 100 mi.

The second variable is the relative scores earned by various vehicle types, particularly longer-range vehicles (likely to be fuel cells) as opposed to shorter-range vehicles (likely to be BEVs). ICCT believes it is appropriate to continue to provide higher credit for longer-range vehicles to compensate for their added functionality and the added cost that may not be fully recouped through vehicle price. To recognize that above a certain level, additional range is of less value, and to minimize gaming, ICCT recommends that a reduced credit value be provided for range >350 mi and that no additional credit be provided for range >500 mi.

Taking all of these factors into account, the specific recommended form of the credit calculation is as follows:

$$\text{ZEV range credit} \times \text{footprint credit}$$

where

$$\text{ZEV range credit} = \frac{\text{adjusted ZEV range up to 350}}{100} + \frac{\text{adjusted ZEV range between 351 and 500}}{200}$$

up to a maximum range of 500 (maximum range credit 4.25), and

$$\text{ZEV footprint credit} = \text{footprint}/6,400$$

A comparison of the ARB and ICCT credit formulas reveals that ICCT metrics result in lower per-vehicle credit values for all but the longest-range vehicles. However, the overall impact of the program is a product of several factors, including the percentage requirement, the credit structure, and the assumed mix of vehicles. Using ARB assumptions regarding vehicle mix, the ICCT proposal would require similar but slightly lower numbers of vehicles.

The current ZEV regulation provides credits to vehicles such as neighborhood electric vehicles (NEVs) that are not legal to operate on streets with a speed limit greater than 25 miles per hour. ICCT believes that NEVs have a market niche and can provide environmental benefits, but they are not helping to facilitate the commercialization of electric drive passenger vehicles. Therefore, ICCT recommends that beginning in 2018, NEVs should no longer earn ZEV credit.

ICCT considered providing additional credit for vehicles that have fast refueling/recharging capability, as is the case with the current ZEV regulation. On balance, ICCT does not recommend the inclusion of a fast-refueling factor. ICCT also considered taking into account the durability of the energy storage system but rejected this approach because of the lack of data and the manufacturer incentive to meet customer expectations independent of any credit value. Finally, some interested parties have suggested the use of the “technology portfolio” credit identified by ARB. Although the idea has merit, ICCT does not recommend including it, because an appropriate credit level for FCEVs can be accomplished by other means, and we see no rationale for requiring manufacturers to also build BEVs to get an appropriate credit level for FCEVs or vice versa.

ARB has stated its intent that for 2026 and beyond, the ZEV program will be incorporated into the LEV program GHG fleet average. Although such a transition is many years off, there is merit in beginning now to consider some of the issues that will need to be addressed along the way. Such issues move beyond the design and operation of the ZEV regulation and begin to address how ZEVs can best be incorporated into the broader LEV III program. Two areas of interest are estimating per vehicle ZEV upstream GHG emissions for the purposes of including them in the GHG fleet average standard and determining the appropriate timing of the transition to a fleet average.

Although electric vehicles have no tailpipe emissions, upstream emissions are generated to the extent that any fossil fuel is combusted during the production of the electricity or hydrogen used to power the vehicle. Upstream emissions are relevant in several contexts, including compliance with the GHG fleet average standard, compliance with vehicle labeling requirements, and calculation of real-world emissions for purposes of emission inventories and tracking progress toward GHG reduction goals. The treatment of upstream emissions varies based on the particular purpose for which they are being calculated and the regulatory jurisdiction making the calculation. The different methodologies result in quite different estimates of the GHG emissions from a particular vehicle.

“Super credits” or “bonus” credits refer to mechanisms that give BEVs, plug-in hybrid electric vehicles (PHEVs), or FCEVs credit for lower GHG emissions than the vehicles will actually produce, taking into account both tailpipe and upstream emissions. Upstream emissions are important and should not be permanently given a value of zero. For some period of time, and for a defined number of vehicles, the use of a zero upstream factor as an incentive to stimulate the early penetration of electric vehicles may be appropriate. The treatment of upstream emissions for purposes of compliance with the fleet average is a complex issue that merits additional discussion, and ICCT does not provide a recommendation at this time.

The emission intensity of California electricity production is expected to decline because of the California renewable electricity goals. Thus, periodic updates to



the upstream emission factors would help improve the accuracy of accounting for environmental standards and would likely also benefit electric vehicle manufacturers and the auto industry. ICCT suggests defining 5-year windows with the assigned values determined several years in advance.

PHEVs do not always use grid electricity, whereas some pure electric vehicles have a limited range and thus should not be expected to displace the typical 14,000 mi per year of driving undertaken in a conventional vehicle. As experience is gained, research is needed to determine whether this is a significant accounting issue.

From its inception, the ZEV regulatory mandate has been viewed as a “jump start” measure to incentivize production to a level that could become self-sustaining. Thus, it is now germane to attempt to determine what constitutes commercialization in the ZEV context to better inform decisions regarding the timing of a transition to a fleet average.

There are several possible approaches. First is a trigger-level percentage of sales, along the lines of the original 10% mandate. Another approach is to measure annual or cumulative production volume. The measure used will need to take into account that the ZEV mandate itself is creating an artificial sales level in California that presumably would not be reached in the absence of the regulation. Similarly, incentives in place in a variety of jurisdictions will increase demand beyond the unincentivized level.

Any discussion of transitioning to a GHG fleet average must take into account the stringency of the fleet average that is in place. The fleet average must be on a trajectory that will allow achievement of environmental goals such as reducing statewide GHG emissions 80% below 1990 levels by 2050. A fleet average that is sufficiently stringent will provide a significant incentive toward vehicle electrification, thus replacing the market push provided by the ZEV mandate. Thus, the determination of whether it is appropriate to transition to a fleet average is the product of two factors—the commercialization status of ZEV technology, as measured by one of the factors noted previously, and the stringency of the fleet average standard vis-à-vis the level needed to promote vehicle electrification.

Although it is possible to just set a “date certain” and use that as the transition point regardless of production or sales, such an approach would leave the ultimate status of ZEV production uncertain and would not necessarily ensure continued progress toward our GHG reduction goals. Rather, ICCT recommends that in the 2018–2020 timeframe, well in advance of the 2026 target date, the ARB conduct a review to determine the underlying conditions and the appropriate response along the lines outlined previously.

## INTRODUCTION

### ICCT Vehicle Electrification Policy Study

ICCT has undertaken a Vehicle Electrification Policy Study to evaluate, recommend, and support the adoption of policies that can achieve motor vehicle emission reductions beyond those achieved by traditional tailpipe standards. Although ICCT recognizes the important role that plug-in hybrid electric vehicles (PHEVs) are likely to play in the transition to vehicle electrification, the study is focused on the encouragement of “pure” electric vehicles—battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs). These two major electric-drive technology areas are grouped here and in many international policy efforts because of their electric drivetrain commonality, their diversity of potential upstream energy carriers, and their prospects for long-term, ultra-low energy and emissions impacts. Throughout this project the term *electric vehicle* refers to both BEVs and FCEVs.

The study is intended to provide information relevant to the upcoming consideration of modifications to the California Zero Emission Vehicle (ZEV) program, due to be considered by the California Air Resources Board (ARB) in October 2011. The study is organized around five tasks, with the results of each task presented in a policy report:

1. *What is the current status of vehicle and infrastructure technology and what are the current and projected costs?*

On the basis of a review of existing studies, Task 1 provides an overview of technology status and projected costs for BEVs and FCEVs. The report compiles existing estimates of incremental cost over time, taking into account expected technical development and increased production volume. The report also evaluates global deployment projections and compares the likely California share of those deployments to the targets for the ZEV program under consideration by the California ARB staff.

2. *What metrics should be used to measure progress toward ZEV commercialization?*

Currently the ZEV program requirements are expressed primarily in terms of the number of vehicles to be offered for sale, with adjustments for different types of technology. This approach has the benefit of being tangible and readily verified because it is based on available sales data. Depending on technology progress over time, however, this approach can lead to over- or underinvestment in the various deployment stages. Other metrics that have been used or recommended include componentry-based approaches (such as vehicle battery capacity), measures of full lifecycle emissions, or the number of zero emission miles traveled. The ideal set of metrics also should incentivize efficiency, which for ZEVs can vary even though all vehicles have zero tailpipe emissions. Task 2 evaluates the key goals that potential metrics should support and the relevance and practicality of various metrics.

3. *What will be the cost in California of the transition to a self-sustaining market, and how long will it take?*

Building on work that has been undertaken nationally and internationally, this task will quantify to the extent possible the public or private investment needed to get through the proverbial “valley of death” before zero emission electric drive technologies can compete in the market without subsidies. Task 3 will address the magnitude and duration of needed policies under various scenarios. This task is currently in progress.

4. *Which complementary policies (e.g., infrastructure rollout, incentives) are needed to support a transition to an electrified vehicle fleet, and what is the appropriate framework for considering possible policy actions?*

Task 4 identifies and recommends policies that most effectively support the necessary transition and that are applicable in the California context. The study also assesses the extent to which existing global policies will facilitate this transition, such as global private and public investments in research, development, and demonstration; manufacturing scale-up; and the need for California-specific investments in areas such as infrastructure.

5. *What can we learn from work under way elsewhere in the world?*

Task 5 (forthcoming) reviews region-specific market niches, infrastructure challenges, and existing policies to identify lessons applicable to California and how they can best be applied in the California context. Although specific insights relevant to the previous tasks are included in those reports as appropriate, this task presents a comprehensive review of global policies. The selection of regions accounts for the targets, goals, and policies in place in each jurisdiction and the existence of market opportunities as evidenced by manufacturer vehicle introductions and interest.

### **The Task 2 Report**

This document presents ICCT analysis and findings for Task 2 (the evaluation of “metrics” that can be used to measure progress and manufacturer compliance under the ZEV program). ARB staff have asked for comment on the issues addressed herein, and this document is intended to assist staff in their deliberations.

## BACKGROUND

### The ZEV Regulation

The California ZEV program requires that large-volume manufacturers<sup>2</sup> produce and offer for sale in California a specified number of ZEVs. The existing ZEV program requirements are primarily expressed in terms of the number of vehicles that must be offered for sale, with adjustments for different types of technology. Table 1 shows the various ZEV “types” and their characteristics. The table shows the efforts by the ZEV program to reflect the differing functionality of new vehicle technologies in terms of their range—the distance traveled between refueling events. Each of the vehicle types receives a different amount of ZEV “credit,” with vehicles that are capable of greater range receiving greater credit because of their higher cost and their likelihood of displacing more conventional petroleum-fueled vehicle travel. The range is based on the “city” test cycle that is part of the conventional combined city-plus-highway regulatory testing procedure for CO<sub>2</sub> and fuel economy in the United States and California.<sup>3</sup> In the current structure, the relative credit values change over time, as shown. Note how in 2018 and beyond the credit values for Type II, III, IV, and V vehicles are all the same, unlike in the previous periods. This change reflects the phasing out of the near term additional credit given to FCEVs and longer range BEVs.

