

**WORLD
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World Energy Perspectives

E-Mobility | 2016



**E-MOBILITY:
CLOSING THE
EMISSIONS GAP**

In collaboration with Accenture Strategy

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ABOUT THE WORLD ENERGY PERSPECTIVES – E-MOBILITY: CLOSING THE EMISSIONS GAP

The World Energy Perspectives on E-Mobility is part of a series of reports based on expert insights from our network of energy leaders and practitioners. This series provides a bottom-up assessment of the key issues and technologies in the transport sector.

There are a variety of clean vehicle technologies and fuels under development and in use, but electric vehicles represent one of the most promising technologies for reducing oil use and cutting emissions. E-Mobility holds significant potential for increasing energy security, reducing carbon emissions and improving local air quality.

Governments across the globe have been emboldened to set increasingly ambitious fuel economy targets over the next five to ten years. Car makers are now required to make continuous improvements well above historical rates of enhancement to placate regulators across the globe. This first E-Mobility report examines the potential of electric vehicles to meet the stringent fuel economy and emissions standards and close the gap.

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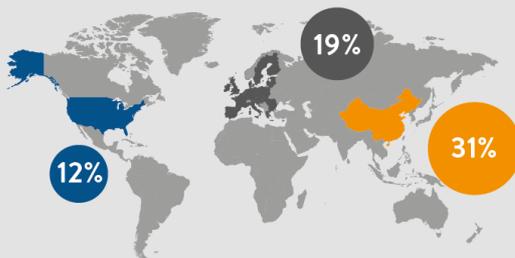


ELECTRIC VEHICLES: CLOSING THE EMISSIONS GAP BY MEETING FUEL EFFICIENCY TARGETS

WORLD ENERGY COUNCIL

NEW PASSENGER VEHICLES MARKET SHARE

The EU, US and China are the world's largest car markets with collective annual demand of over 40 million passenger vehicles.



FUEL ECONOMY IMPROVEMENT TARGETS

Regulators in the EU, US and China have all demanded major improvements in fuel economy by 2020, requiring efficiency improvements two to three times higher than current levels.



KEY

- CHINA
- US
- EU

ELECTRIC VEHICLE SALES GAP

Even capturing less than 1% of combined sales across the three markets, electric vehicles can be key to lowering overall fuel economy to meet new requirements. The **EV GAP** is the number of electric vehicle sales that will be needed in each market to meet the regulatory requirements.



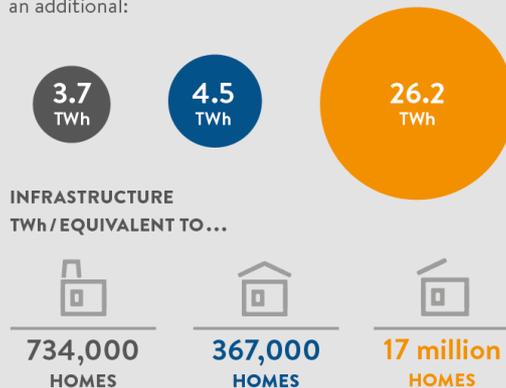
CO₂ SAVINGS

If regulators work with industry (through financial and operational incentive programmes) and consumers to make this growth a reality, the CO₂ savings could put us on the right path to closing the transport emissions gap for the decades to come.



IMPACT ON INFRASTRUCTURE

The impact on energy infrastructure would be manageable and could also create a potential growth opportunity. By 2020 each market would need an additional:



EXECUTIVE SUMMARY

Over the next five to ten years, passenger vehicle manufacturers will be confronted with regulatory pressure and material penalties as gains in fuel economy fall behind the required rates of improvement set to address environmental preservation and climate change mitigation. The fuel economy targets are expected to exceed forecasted new internal combustion engine powered passenger vehicle capabilities. This report examines to what extent electric vehicles (EV) – battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) – are the latest technologies to increase average fuel efficiency in the bid to close the emissions gap and meet stringent fuel economy standards. This new frontier represents a significant opportunity for the energy sector.