**Table 1. ZEV Program Vehicle Types**

ZEV Tier	UDDS Range (mi)	Fast Refueling Capability	Credit Earned, 2009–2017	Credit Earned, 2018+
NEV	No minimum	N/A	0.3	0.3
Type 0	<50	N/A	1	1
Type I	≥50, <75	N/A	2	2
Type I.5	≥75, <100	N/A	2.5	2.5
Type II	≥100	N/A	3	3
Type III	≥100	Must be capable of replacing 95 mi (UDDS ZEV range) in ≤10 min	4	3
	≥200	N/A		
Type IV	≥200	Must be capable of replacing 190 mi (UDDS ZEV range) in ≤15 min	5	3
Type V	≥300	Must be capable of replacing 285 mi (UDDS ZEV range) in ≤15 min	7	3

*ZEV = zero emission vehicle; UDDS = Urban Dynamometer Drive Schedule, which is the “city” drive cycle for emission testing; NEV = neighborhood electric vehicle; N/A = not applicable.*

<sup>2</sup> Current large-volume manufacturers are General Motors, Toyota, Ford, Chrysler, Honda, and Nissan.

<sup>3</sup> Note that the city range is based on the test result and is not representative of real-world driving conditions. For example, the city/highway test result for the Nissan Leaf is adjusted downward by 30% for use on fuel economy labels.

Other provisions grant additional ZEV credit for several factors, including offering a vehicle for sale or extended lease or placing a vehicle in a “transportation system” such as a car-sharing program.<sup>4</sup> These ancillary provisions are not related to the attributes of the vehicle itself but rather are based on how the vehicle is marketed or used. This report focused on vehicle attributes, and, therefore, these additional factors are not considered further.

ZEV credits can be banked for later use or traded or sold to other manufacturers. These provisions are intended to provide flexibility to manufacturers regarding the scope and timing of their product development. Recent press reports indicated that Tesla, which does not need ZEV credits because it is not a large-volume manufacturer, has sold some of its ZEV credits to Honda.<sup>5</sup> In addition, as outlined by ARB staff in a 2007 status report on the ZEV program,

Prior to 2003, neighborhood electric vehicles could be used to meet ZEV obligations, earning relatively high credit levels with fairly low cost. A few manufacturers took advantage of this compliance path and delivered a large number of NEVs to California. The resulting glut of credits created a challenge for implementation of the ZEV regulation, and the Board reacted in 2001 by drastically reducing the credits earned per vehicle and limiting the amount of banked NEV credits that could be applied towards compliance in a given year.<sup>6</sup>

Manufacturers still retain ZEV credit balances, and this issue needs to be kept in mind in any discussion of the number of vehicles that will result from various ZEV provisions.

The treatment of PHEVs within the ZEV program has evolved over the years. Originally, PHEVs did not accrue credit that could be used toward the pure ZEV requirement. In the 2008 amendments to the ZEV program, ARB established the category of enhanced Advanced Technology Partial Zero Emission Vehicle (AT PZEV), which is a vehicle using a fuel that would be used in a ZEV such as hydrogen or electricity, and allowed such vehicles to count toward a portion of the pure ZEV requirement. Examples for this category are hydrogen internal combustion engine vehicles and PHEVs. Even in the 2008 amendments, however, the crediting scheme for enhanced AT PZEVs was separate from that for ZEVs. Going forward, it would be helpful to have a single metric that worked for all electric drive vehicles. There is considerable uncertainty regarding which platform(s) will best meet customer needs, and the credit system should encompass all competing vehicle types.

This is a separate issue from the question of allowing PHEVs to be used for compliance with the pure ZEV portion of the program. Even if there is a separate requirement that can be met only by BEVs or FCEVs, it still makes sense to have metrics that provide a valid comparison of the various vehicle types including PHEVs.

<sup>4</sup> Transportation systems are considered attractive potential applications for electric vehicles because the duty cycle is primarily urban, short-range driving. See, for example, <http://econpapers.repec.org/paper/cdlitsdav/1586265.htm>

<sup>5</sup> [www.evworld.com/news.cfm?newsid=23481](http://www.evworld.com/news.cfm?newsid=23481)

<sup>6</sup> [www.arb.ca.gov/msprog/zevprog/zevreview/zev\\_review\\_staffreport.pdf](http://www.arb.ca.gov/msprog/zevprog/zevreview/zev_review_staffreport.pdf), p. 23

## Statewide Policy Goals

The ZEV program supports three broad statewide policy goals:

- Reduce criteria pollutant emissions to help meet ambient air quality standards and reduce statewide greenhouse gas emissions to 80% below 1990 levels by 2050 as called for in California Executive Order S-03-05,
- Reduce gasoline and diesel fuel demand to 15% below 2003 demand levels by 2020 and maintain that level for the foreseeable future, as recommended by the California ARB and the California Energy Commission pursuant to Chapter 936, Statutes of 2000 (AB 2076, Assemblyman Shelley), and
- Maintain leadership in environmental technology policy and foster job growth.

Similar air quality, energy security, and industrial policy goals exist at the federal level, and progress by California will help with the achievement of national goals as well.

## ZEV Program Objectives

To help achieve the overriding environmental protection and energy goals, the ARB established the ZEV program to promote the deployment of extremely low-emission vehicles. At a May 3, 2010, public workshop ARB staff defined two major technology development objectives for the ZEV regulation:

- Launch ZEV markets to commercial scale by 2025, and
- Encourage a diversified spectrum of ZEV applications in the light-duty vehicle sector.

This framing of the issue, under which the role of the ZEV program is to advance technology to the point at which meaningful numbers of ZEVs can be deployed, is appropriate. Only then will significant emission and petroleum reductions be achieved. Thus, as discussed more completely in the ICCT Task 1 report, the ZEV program fulfills a transitional technology-forcing role.

As commercialization is achieved and vehicle volumes increase to significant levels, ARB expects that the program will be incorporated into the overall LEV III approach using fleet average standards. Thus, another metrics-related issue is how to accurately account for ZEVs in a fleet-average approach. This issue is discussed in more detail in the section on long-term metrics later in this paper.

## Possible Metrics

At the May 3, 2010, public workshop ARB identified several metrics (or *credit factors*) that were under consideration. These are listed in the following bullets, with descriptions developed by ICCT:

- *Range*: The distance that a vehicle can travel before needing to refuel, ideally measured under diverse and realistic driving conditions. The greater the range, the greater the convenience for the customer.

- *Refueling rate*: The time that it takes to replace a specified percentage of the energy stored on the vehicle. Vehicles with a fast refuel/recharge capability provide greater convenience for the customer.
- *Refueling access*: Station or charger availability. The greater the number of easily accessible refueling points, the greater the convenience for the customer.
- *Full function capability*: This criterion acknowledges broader consumer demands to retain the basic vehicle functionality and use afforded by conventional vehicles, such as vehicle cargo space utility, passenger climate control under heating and cooling conditions, ability to maintain basic vehicle performance under varied driving conditions (e.g., urban and highway), cabin payload, and off-vehicle towing.
- *Long-term vehicle cost potential*: Rewards technologies that have the potential for lower cost at high production volumes. Although it is difficult to predict technology trends, the ARB intent in considering this metric is to incentivize fuel cell technology, which according to some estimates<sup>7</sup> is believed to have greater long-term potential for cost reduction.
- *Well-to-wheels performance*: Well-to-wheel greenhouse gas (GHG) emissions. The lower the total emissions, the greater the contribution toward meeting greenhouse gas reduction goals. Defining this metric would require assumptions regarding future electricity and hydrogen production.
- *Innovation*: Reward for higher investment risk. This is intended to encourage investment in technologies with a longer term payoff and is targeted at FCEVs.
- *Technology portfolio*: Rewards original equipment manufacturers pursuing multiple technologies. Again, this is intended to encourage FCEV production.

The ICCT team, and other observers have identified other metrics of possible interest:

- *Zero emission vehicle miles traveled*: The number of electric miles driven. This metric is an alternative measure of the degree of electrification and range of the vehicle. It also captures greenhouse gas benefits.
- *Efficiency*: The number of miles driven per unit of energy consumed. Vehicles can have zero tailpipe emissions yet still vary dramatically in their energy consumption and therefore related upstream emissions.
- *Energy storage power capacity*: The amount of energy stored in the vehicle battery (for BEVs and PHEVs) or as hydrogen storage (for FCEVs). Because battery cost is a key driver of commercialization, this metric is intended to

<sup>7</sup> See for example, Bandivadekar, A., Bodek, K., Cheah, L., Evans, C., Groode, T., Heywood, J., Kasseris, E., Kromer, M., & Weiss, M. *On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions*. Cambridge, MA: MIT Laboratory for Energy and the Environment, LFEE 2008-05 RP, 2008. Available at: <http://web.mit.edu/sloan-auto-lab/research/beforeh2/otr2035/>; and *A portfolio of power-trains for Europe: A fact-based analysis. The role of battery electric vehicles, plug-in hybrids and fuel cell electric vehicles*. Available at: [www.zeroemissionvehicles.eu/uploads/Power\\_trains\\_for\\_Europe.pdf](http://www.zeroemissionvehicles.eu/uploads/Power_trains_for_Europe.pdf)



incentivize battery production and thereby accelerate technical progress and achieve economies of scale.

- *Multiple platforms*: This metric would reward “first in class” deployment of different passenger vehicle types. The greater the variety of platforms, the greater the number of potential customers.
- *Vehicle footprint*: Defined as track x wheelbase, this is a measure of vehicle size and is used in the calculation of the fleet average GHG emission limit for conventional vehicles.
- *Electricity-Powered Fraction of Energy Consumption*: For PHEVs, this metric would measure the proportion of total vehicle miles powered by electricity as opposed to petroleum.

### Metrics Used in Other Jurisdictions

Although California is the only jurisdiction that has a regulatory ZEV production mandate, metrics are used in other jurisdictions to determine eligibility for subsidies and in some cases to determine the amount of subsidy received. Thus, they are functionally similar to the ZEV credit metrics, which determine the amount of ZEV credit earned by each vehicle. Some examples of performance and other criteria for ZEVs in other jurisdictions are discussed in the following sections.

The criteria imposed by the various countries establish minimum, threshold standards that must be met to qualify for vehicle incentives. The amount of the subsidy then varies according to battery capacity or the price of the vehicle. Given that battery capacity is the prime determinant of vehicle cost, these approaches essentially use cost as the metric for determining the amount of subsidy. Note that no additional credit is given for performance (e.g., range, top speed) above the minimum, except insofar as additional battery capacity supports higher performance.

#### *United States*

Table 2 shows the criteria that electric vehicles and PHEVs must meet to qualify for the U.S. tax credit.<sup>8</sup> The tax credit for new plug-in electric vehicles, based on battery capacity, is \$2,500 plus \$417 for each kilowatt-hour of battery capacity >5 kWh. The portion of the credit determined by battery capacity cannot exceed \$5,000, such that the maximum amount of the credit allowed for a new electric vehicle or PHEV is \$7,500.

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<sup>8</sup> [www.fueleconomy.gov/feg/taxphev.b.shtml](http://www.fueleconomy.gov/feg/taxphev.b.shtml)



**Table 2. Qualification Criteria for U.S. Electric Vehicle Tax Credit**

Criterion	Details
<b>Vehicle type</b>	<ul style="list-style-type: none"> <li>• Must be made by a manufacturer (does not cover conventional vehicles converted to electric drive)</li> <li>• Small neighborhood electric vehicles do not qualify</li> <li>• Must be treated as a motor vehicle for purposes of Title II of the Clean Air Act</li> <li>• Must have a gross vehicle weight rating of <math>\leq 14,000</math> lbs</li> </ul>
<b>Basis of tax credit</b>	<ul style="list-style-type: none"> <li>• Battery capacity (\$2,500 plus \$417 for each kilowatt-hour of battery capacity over 5 kWh)</li> </ul>
<b>Emissions</b>	<ul style="list-style-type: none"> <li>• Must meet U.S. Environmental Protection Agency emissions standards (if it is a highway vehicle):</li> <li>• Bin 5 Tier II standards for vehicles with GVWR <math>\leq 6,000</math> lbs</li> <li>• Bin 8 Tier II standards for vehicles with a GVWR <math>&gt; 6,000</math> lbs and <math>\leq 8,500</math> lb</li> </ul>
<b>Vehicle performance</b>	<ul style="list-style-type: none"> <li>• Must be propelled to a significant extent by an electric motor that draws electricity from a battery that—</li> <li>• Has a capacity of <math>\geq 4</math> kWh, and</li> <li>• Is capable of being recharged from an external source of electricity</li> </ul>

*GVWR = gross vehicle weight rating.*

*China*

Starting June 1, 2010, private purchasers of PHEVs and BEVs meeting the requirements shown in Table 3 receive 3,000 yuan (\$U.S.440) for each kWh of battery capacity, with the total amount of subsidy up to 50,000 yuan (\$U.S.7,400) for PHEVs and 60,000 yuan (\$U.S.8,800) for electric vehicles, respectively.<sup>9</sup>

**Table 3. Criteria for Qualification for Chinese Electric Vehicle Subsidy**

<b>Criterion</b>	<b>Details</b>
<b>Vehicle type</b>	<ul style="list-style-type: none"> <li>• PHEV and BEV</li> <li>• M1 vehicles (i.e., not exceeding 3,500 kg in kerb mass), with up to 9 passenger seats</li> </ul>
<b>Basis of subsidy</b>	<ul style="list-style-type: none"> <li>• Battery Capacity (CNY3,000 (\$U.S.440) for each kWh of battery capacity, up to CNY50,000 (\$U.S.7,400) for PHEVs and CNY60,000 (\$U.S.8,800) for BEVs.</li> </ul>
<b>Vehicle performance</b>	<ul style="list-style-type: none"> <li>• For BEV, minimum battery capacity 15 kWh</li> <li>• For PHEV, minimum battery capacity 10 kWh, minimum driving range in electric mode 50 km</li> <li>• Warranty on key parts and battery: 5 years or 100,000 km, whichever is reached first</li> <li>• Vehicle and battery recycling: Manufacturers must establish a system to recycle used cars and batteries</li> </ul>
<b>Other</b>	<ul style="list-style-type: none"> <li>• Vehicle models must be on the Recommendation List</li> <li>• Manufacturers must disclose key technical and performance information to consumers, including maximum speed, acceleration, maximum climbing degree, energy consumption, and charging time.</li> </ul>

*PHEV = plug in hybrid electric vehicle; BEV = battery electric vehicle.*

<sup>9</sup> China Ministry of Finance Ministry of Industry and Information Technology Ministry of National Development and Reform Commission. *On the Private Purchase of New Energy Vehicles to Carry Out the Pilot Notified Subsidies*. Available at: [http://jjs.mof.gov.cn/zhengwuxinxi/zhengcefagui/201005/t20100531\\_320528.html](http://jjs.mof.gov.cn/zhengwuxinxi/zhengcefagui/201005/t20100531_320528.html). Accessed July 23, 2010.

*United Kingdom*

The United Kingdom offers a grant to reduce the cost of eligible BEV, PHEV, and hydrogen cars by 25%, to a maximum of £5,000 (~\$U.S.7,700). The incentive, which will be reviewed after 1 year of operation, became available to consumers and business buyers in January 2011.<sup>10</sup> The criteria that must be met to receive the subsidy are shown in Table 4.

**Table 4. Criteria for Qualification for U.K. Electric Vehicle Subsidy**

Criterion	Details
<b>Vehicle type</b>	<ul style="list-style-type: none"> <li>• M1 (i.e., cars only)</li> <li>• Must be BEV, PHEV, or hydrogen fuel cell vehicle</li> </ul>
<b>Basis of subsidy</b>	<ul style="list-style-type: none"> <li>• Vehicle price [25%, to a maximum of £5,000 (~\$U.S.7,700)]</li> </ul>
<b>Emissions (tailpipe only)</b>	<ul style="list-style-type: none"> <li>• 0 g/km CO<sub>2</sub> for electric vehicle</li> <li>• Max 75g/km CO<sub>2</sub> for PHEV</li> </ul>
<b>Vehicle performance</b>	<ul style="list-style-type: none"> <li>• Electric vehicle minimum range 70 mi (113 km)</li> <li>• PHEV minimum range 10 mi (16 km)</li> <li>• Maximum speed at least 60mph (96 kph)</li> <li>• Warranty, vehicle: 3 years or 75,000 mi (120,000 km)</li> <li>• Warranty, battery: 3 years, required to offer 5 if requested by consumer</li> <li>• Battery degradation: a rate of degradation such that battery retains a reasonable degree of performance after a 3-year period of normal use.</li> </ul>

*BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle.*

**ARB Staff Proposal**

At the November 16, 2010, public workshop<sup>11</sup> ARB staff laid out current staff thinking regarding metrics. In brief, staff members proposed to base ZEV credit on range, as follows:

- Credit is based on Urban Dynamometer Driving Schedule range (city test cycle) rather than real-world (label) range
- Minimum range to earn credit is 50 mi
- Additional range >50 mi earns 0.01 credit per mile, up to a maximum of three additional credits at 350 mi total range
- Credit for range >350 remains at 4.0

Thus the staff proposed formula for ZEV credit is as follows:

$$\text{ZEV credit} = 1 + \frac{\text{UDDS range} - 50}{100}$$

Minimum range = 50 and maximum credit = 4.0

<sup>10</sup> Department for Transport. *OLEV Plug-in Car Grant*. Available at: <http://webarchive.nationalarchives.gov.uk/+http://www.dft.gov.uk/pgp/sustainable/olev/grant/>

<sup>11</sup> 2010 Zero Emission Vehicle (ZEV) Regulatory Activities—Submit Comments. See staff presentation at [www.arb.ca.gov/msprog/zevprog/2010zevreg/2010zevreg.htm](http://www.arb.ca.gov/msprog/zevprog/2010zevreg/2010zevreg.htm)

## NEAR-TERM METRICS: VEHICLE COMMERCIALIZATION

As was discussed in the ICCT Task 1 report on ZEV technology status,<sup>12</sup> policies to encourage vehicle electrification must be mindful of quite different near-term and long-term challenges. In the near term, the goal is commercialization, to be accomplished through successful deployment of the first waves of vehicles and ramping up to larger production volumes. Because vehicle numbers are small, the emission reductions at this stage are relatively minor. In the long term, the focus needs to shift to emission reductions and energy security. At some point, the ZEV program will be incorporated into the broader Low-Emission Vehicle program fleet average standard. This section evaluates metrics that support ZEV commercialization. The section on long-term metrics discusses issues associated with the transition to a fleet average.

### Incentivized Outcomes

Any metric rewards a particular attribute or characteristic and, thus, incentivizes a particular outcome. The outcomes encouraged by ZEV program metrics fall into three general categories:

1. *Marketability*. The fundamental challenge facing advanced technology vehicles is the need to appeal to vehicle purchasers. To achieve widespread deployment, ZEVs will need to offer acceptable performance to the customer at a competitive price. Although *acceptable* need not mean “equivalent to conventional vehicles,” vehicle functionality is a key determinant of marketability to customers.
2. *Diversity of platforms and technologies*. Most of the early ZEV production vehicles are relatively small BEVs aimed at urban users and niche market high-end high-performance vehicles. This makes sense given current battery and fuel cell costs, energy storage and weight limitations and the limited range needed for most urban driving. However to move beyond niche status, a variety of vehicle types must be made available to customers. Many experts believe that there will ultimately be a “continuum” of drivetrains in which small, short-range vehicles use batteries while larger, longer-range vehicles use fuel cells.<sup>13</sup>
3. In addition, there is value in encouraging continued FCEV development to maintain multiple pathways, even though currently FCEVs are more expensive than the shorter-range BEVs being brought to market. This point is supported by a recent National Research Council Review of the Research Program of the FreedomCar and Fuel Partnership, which states
 

Given the uncertainty of technical and market success of many of the technologies under development, the committee believes that longer-term hydrogen and automotive fuel cell programs should remain in a balanced R&D portfolio of different options and is an appropriate strategy for the Partnership to pursue.<sup>14</sup>
4. *Emission reductions*. As noted previously, one of the fundamental objectives of the ZEV program is to reduce criteria pollutant and greenhouse gas emissions. Thus measures are needed to quantify the emissions performance of the vehicles.

<sup>12</sup> International Council on Clean Transportation. *Technology and Innovation Project, Vehicle Electrification Policy Study, Task 1 Report: Technology Status*.

<sup>13</sup> See for example *A portfolio of power-trains for Europe*, op. cit.

<sup>14</sup> Review of the Research Program of the FreedomCar and Fuel Partnership: Third Report, Committee on Review of the FreedomCAR and Fuel Research Program, Phase 3; National Research Council, p. S-1

Table 5 lists all of the metrics used or under consideration in the ZEV program and in other jurisdictions. For each metric, the table provides an example of how it might be structured and identifies the outcome(s) that it encourages.

**Table 5. Summary of Metrics and Incentivized Outcomes**

Metric	Example(s)	Incentivized Outcome(s)		
		Marketability	Diversity	Emissions
Range	<ul style="list-style-type: none"> <li>Average distance traveled on the city/hwy/US06 test cycles, including 20°F cold test and 95°F air conditioning test</li> </ul>	X	X	
Refueling rate	<ul style="list-style-type: none"> <li>Number of miles of range added in 15 min refueling</li> </ul>	X	X	
Refueling access	<ul style="list-style-type: none"> <li>Availability of electric infrastructure and H<sub>2</sub> clusters</li> </ul>	X	X	
Full function capability	<ul style="list-style-type: none"> <li>Ability to maintain 70% of tested range (or kWh/mi) w/ heating or air conditioning</li> <li>Highway merging—ability to achieve 0–60 mph within 11 s</li> <li>Ability to follow an entire real-world (e.g., US06) testing cycle.</li> </ul>	X		
Long-term vehicle cost potential	<ul style="list-style-type: none"> <li>High-volume cost estimations for 2015, 2020, 2030 for given vehicle technologies</li> <li>Fueling infrastructure cost estimations for 2015, 2020, 2030 for given e-, H<sub>2</sub> fuel pathways</li> </ul>	X	X	
Well-to-wheel emissions	<ul style="list-style-type: none"> <li>Estimated GHG emissions per mile, including upstream</li> </ul>			X
Innovation	<ul style="list-style-type: none"> <li>Investment in multiple drivetrain options</li> </ul>		X	
Technology portfolio	<ul style="list-style-type: none"> <li>Current availability of low-GHG primary energy sources (e.g., renewable electricity or H<sub>2</sub>)</li> <li>Assessment of near and long-term future prospects for increasingly lower GHG energy sources</li> </ul>		X	
Zero emission VMT	<ul style="list-style-type: none"> <li>Assumed or measured annual miles traveled in ZEV mode</li> </ul>	X	X	X
Efficiency	<ul style="list-style-type: none"> <li>Miles per kWh or MJ</li> </ul>	X		X
Energy storage power capacity	<ul style="list-style-type: none"> <li>Useable kWh (based on rated kWh, operating state-of-charge)</li> <li>Rated H<sub>2</sub> energy capacity (in MJ or kWh equivalent)</li> </ul>	X	X	
Durability	<ul style="list-style-type: none"> <li>Calendar years or VMT to 80% of initial rated capacity</li> </ul>	X		
Multiple platforms	<ul style="list-style-type: none"> <li>Technology availability in several vehicle classes—subcompacts, midsize sedans, SUVs, large pick-ups</li> </ul>		X	
Footprint	<ul style="list-style-type: none"> <li>Track x wheelbase</li> </ul>	X	X	
Electricity-powered fraction of energy consumption	<ul style="list-style-type: none"> <li>100% for battery electric vehicles, FCEV</li> <li>For PHEV, approximated based on electric fraction of total energy consumption for average driving patterns</li> </ul>		X	
Warranty	<ul style="list-style-type: none"> <li>Length of warranty provided on battery or fuel cell stack</li> </ul>	X		

VMT = vehicle miles traveled; SUV = sport utility vehicle; FCEV = fuel cell electric vehicle; PHEV = plug in hybrid electric vehicle; ZEV = zero emission vehicle; GHG = greenhouse gas.

## Desired Outcomes

As noted previously, metrics seek to encourage two attributes to support commercialization—marketability and a diversity of platforms and technologies. At today’s early stage of ZEV development, there is substantial uncertainty as to what mix of vehicle features and performance characteristics will have the greatest appeal to consumers. The design of any vehicle involves a multitude of choices, compromises, and tradeoffs; for electric vehicles, this phenomenon is even more pronounced. BEVs, PHEVs, and FCEVs each have very different performance characteristics. Within each platform, there is a broad range of approaches that seek to balance cost, range, performance, durability, and other attributes. Manufacturers are pursuing a variety of approaches—small BEV city cars, midsize BEVs, performance-oriented BEV roadsters, PHEVs with varying all-electric ranges, and differing styles and sizes of FCEVs.

Given this uncertainty and the broad range of experimentation now taking place, ICCT believes that metrics should allow manufacturers the flexibility to design, manufacture, and market vehicles that will meet customer needs rather than encourage a specific technology or design. From a metric standpoint, this argues for an emphasis on supporting a diversity of platforms and technologies.

This does not imply, however, that the program should simply treat all electric vehicles the same. Because increased performance comes at increased cost, not all of which is likely to be recoverable through increased vehicle price,<sup>15</sup> an approach that treats all vehicles the same provides a de facto incentive for manufacturers to produce the cheapest, least capable vehicles. This strategy works against the diversity objective. Thus, the basic underlying objective is to define metrics that compensate manufacturers for higher cost/higher function solutions so that the ZEV program encourages rather than discourages manufacturers to pursue a variety of approaches.

The following sections evaluate the identified diversity metrics to determine which are best suited for the task.

## Criteria for Evaluation

Several criteria can be applied to determine which metrics or combinations of metrics should be pursued:

- *Simplicity.* Stakeholders want a simplified ZEV regulation, one with fewer and less complex metrics.
- *Correlation with increased functionality.* The uncompensated increased cost of higher function approaches should be addressed.
- *Measurability.* The ease or difficulty of quantifying what the metric is trying to measure should be addressed.

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<sup>15</sup> See, for example, Turrentine, T., & Kurani, K. *The Household Market For Electric Vehicles: Testing the Hybrid Household Hypothesis—A Reflexively Designed Survey of New-car-buying, Multi-Vehicle California Households*. UCD-ITS-RR-95-5. May 12, 1995. Available at: [http://pubs.its.ucdavis.edu/publication\\_detail.php?id=666](http://pubs.its.ucdavis.edu/publication_detail.php?id=666)

## Evaluation

The evaluation is summarized in Table 6, which shows for each metric how it performs on each of the criteria identified previously (simplicity, correlation with increased functionality, measurability).

**Table 6. Evaluation of Identified Diversity Metrics**

Metric	Simplicity	Correlation With Increased Functionality	Measurability
ZEV Range	Complex	Good for pure BEVs and FCEVs, moderate for PHEVs	Initial range easy to measure once defined
Refueling rate	Straightforward	Moderate	Easy to measure once defined
Refueling access	Complex	Weak	Difficult to define and measure
Long-term vehicle cost potential	Complex	Good	Difficult to measure
Innovation	Complex	Good	Difficult to measure
Technology portfolio	Complex	Good	Difficult to measure
Zero emission VMT	Complex	Good	Easy to measure once defined
Energy storage power capacity	Straightforward	Good for BEVs, weak for FCEVs	Easy to measure
Multiple platforms	Complex	Good	Difficult to measure
Footprint	Straightforward	Weak	Easy to measure
Electricity-powered fraction of energy consumption	Complex	Good for PHEVs, weak for BEVs and FCEVs	Easy to measure once defined

*ZEV = zero emission vehicle; PHEV = plug-in hybrid electric vehicle; BEV = battery electric vehicle; FCEV = fuel cell electric vehicle; VMT = vehicle miles traveled.*

## Recommendation

For the reasons discussed earlier, the most important criterion is correlation with increased functionality. As Table 6 illustrates, several metrics are well correlated with this attribute. Many, however, are difficult to measure. The only reasonably well-correlated metrics that are also easy to measure are ZEV range, energy storage power capacity, and electricity-powered fraction of energy consumption. None of these works well for all vehicle types. ZEV range does not capture the extra cost that a PHEV incurs for the conventional drivetrain, energy storage power capacity does not capture the stack cost for a FCEV, and electricity-powered fraction of energy consumption would be the same (100%) for all BEVs and FCEVs.

### 1. Recommended Metrics

- Range.* Because the focus of the ZEV program and this project is on BEVs and FCEVs, ICCT recommends the use of ZEV range, which works well for those technologies. The range metric should use the adjusted mileage value (based on the U.S. Environmental Protection Agency methodology to correct the city/highway results to reflect real-world driving conditions) or on “five-cycle” testing (city, highway, US06, SC03, cold federal test procedure<sup>16</sup>). This metric can be structured as bins (similar to the current approach) or as a continuous function. ICCT recommends the use of a continuous function to provide maximum flexibility to manufacturers and appropriately recognize performance differences across vehicles. To recognize that above a certain level, additional range is of less value, and to minimize gaming, ICCT recommends that a reduced credit value be provided for range >350 mi and that no additional credit be provided for range >500 mi.
- Footprint.* Using only a range metric would incentivize the production of small vehicles, which can travel farther on a given amount of stored energy. In practical terms, this may be a moot point, because cost and technology trends will similarly favor small vehicles. In light of the desire to encourage diverse applications, however, it is useful to include a size component in the vehicle scoring metric as well. This will support the development of ZEVs that cover multiple market niches. Options here include vehicle weight, shadow (length x width), and footprint (wheel-base x track). ICCT recommends the use of footprint because this metric rewards downweighting; for that reason, it is already used in the California and federal GHG fleet average calculation methodology.

One concern that should be acknowledged is that a footprint factor, by providing additional credit for larger vehicles, could lower incentives to reduce size and thus also energy usage and GHG emissions. On balance, ICCT believes that the advantages to be gained by application of a moderate footprint factor in this limited

<sup>16</sup> The additional test cycles measure performance under circumstances not captured by the city and highway test cycles. The US06 procedure simulates aggressive highway driving, the SC03 simulates air conditioner usage, and the cold federal test procedure simulates cold weather operation. All of these factors can significantly affect electric vehicle range.



and specific circumstance outweigh the potential disadvantages of incentivizing increased size. Moreover, as discussed later, this concern can be mitigated based on the relative weighting afforded to the range factor versus the footprint factor.

## 2. Scoring Approach

Range and footprint could be used in a variety of ways to calculate ZEV credit. The method chosen will affect both the overall credit awarded to a particular vehicle as well as the relative credit of that vehicle versus other configurations.

The first consideration is the relative weight to be attached to the range factor versus the footprint factor. Because range is the primary determinant of vehicle functionality, and in recognition of the desire to not overincentivize increased vehicle size, ICCT recommends that the scoring system primarily rely on range. In the proposed structure, for the example vehicles shown in Table 7, the range score varies from 3.85 to 0.53, a ratio of approximately 7:1, whereas the footprint score varies from 1.08 to 0.80, a ratio of 1.25:1. This provides some adjustment for larger vehicles but leaves range as the dominant element.

**Table 7. Example Scores Using Recommended Metrics, ARB and ICCT**

Vehicle	Vehicle Specifications			ICCT Scoring			ARB Scoring	
	Unadjusted ZEV Range (UDDS)	Adjusted ZEV Range (USEPA Label)	Footprint	Range Score	Footprint Score	Total Score	Range Score	Total Score
ICCT "1-credit" vehicle	143	100	6,400	1.00	1.00	1.00	1.93	1.93
ARB "1-credit" vehicle	50	35	6,400	0.35	1.00	0.35	1.00	1.00
i-Miev	75	53	5,100	0.53	0.80	0.42	1.25	1.25
Nissan Leaf	100	73	6,378	0.70	0.99	0.69	1.5	1.5
Tesla Roadster	245	172	5,403	1.72	0.84	1.45	2.95	2.95
Honda Clarity	337	240	6,888	2.40	1.08	2.58	3.87	3.87
Midsize SUV FCEV	300	210	6,936	2.10	1.08	2.28	3.5	3.5
Long-range midsize SUV FCEV	600	420	6,936	3.85	1.08	4.17	4.00	4.00

ARB = Air Resources Board; ZEV = zero emission vehicle; UDDS = Urban Dynamometer Driving Schedule; USEPA = U.S. Environmental Protection Agency; SUV = sport utility vehicle; FCEV = fuel cell electric vehicle.

Turning next to the overall credit value, the average credit earned per vehicle determines the number of vehicles produced in response to a given percentage mandate. For example, assuming California annual sales by major manufacturers of 1 million vehicles, a nominal “2%” mandate will result in 20,000 ZEVs if the average vehicle earns 1 credit, but only 4,000 vehicles if the average vehicle earns 5 credits. As illustrated in Table 1, in past and current iterations of the ZEV regulation, many vehicle types earned in excess of 1 credit, leading to a sometimes confusing disconnect between the nominal mandate and the expected number of vehicles. The discussions in the Task 1 report regarding analyst projections and regulatory requirements are all expressed in terms of actual vehicles. To provide a firmer link between the nominal percentage requirement and the resulting number of vehicles, ICCT recommends that the credit calculation be structured such that the “average” vehicle receives 1 credit. Given the considerable uncertainty that surrounds future vehicle packaging and consumer preferences, this approach is challenging. It appears clear, however, that as an overall design objective, the “1-credit” vehicle should not be one that scores at the bottom end of possible credit values. ICCT recommends that the “1 credit” vehicle should be a small vehicle (footprint = 6,400, similar to a Nissan Leaf) with an adjusted [U.S. Environmental Protection Agency (USEPA) label] range of 100 mi.

The second variable is the relative scores earned by various vehicle types, particularly longer range vehicles (likely to be FCEVs) as opposed to shorter range vehicles (likely to be BEVs). A review of the current credit values shown in Table 1 indicates that through 2017, a Type V vehicle (typically a longer range FCEV) earns 7 credits whereas a Type II vehicle (typically a BEV with 100 mi city test cycle range and no fast refueling) earns 3 credits, for a ratio of 2.33 to 1. Barring any modifications, in 2018 the ratio will drop to 1:1. ICCT believes it is appropriate to continue to provide higher credit for longer-range vehicles to compensate for their added functionality and the added cost that may not be fully recouped through vehicle price. The ICCT proposed credit structure provides a credit value of 2.28 for a FCEV midsize SUV with a 210-mi label range and 0.69 for a small BEV with a 70-mi label range, a ratio of approximately 3.3:1. Although it is impossible to quantify precisely the long-term relative cost of various technologies, this value is intended to reflect the cost and risk premium associated with FCEV vehicle and infrastructure development.

Taking all of these factors into account, the specific recommended form of the credit calculation is as follows:

$$\text{ZEV range credit} \times \text{footprint credit}$$

where

$$\text{ZEV range credit} = \frac{\text{adjusted ZEV range up to 350}}{100} + \frac{\text{adjusted ZEV range between 351 and 500}}{200}$$

up to a maximum range of 500 (maximum range credit 4.25), and

$$\text{ZEV footprint credit} = \text{footprint}/6,400$$

### Comparison of ARB and ICCT Proposals

Table 7 provides examples of how some planned and hypothetical vehicles would score under the metrics proposed by ICCT and by ARB staff. The assumed label range used by ICCT was derived by discounting the unadjusted range by 30%. The ARB scores are consistently higher than ICCT scores, except for a long-range vehicle that earns credit above the ARB range cap. This affects the calculation of credit but does not by itself affect the stringency of the regulation, which also depends on the overall percentage requirement.

Table 8 shows the required number of vehicles that result from the ARB and ICCT proposals, using ARB assumptions regarding vehicle sales, the baseline BEV and FCEV, and the mix of BEVs and FCEVs by year. In all cases, these calculations assume full use of the transitional zero emission vehicle (TZEV) option,<sup>17</sup> which is considered the most likely scenario by ARB staff. The resulting number of TZEVs is not included on this table and would be in addition to the totals shown. Note that although the nominal percentage requirement is higher under the ICCT formulation, the required number of vehicles actually is somewhat lower because of the larger number of credits required under the ARB proposal. Note also that using the standard ARB assumptions, the actual sales percentage in 2025 is 7.6% for ARB and 6.8% for ICCT.

<sup>17</sup> The ARB staff proposal allows manufacturers to use TZEVs (typically PHEVs or hydrogen internal combustion vehicles) to meet a specified portion of the ZEV requirement.

**Table 8. Number of Required Vehicles Using Proposed Metrics and Percentage Requirements, ARB and ICCT**

	Phase V				Phase VI			
	2018	2019	2020	2021	2022	2023	2024	2025
<b>Vehicle sales (millions)</b>	1.458	1.481	1.504	1.493	1.516	1.539	1.574	1.590
<b>Nominal ZEV percentage</b>								
<b>ARB</b>	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0
<b>ICCT</b>	1.5	2.0	3.0	4.0	7.0	8.0	9.0	10.0
<b>ARB credit requirement percentage</b>	3.06	4.08	6.12	8.16	11.85	14.22	16.59	18.96
<b>Credit for 100 mi UDDS BEV</b>								
<b>ARB</b>	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
<b>ICCT</b>	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
<b>Credit for 350 mi UDDS FCEV</b>								
<b>ARB</b>	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
<b>ICCT</b>	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65
<b>Assumed vehicle mix percentage</b>								
<b>BEV</b>	82.5	81.4	78.0	75.0	70.8	68.2	64.6	60.0
<b>FCEV</b>	17.5	18.6	22.0	25.0	29.2	31.8	35.4	40.0
<b>Average vehicle credit</b>								
<b>ARB</b>	1.94	1.96	2.05	2.13	2.23	2.30	2.38	2.50
<b>ICCT</b>	1.03	1.06	1.12	1.18	1.26	1.31	1.38	1.47
<b>Required number of ZEVs</b>								
<b>ARB</b>	23,021	30,768	44,894	57,314	80,568	95,333	109,513	120,550
<b>ICCT</b>	21,130	28,063	40,185	50,541	84,026	93,663	102,358	107,823
<b>Percentage of sales</b>								
<b>ARB</b>	1.6	2.1	3.0	3.8	5.3	6.2	7.0	7.6
<b>ICCT</b>	1.4	1.9	2.7	3.4	5.5	6.1	6.5	6.8

ARB = Air Resources Board; ZEV = zero emission vehicle; UDDS = Urban Dynamometer Driving Schedule; BEV = battery electric vehicle; FCEV = fuel cell electric vehicle.

### Applicability

The current ZEV regulation provides credits to vehicles, such as NEVs, that are not legal to operate on streets with a speed limit >25 miles per hour. ICCT believes that NEVs have a market niche and can provide environmental benefits, but they are not helping to facilitate the commercialization of electric drive passenger vehicles. Therefore, ICCT recommends that CARB's program revisions for 2018 no longer provide ZEV credits for NEVs. The credit should be retained as currently specified through 2018, because manufacturers have incorporated this value into their product planning.

Ideally, the recommended metrics should also apply in a consistent fashion to PHEVs, but the calculation of PHEV all electric range presents several difficulties that are not yet fully resolved. More work is needed to determine how best to accommodate PHEVs within the scoring system.

### Interaction with the "Travel" Provision

Section 177 of the Clean Air Act allows other states to adopt the California vehicle standards.<sup>18</sup> Thirteen other states and the District of Columbia have exercised this authority,<sup>19</sup> roughly tripling the population and vehicle sales subject to the ZEV regulation compared with California alone. Under the "travel" provision of the ZEV regulation, vehicles placed in any Section 177 state count for compliance in all states. This provision is intended to recognize that ZEV placement can be more easily accomplished in some states because of infrastructure readiness, weather, incentives and other factors.

The ARB staff proposal outlined at the November 16, 2010, public workshop would sunset the travel provision in 2018 for all vehicles other than FCEVs.<sup>20</sup> Travel for FCEVs would extend until sufficient complementary policies (e.g., infrastructure and incentive programs) are established in Section 177 states. ICCT supports this extension, because a lack of infrastructure would preclude manufacturers from using FCEVs as part of their compliance strategy, undercutting the goal of fostering a diversity of technologies and applications. Because the travel provision has the effect of increasing the credit value of a covered vehicle by a factor of three, the impact of this proposal is to provide a threefold increase in the relative credit for FCEVs as opposed to BEVs for 2018 and beyond. This is not expected to reduce the number of FCEVs placed in California, because of California's aggressive hydrogen infrastructure development. However, it does significantly increase the relative attractiveness of FCEVs from a credit standpoint at a time when their incremental

<sup>18</sup> Title 1 of the Clean Air Act (Air Pollution Prevention and Control). Available at: [www.epa.gov/oar/caa/title1.html](http://www.epa.gov/oar/caa/title1.html).

<sup>19</sup> States that have adopted the California program are Arizona, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont and Washington. Union of Concerned Scientists. *The Clean Car Standards: Background and FAQs*. Cambridge, MA: Union of Concerned Scientists; 2009. Available at: [www.ucsusa.org/clean\\_vehicles/solutions/cleaner\\_cars\\_pickups\\_and\\_suvs/clean-car-standards-background-faqs.html](http://www.ucsusa.org/clean_vehicles/solutions/cleaner_cars_pickups_and_suvs/clean-car-standards-background-faqs.html).

<sup>20</sup> ZEV Regulation 2010 Staff Proposal. Public Workshop. November 16, 2010. [www.arb.ca.gov/msprog/zevprog/2010zevreg/11\\_16\\_10pres.pdf](http://www.arb.ca.gov/msprog/zevprog/2010zevreg/11_16_10pres.pdf), p. 23

cost relative to BEVs is expected to decline. Thus, care must be taken to avoid overincentivizing FCEVs. The need for the ongoing extension of the travel provision should be revisited during future reviews of the ZEV program, and, as noted previously, ICCT supports a cap on range credit to limit the overall incentive provided.

### **Other Possible Metrics**

ICCT considered providing additional credit for vehicles that have fast refueling or recharging capability, as is the case with the current ZEV regulation. The advantages of such an approach are that it would help incentivize electric vehicle batteries that can also handle fast recharging (which will facilitate the mainstream appeal of BEVs) and that it rewards the ability of FCEVs to provide functionality similar to that of conventional vehicles. Disadvantages include not recognizing the convenience value of home recharging for BEVs, uncertainty as to the real-world availability of fast refueling and fast recharging and the potential for BEV fast recharging to result in large demand during daytime peak load hours. On balance, ICCT does not recommend the inclusion of a fast refueling factor.

ICCT also considered taking into account the durability of the energy storage system. Batteries lose capacity with use and over time, such that the range of the vehicle after several thousand battery cycles or after ten calendar years will be less than when new. This in turn would affect the utility of the vehicle and the number of ZEV miles and resulting emission benefits. At present, however, there is insufficient experience to reliably gauge battery performance over time, particularly with regard to calendar life. In addition, battery life will be a key feature from the customer standpoint, such that manufacturers will have an incentive to ensure that customer expectations are satisfied through battery leasing, warranty or other mechanisms. Therefore, ICCT does not recommend the inclusion of a battery life factor at this time.

Finally, some interested parties have suggested the use of the “technology portfolio” credit identified by ARB, as noted previously. Under this approach, a manufacturer that is already pursuing one technology type (e.g., BEVs) would get additional credit per vehicle for some number of vehicles of a different technology type (e.g., FCEVs). This metric is intended to promote diversity of technologies, in practical terms by providing additional credit for FCEVs (we are not aware of any manufacturer that is pursuing FCEVs only). Although the idea has merit, ICCT does not recommend including it because an appropriate credit level for FCEVs can be accomplished by other means, and we see no rationale for requiring manufacturers to also build BEVs to get an appropriate credit level for FCEVs, or vice versa.

## LONG-TERM METRICS: TRANSITION TO A PERFORMANCE STANDARD

Up to this point, this report has focused on the ZEV regulation and how to measure compliance with the percentage sales requirement through 2025. The remainder of the document addresses the longer-term future of the ZEV program. ARB has stated its intent that for 2026 and beyond, the ZEV program will be incorporated into the LEV program GHG fleet average. Although such a transition is many years off, there is merit in beginning now to consider some of the issues that will need to be addressed along the way. Such issues move beyond the design and operation of the ZEV regulation and begin to address how ZEVs can best be incorporated into the broader LEV III program. Although the areas of concern do not involve metrics in the same sense as the previous discussion, they relate to the measurement of program outcomes and, thus, are an extension of the metrics concept. Two areas of interest are as follows:

- The estimation of per-vehicle ZEV upstream GHG emissions for purposes of including them in the GHG fleet average standard, and
- The determination of the appropriate timing of the transition to a fleet average

### Upstream Emissions

Although electric vehicles have no tailpipe emissions, upstream emissions are generated to the extent that fossil fuel is combusted during the production of the electricity or hydrogen used to power the vehicle. Such emissions can be significant depending on the mix of generation sources. California's 2009–2016 passenger vehicle GHG standards include emission factors that account for upstream emissions from BEVs and FCEVs. Currently, neither the European Union nor the USEPA include electric vehicle upstream emissions in the fleet average GHG calculation, based on the assumption that the exemption incentivizes electric vehicle production. Holding aside for the moment any discussion of the merits of this approach, it is clear that as vehicle numbers increase and electric vehicles begin to make up a larger fraction of the fleet, it will be increasingly important to have an accurate accounting of their emission consequences.

Acknowledging that there is considerable uncertainty about how best to calculate ZEV-related GHG emissions to comply with the California GHG fleet average, this section discusses several related issues and proposes some aspects of an accounting method to calculate ZEV GHG emissions based on known upstream impacts. Additional issues arise with the respect to the treatment of upstream emissions for purposes of federal standards; ICCT intends to examine those issues in a separate paper.

Upstream emissions are relevant in several contexts, including compliance with the GHG fleet average standard, compliance with vehicle labeling requirements,<sup>21</sup> and calculation of real-world emissions for maintaining emission inventories and tracking

<sup>21</sup> For a discussion of vehicle fuel economy and emission labeling see U.S. Environmental Protection Agency. Fuel Economy: Regulations and Standards. 2010. Available at: [www.epa.gov/fueleconomy/regulations.htm](http://www.epa.gov/fueleconomy/regulations.htm).

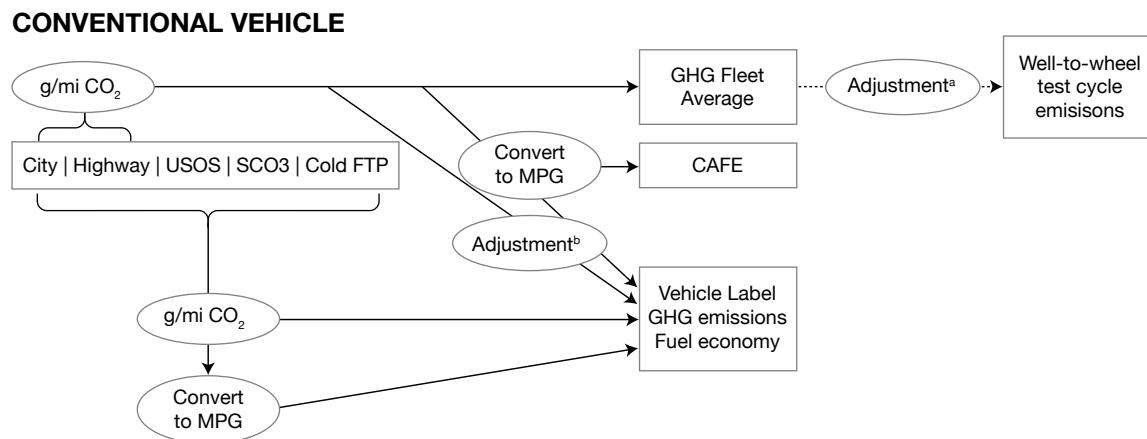
progress toward GHG reduction goals. The treatment of upstream emissions varies based on the particular purpose for which they are being calculated and the regulatory jurisdiction making the calculation.

- To comply with the GHG fleet average—
  - » California and USEPA estimated tailpipe GHG emissions are based on “unadjusted” city/highway fuel economy estimates. These estimates do not take into account many factors that affect fuel economy and emissions, such as aggressive driving or air conditioner usage.
  - » California assigns default upstream emission factors of 130 g/mi CO<sub>2</sub> for BEVs and 210 g/mi CO<sub>2</sub> for FCEVs.
  - » The USEPA assigns electric vehicles an upstream emissions value of 0 g/mi CO<sub>2</sub>.
  - » The European Union also assigns electric vehicles a value of 0 g/mi CO<sub>2</sub>.
- To report on the fuel economy/emissions label—
  - » Estimates of tailpipe GHG emissions and fuel economy are based on additional five-cycle testing. These adjusted estimates take more varied driving conditions into account and more closely reflect real-world driving.
  - » California uses the same default upstream emission factors of 130 g/mi CO<sub>2</sub> for BEVs and 210 g/mi CO<sub>2</sub> for FCEVs.
  - » The USEPA assigns electric vehicles an upstream emissions value of 0 g/mi CO<sub>2</sub>.



Figure 1 provides an illustration of the relationship among the various approaches for conventional vehicles, starting with the test cycles used (on the left hand side). Figure 2 and Figure 3 show the same relationships for BEVs and FCEVs respectively. In the figures, the solid lines show the current approach plus the approach outlined in the recently released USEPA proposed rule regarding vehicle labeling,<sup>22</sup> whereas the dotted lines show possible alternative calculations.

**Figure 1. Conventional vehicle.**



*Notes to Figure 1*

- a. The greenhouse gas (GHG) fleet average takes into account only tailpipe emissions. Therefore, an adjustment is needed to account for upstream emissions. Based on analysis performed by ICCT staff, a reasonable assumption for this factor is the ratio of the Low Carbon Fuel Standard estimated lifecycle emissions for gasoline (11,098 g CO<sub>2</sub>/gallon) to the U.S. Environmental Protection Agency (USEPA) estimated direct (tailpipe) emissions per gallon (8,887 g CO<sub>2</sub>/gal), or 1.25.
- b. The USEPA has defined an updated industry average based correction methodology to adjust the city/highway test cycle results to more closely approximate the mileage obtained in normal driving. This results in a discounting of roughly 20–25% versus the test values. The new calculation uses a new composite city/highway weighting (i.e. 43% city/57% hwy), based on the following formulas:

$$FE_{\text{city, adjusted}} = 1/[0.003259 + 1.1805/FE_{\text{city}}]$$

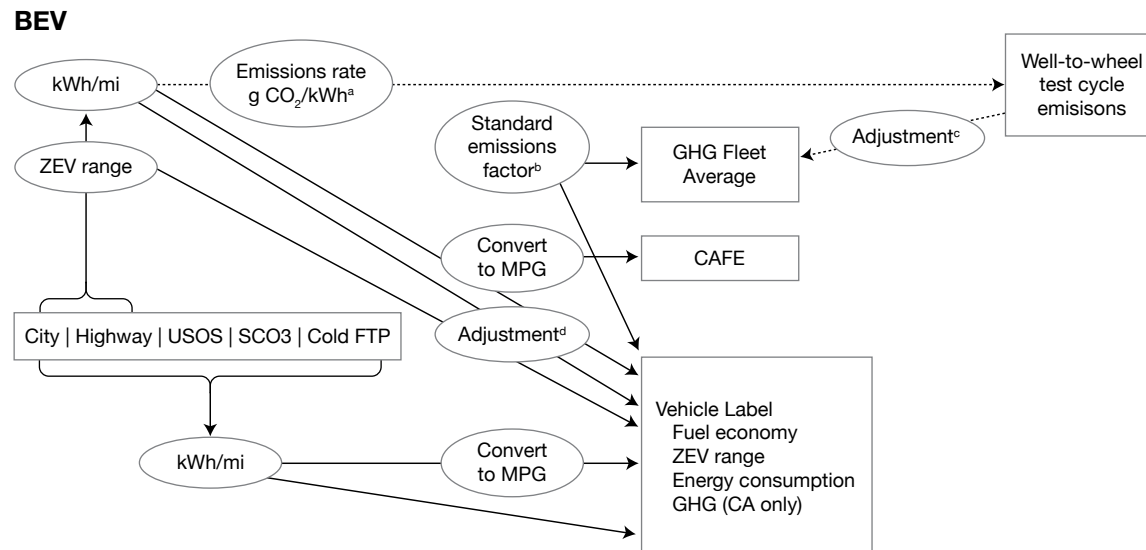
$$FE_{\text{highway, adjusted}} = 1/[0.001376 + 1.3466/FE_{\text{highway}}]$$

Where FE = fuel economy.

Manufacturers are now required to use the “five cycle” testing method.

<sup>22</sup> Environmental Protection Agency, 40 CFR Parts 85, 86 and 600, Department Of Transportation, National Highway Traffic Safety Administration, 49 CFR Part 575 [EPA-HQ-OAR-2009-0865; FRL-9088-2; NHTSA-2010-0087]’ RIN 2060-AQ09; RIN 2127-AK73, Revisions and Additions to Motor Vehicle Fuel Economy Label, August 30, 2010. Available at: <http://edocket.access.gpo.gov/2009/E9-28836.htm>.

Figure 2. Battery electric vehicle.



Notes to Figure 2

- a. Calculation of the greenhouse gas (GHG) emission rate for electricity is complex. Actual emissions will vary according to region, season, time of day, and other factors. The Low Carbon Fuel Standard estimates a 2010 value of 447 g/kWh, taking into account transmission and distribution losses. This number will decrease over time as cleaner generation sources are added to the mix.
- b. The USEPA assigns electric vehicles an emission factor of 0 g/mi (upstream emissions are not included) for both the GHG fleet average and the proposed vehicle label. The California Air Resources Board (ARB) uses an emission factor of 130 g CO<sub>2</sub>e/mi. The California ARB is considering changes to this methodology as part of the upcoming Low Emission Vehicle (LEV) III rulemaking.
- c. The GHG fleet average takes into account only tailpipe emissions from conventional vehicles, thus understating their total emissions. Therefore, an adjustment is needed to treat electric vehicles in a comparable fashion. Based on analysis performed by ICCT staff, a reasonable assumption for this factor is the ratio of the Low Carbon Fuel Standard estimated lifecycle emissions for gasoline (11,098 g CO<sub>2</sub>/gal) to the USEPA estimated direct (tailpipe) emissions per gallon (8,887 g CO<sub>2</sub>/gal), or 1.25. Note that this is the “reverse” of the adjustment proposed for conventional vehicles.
- d. The USEPA has defined an updated industry average based correction methodology to adjust the city/highway test cycle results to more closely approximate the mileage obtained in normal driving. This results in a discounting of roughly 30% versus the test values for electric vehicles. The new calculation uses a new composite city/highway weighting (i.e. 43% city/57% hwy), based on the following formulas:

$$FE_{\text{city, adjusted}} = 1 / [0.003259 + 1.1805/FE_{\text{city}}]$$

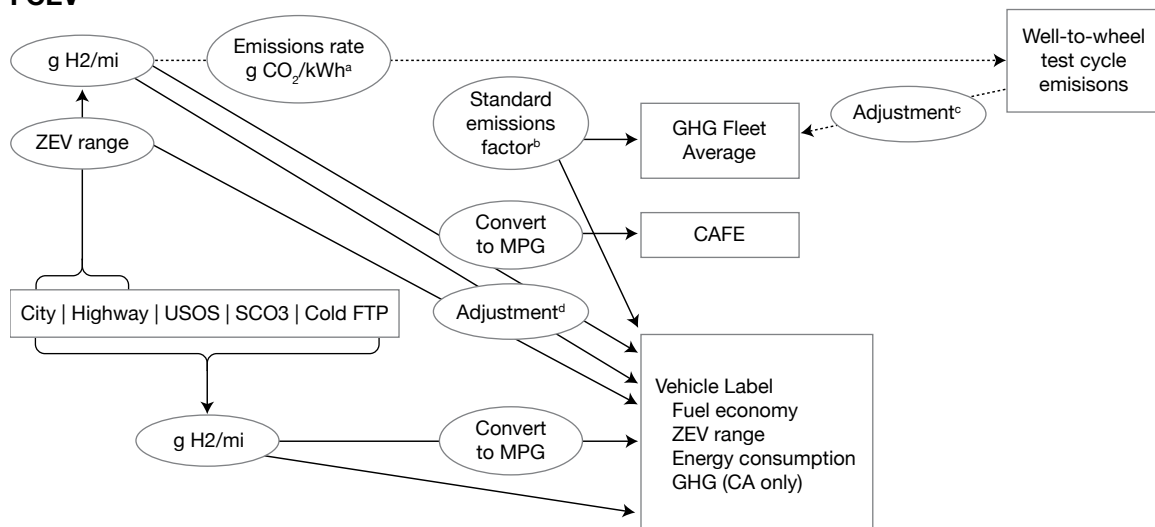
$$FE_{\text{highway, adjusted}} = 1 / [0.001376 + 1.3466/FE_{\text{highway}}]$$

Where FE = fuel economy.

Manufacturers have the option to use the “five cycle” testing method.

Figure 3. Fuel cell electric vehicle.

FCEV



Notes to Figure 3

- a. Calculation of the greenhouse gas (GHG) emission rate for hydrogen production is complex. Actual emissions will vary according to the production method used. The Low Carbon Fuel Standard estimates a 2010 value of 9,132 g CO<sub>2</sub>/kg H<sub>2</sub> for hydrogen produced using a 33% renewable mix and 11,796 g CO<sub>2</sub>/kgH<sub>2</sub> for hydrogen produced using natural gas.
- b. The USEPA assigns electric vehicles an emission factor of 0 g/mi (upstream emissions are not included) for both the GHG fleet average and the proposed vehicle label. The California Air Resources Board (ARB) uses an emission factor of 210 g CO<sub>2</sub>e/mi. The California ARB is considering changes to this methodology as part of the upcoming LEV III rulemaking.
- c. The GHG fleet average only takes into account tailpipe emissions from conventional vehicles, thus understating their total emissions. Therefore, an adjustment is needed to treat EVs in a comparable fashion. Based on analysis performed by ICCT staff, a reasonable assumption for this factor is the ratio of the Low Carbon Fuel Standard estimated lifecycle emissions for gasoline (11,098 g CO<sub>2</sub>/gal) to the USEPA estimated direct (tailpipe) emissions per gallon (8,887 g CO<sub>2</sub>/gal), or 1.25. Note that this is the “reverse” of the adjustment proposed for conventional vehicles.
- d. The USEPA has defined an updated industry average based correction methodology to adjust the city/highway test cycle results to more closely approximate the mileage obtained in normal driving. This results in a discounting of roughly 30% versus the test values for electric vehicles. The new calculation uses a new composite city/highway weighting (i.e., 43% city/57% hwy), based on the following formulae:

$$FE_{\text{city, adjusted}} = 1 / [0.003259 + 1.1805/FE_{\text{city}}]$$

$$FE_{\text{highway, adjusted}} = 1 / [0.001376 + 1.3466/FE_{\text{highway}}]$$

Where FE = fuel economy.

Manufacturers have the option to use the “five cycle” testing method.

The different methodologies result in quite different estimates of the GHG emissions from a particular vehicle. Table 9 shows estimates of GHG emissions that result from using the different approaches for an internal combustion engine compact, a BEV compact, and a FCEV midsize vehicle.

**Table 9. GHG Emissions Estimates (g/mi) for California Vehicles and Fuels Using Various Approaches, 2010**

Vehicle	US EPA GHG Fleet Average Test Procedure (city/highway test)		US EPA Fuel Economy Label Test Procedure (city/highway test plus correction factor)		California Pavley I default factors for ZEV upstream emissions <sup>e</sup>
	Compliance value (excludes upstream emissions) <sup>a</sup>	Compliance value plus ICCT calculated upstream emissions <sup>b</sup>	Compliance value (excludes upstream emissions) <sup>c</sup>	Compliance value plus ICCT calculated upstream emissions <sup>d</sup>	
ICE compact <sup>f</sup>	234	292	308	385	
BEV compact <sup>g</sup>	0	106	0	152	130
FCEV midsize <sup>h</sup>	0	184	0	263	210

- a. Miles per gallon converted to g CO<sub>2</sub>/mi using formula g CO<sub>2</sub>/mi = 8,887/mpg.
- b. The greenhouse gas fleet average only takes into account tailpipe emissions. Therefore an adjustment is needed to account for upstream emissions. For ICEs, based on analysis performed by International Council on Clean Transportation staff a reasonable assumption for this factor is the ratio of the Low Carbon Fuel Standard estimated lifecycle emissions for gasoline (11,098 g CO<sub>2</sub>/gal) to the U.S. Environmental Protection Agency estimated direct (tailpipe) emissions per gallon (8,887 g CO<sub>2</sub>/gal), or 1.25. For electricity and hydrogen, the calculation assumes the Low Carbon Fuel Standard estimates for 2010 of 447 g/kWh for the California electricity grid, taking into account transmission and distribution losses, and 11,796 g CO<sub>2</sub>/kg for hydrogen produced using natural gas.
- c. The relationship between the unadjusted city/highway estimates used for the fleet average and the adjusted estimates used for the label was calculated using the U.S. Environmental Protection Agency composite city/highway weighting (43% city/57% hwy), based on the following formulas:

$$FE_{\text{city, adjusted}} = 1/[0.003259 + 1.1805/FE_{\text{city}}]$$

$$FE_{\text{highway, adjusted}} = 1/[0.001376 + 1.3466/FE_{\text{highway}}]$$

Where FE =fuel economy.

- d. The fuel economy label value for ICE including upstream was obtained by multiplying the fuel economy label compliance value by 1.25 per note b. The calculated upstream values for BEV and FCEV including upstream were obtained by dividing the ICCT calculated city/highway upstream emissions value by 0.7 per the USEPA correction factor.

- e. At present the California Air Resources Board (ARB) uses upstream emission factors of 130 g CO<sub>2</sub>e/mi for BEVs and 210 g CO<sub>2</sub>e/mi for FCEVs. The ARB is considering changes to this methodology as part of the upcoming LEV III rulemaking.
- f. Based on a Nissan Versa four cylinder, 1.8 L, manual six-speed, label fuel economy of 26 city and 31 highway.
- g. Based on a Nissan Leaf, with USEPA GHG fleet average test cycle electricity consumption of 0.222 kWh/mi city, 0.257 kWh/mi highway, and 0.238 kWh/mi combined
- h. Hypothetical, assumes unadjusted values of 14.7 g H<sub>2</sub>/mi city and 16.7 g H<sub>2</sub>/mi highway.

*Note. ICE = internal combustion engine; BEV = battery electric vehicle; FCEV = fuel cell electric vehicle, Pavley I = motor vehicle emission standards for model years 2009-2016 established by the California Air Resources Board pursuant to AB 1493 (Pavley).*

The following sections discuss in more detail some of the issues involved in calculating upstream GHG emissions.

#### *“Supercredits” or “Bonus” Credits.*

*Super credits* or *bonus credits* refer to mechanisms that give BEVs, PHEVs, or FCEVs credit for lower GHG emissions than the vehicles will actually produce, taking into account both tailpipe and upstream emissions. Such credits can be expressed as a fixed amount, an exemption for upstream emissions, or perhaps in other ways. The rationale for such credits is to encourage the deployment of these vehicles. As noted previously, the USEPA and the European Union have both assigned a value of 0 to upstream GHG emissions from electric vehicles.

Automakers have argued that a zero upstream factor is appropriate given that they have no control over grid emissions and should not be held responsible for decisions made in other industries. This argument has some merit. Conversely, from an environmental perspective, it is important to accurately measure and account for fleetwide emissions and fuel consumption. As shown in Table 9, estimated upstream CO<sub>2</sub> emissions for GHG fleet average compliance purposes for a compact BEV are 99 g/mi and for a midsize FCEV are 184 g/mi. As larger numbers of electric vehicles move into the fleet, policies that do not include their upstream emissions will increasingly dilute the actual environmental benefit achieved. Upstream emissions are important and should not be permanently given a value of 0. For some period of time, and for a defined number of vehicles, the use of a 0 upstream factor as an incentive to stimulate the early penetration of electric vehicles may be appropriate. This is a complex issue that merits additional discussion, and ICCT does not provide a specific recommendation at this time.

#### *Average vs. marginal utility mix.*

The emissions attributed to electric vehicle electricity consumption will vary depending on whether the calculation assumes the average emission rate for all electricity versus the emissions from the marginal electricity consumed by electric vehicles. There are

arguments either way. Using the average is the simplest approach, with no information on charging behavior needed. Marginal analysis is more difficult but potentially more representative. Achieving the improved accuracy of a marginal analysis would require an understanding of charging behavior and modeling of the grid dispatch order to determine the marginal plant(s) that would have been held in reserve but are instead turned on to provide power for electric vehicles.

In California, marginal accounting will likely lead to higher imputed GHG emissions because electricity produced by nuclear power and by large hydroelectric facilities would not be included. In areas with a large fraction of coal (around 1,000 g/kWh) and natural gas (400–600 g/kWh), marginal analysis is likely to lead to lower emission estimates because natural gas is likely to be the marginal fuel. Both types of analysis will reward state-level renewable electricity standards. ICCT is planning to undertake further review of this question.

ICCT believes that marginal accounting has the potential to provide the most accurate assessment of the impact of electric vehicles, but more work is needed to develop the appropriate methodology and determine if marginal or average factors are the best starting point.

*Accounting for future grid changes.*

The magnitude of reductions in future California emission rates (because of the adoption of renewable electricity standards and other policies to encourage GHG reduction) is uncertain, but such reductions are likely to favor deployment of BEVs, PHEVs, and, to a lesser extent, FCEVs<sup>23</sup> over conventional vehicles if upstream emission factors are taken into account. The emission intensity of California electricity production is expected to decline because of California renewable electricity goals. Thus, periodic updates to the upstream emission factors would help improve the accuracy of accounting for environmental standards and would likely benefit electric vehicle manufacturers and the auto industry. Some period of certainty is appropriate to reduce administrative overhead and provide industry with certainty for planning purposes. Thus, the emission factors should be defined well in advance and hold firm for a considerable period of time. ICCT suggests defining 5-year windows with the assigned values determined several years in advance.

*Determining vehicle miles traveled.*

PHEVs do not always use grid electricity, whereas some pure electric vehicles have a limited range and thus should not be expected to displace the typical 14,000 mi/year of driving undertaken in a conventional vehicle. One way to account for this issue for BEVs is to look at the commute distances that could be accommodated by an electric vehicle with a given range, and the average vehicle miles traveled for drivers

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<sup>23</sup> Electrolysis is electricity intensive but expensive. Less expensive production using natural gas consumes smaller amounts of electricity.

with a commute distance that falls within that band.<sup>24</sup> This would better represent the actual expected GHG reductions and reward longer-range vehicles that likely will achieve the greatest GHG reductions.

There are also some potential secondary effects that deserve future consideration. If electric vehicle drivers with access to multiple vehicles use a conventional vehicle for longer trips outside their typical commute range, then the real-world emission reduction from the electric vehicle will be overstated. Conversely, electric vehicle drivers with multiple vehicles may use an electric car in preference to a conventional vehicle because of environmental impacts and operating cost savings, and electric vehicle drivers with just one vehicle may forgo some longer trips. As experience is gained, research is needed to determine if this is a significant accounting issue.

### Measuring Commercialization

From its inception the ZEV regulatory mandate has been viewed as a “jump start” measure to incentivize production to a level that could become self-sustaining. The original mandate—10% of vehicle sales in California by 2003—was intended to push production to the point at which larger volumes would be achieved in the open market. Because to date the number of ZEVs produced has not approached a level that can be considered self-sustaining, the intended transitional nature of the program has not received much attention.

Today, for the first time, there are indications that vehicle sales could begin to reach significant volumes. Carlos Ghosn, CEO of Renault and Nissan, predicted that by 2020 electric vehicles will account for 10% of its sales.<sup>25</sup> Volkswagen has announced a goal of having electric vehicles make up 3% of sales in 2018.<sup>26</sup> Along the same lines, several fuel cell manufacturers have stated their expectation for collective placements in the hundreds of thousands beginning in 2015, and their intent to market a commercial FCEV beginning in 2015 in Japan, Korea, Europe, and one U.S. market.<sup>27</sup> The California Fuel Cell Partnership surveyed automakers in 2009 and projected >4,000 vehicles in operation in California by the end of 2015 and >50,000 vehicles in operation by the end of 2018.<sup>28</sup>

As noted, ARB staff has stated its intent that for 2026 and beyond the ZEV program will be incorporated into the LEV program GHG fleet average. Thus, it is now germane to attempt to determine what constitutes commercialization in the

<sup>24</sup> For instance, through National Household Transportation Survey data.

<sup>25</sup> LeBeau, P. Ghosn's Bet: 10% of World Will Drive EVs in 10 Years. [www.cnn.com. 13 November 2009. Available at: www.cnn.com/id/33907442/Ghosn\\_s\\_Bet\\_10\\_of\\_World\\_Will\\_Drive\\_EV\\_s\\_in\\_10\\_Years.](http://www.cnn.com/2009/11/13/cars/ghosn.ev.10/index.html)

<sup>26</sup> Merchant, B. Volkswagen Plans to Sell 300,000 Electric Cars a Year by 2018. [www.treehugger.com/. 2 March 2010. Available at: www.treehugger.com/files/2010/03/volkswagen-plans-sell-300000-electric-cars-year-2018.php.](http://www.treehugger.com/2010/03/volkswagen-plans-sell-300000-electric-cars-year-2018.php)

<sup>27</sup> Daimler, Ford, GM/Opal, Honda, Hyundai/Kia, the Alliance Renault/Nissan, Toyota. Letter of Understanding on the Development and Market Introduction of Fuel Cell Vehicles. 8 September 2009. Available at: [www.h2carblog.com/wp-content/uploads/2009/10/Letter-of-Understanding.pdf.](http://www.h2carblog.com/wp-content/uploads/2009/10/Letter-of-Understanding.pdf)

<sup>28</sup> California Fuel Cell Partnership. *Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A Strategy for Meeting the Challenge Ahead.* February 2009. Available at: [cafcp.org/sites/files/Action%20Plan%20FINAL.pdf.](http://cafcp.org/sites/files/Action%20Plan%20FINAL.pdf)



ZEV context to better inform decisions regarding the timing of a transition to a fleet average.

There are several possible approaches. First is a trigger level percentage of sales, along the lines of the original 10% mandate. Because ZEVs are more likely to meet consumer needs in certain applications (e.g., urban vehicles), perhaps sales figures could be disaggregated to more closely track market penetration. Another approach is to measure annual or cumulative production volume. For cost estimation purposes, ARB staff often define fully learned out production as three suppliers each manufacturing 500,000 units (worldwide) of a particular component per year. A similar approach could be taken for ZEVs.

The measure used will need to take into account that the ZEV mandate itself is creating an artificial sales level in California that presumably would not be reached in the absence of the regulation. Similarly, incentives in place in a variety of jurisdictions will increase demand beyond the unincentivized level. Thus, it may be more appropriate to measure production and sales in areas outside of California (while recognizing that some vehicles produced outside the United States may not be marketable in California) and to take into account the existence of incentives where appropriate. The consideration of sales or production levels should incorporate global production levels.

Any discussion of transitioning to a GHG fleet average must also take into account the stringency of the fleet average that is in place. It is critical that the fleet average be on a trajectory that will allow achievement of environmental goals such as reducing statewide GHG emissions 80% below 1990 levels by 2050. A fleet average that is sufficiently stringent will provide a significant incentive toward vehicle electrification, thus replacing the market push provided by the ZEV mandate. Some have argued for example that the European Union's proposed 95 g/km fleet average standard will in practical terms require increased vehicle electrification if manufacturers want to continue to produce a full line of vehicles.<sup>29,30</sup>

Thus, the determination of whether it is appropriate to transition to a fleet average is the product of two factors—the commercialization status of ZEV technology, as measured by one of the factors noted previously, and the stringency of the fleet average standard vis-à-vis the level needed to promote vehicle electrification. Table 10 shows in simplified form the various possible combinations along with ICCT's view as to how to proceed in each situation. As is shown in Table 10, if the fleet average is sufficient to drive electrification, then the program should transition to a fleet average without regard to the state of technology progress. Similarly, if

29 Roland Berger Strategy Consultants. "Powertrain 2020—The Future Drives Electric": *Global Sales of Electric Vehicles Will Rise to Ten Million in 2020*. 15 September 2009. [www.rolandberger.com/company/press/releases/519-press\\_archive2009\\_sc\\_content/Global\\_sales\\_of\\_electric\\_vehicles.html](http://www.rolandberger.com/company/press/releases/519-press_archive2009_sc_content/Global_sales_of_electric_vehicles.html).

30 Deutsche Bank. *Electric Cars: Plugged In 2, A mega-theme gains momentum*. Deutsche Bank Securities, 3 November 2009. Press archive 2009. Available at: [www.rolandberger.com/company/press/releases/519-press\\_archive2009\\_sc\\_content/Global\\_sales\\_of\\_electric\\_vehicles.html](http://www.rolandberger.com/company/press/releases/519-press_archive2009_sc_content/Global_sales_of_electric_vehicles.html)



technology progress is insufficient to bring commercialization within reach, then the mandate should not be continued regardless of the status of the fleet average.

**Table 10. Interaction of Technology Progress and Stringency of the Fleet Average**

	<b>Fleet Average Sufficiently Stringent to Drive Electrification</b>	<b>Impact of Fleet Average Unclear</b>	<b>Fleet Average Not Sufficiently Stringent to Drive Electrification</b>
<b>Technology progress sufficient for commercialization</b>	Rely on fleet average	Continue mandate	Continue mandate
<b>Commercialization prospects unclear</b>	Rely on fleet average	Continue mandate	Continue mandate
<b>Technology progress insufficient for commercialization</b>	Rely on fleet average	New approach needed	New approach needed

Although it is possible to set a “date certain” and use that as the transition point regardless of production or sales, such an approach would leave the ultimate status of ZEV production uncertain and would not necessarily ensure continued progress toward GHG reduction goals. Rather, ICCT recommends that in the 2018–2020 timeframe, well in advance of the 2026 target date, the ARB conduct a review to determine the underlying conditions and the appropriate response along the lines outlined previously.







The International Council on Clean Transportation is an independent nonprofit organization that works directly with regulatory agencies and policymakers to control greenhouse gas emissions and conventional pollution in the transportation sector. The ICCT provides scientifically sound, technically rigorous analysis to inform the design, implementation, and enforcement of vehicle efficiency and fuel standards in countries accounting for 80 percent of the global automotive market, including China, the European Union, the United States, India, Brazil, South Korea, and Mexico.

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