KEY FINDINGS

1. Fuel economy improvement targets of approximately 30 % for cars from 2014 to 2020 have been set by the European Union, US and China. These are the world's largest car markets with collective annual demand of over 40 million passenger vehicles.
2. Electric vehicles currently represent less than 1% combined market share across the world's largest car markets for new passenger cars. To achieve the fuel economy improvement targets, the combined market share for electric vehicles needs to increase to 16% by 2020. EVs should therefore be considered for a central role in any policy and technology portfolio designed to lower transport emissions.
3. The number of electric vehicle sales required to meet fuel economy targets for passenger cars is referred to as the "EV gap". In the EU, the EV gap is 1.4 million (10% of the projected 2020 passenger car sales), in the US, it is closer to 0.9 million (11%), and in China, it is 5.3 million (22%).

TABLE 1: EV SALES REQUIREMENT TO MEET THE 2020 STANDARDS

	New passenger vehicle emissions standards (gCO ₂ /km)		Actual and forecast of new passenger vehicle emissions (gCO ₂ /km)		EV gap (vehicle)	EVs forecast in 2020 from the Global Transport Scenarios (vehicle)	
	2015	2020	2015	2020		Freeway	Tollway
EU	130	95	120	104	1.4m	1m	6m
US	182	133	163	145	0.9m	1m	6m
China	161	117	165	150	5.3m	0m	1m

Note: The Freeway Scenario describes a market-driven world and the Tollway Scenario a regulated world.
Source: ICCT (2015), World Energy Council (2011a)

4. Electric vehicle adoption faces persistent cost and range anxiety hurdles, which are being addressed to varying degrees of success with government intervention and may be further allayed through regulator and market collaboration.
5. Road transport is responsible for approximately one quarter of all greenhouse gas emissions in the EU and US as well as 10% in China, and generates over 3 Gt CO₂. EV adoption and “closing the EV gap” could make a significant impact towards meeting country level CO₂ emissions reduction goals.

IMPLICATIONS FOR THE ENERGY SECTOR

- New fuel economy standards across the globe have made it clear that transport emissions (and liquid fuels) are a priority for regulators to address environmental preservation and climate change mitigation.
- The attractiveness of EVs as a viable option to accelerate new fuel economy improvements and meet stated objectives could result in generous incentive policies which present utilities with a potential growth opportunity.
- Electricity demand attributed to new EVs can be managed with proper planning by utilities (expected annual incremental generation requirements fall below 0.5% of 2014 total electricity generation in all three markets analysed) and could be further mitigated at the local level with emerging technologies such as vehicle-to-grid (V2G) solutions.

RECOMMENDATIONS

- **Industries:** Vehicle manufacturers will need to respond to regulatory pressures and shift their product portfolio to avoid material penalties. Additionally there is an opportunity for vehicle manufacturers and utility electricity providers to partner to deliver a superior value proposition to consumers.
- **Policymakers:** Ensure that consumer and manufacturer incentives align with new or considered emissions standards. Monitor effects of increased electricity demand to preserve the integrity of grid operations. Regulators should examine how the proposed fuel economy requirements can be matched with incentive programmes (financial and operational) and collaborate with industry in order to realise desired reduction in CO₂ emissions.
- **Consumers:** Evaluate the economic and environmental benefits of EVs alongside other alternative transportation methods that are coming online. Provide feedback to regulators and manufacturers.

INTRODUCTION

CAN EVs DELIVER THE AGGRESSIVE FUEL ECONOMY TARGETS SET ACROSS THE WORLD'S LARGEST CAR MARKETS?

Over the past decade, the impacts of climate change and fuel price volatility as a headline issue have caused many countries to set aggressive emissions and fuel economy standards for new vehicle fleets. Faced with a complex array of policy and technology options including hybrid technology, down-weighting technology, off-cycle credit, aerodynamic improvements and many more, it is important for decision makers to understand the potential influence and feasibility of each option. This report focuses on the growth in sales of EVs as an opportunity to address mandated incremental passenger vehicle fuel economy performance improvements in three of the largest car markets in the world – the EU, US and China.

TABLE 2: NEW PASSENGER VEHICLE AND EV SALES IN 2014

	World	EU	US	China	Others	% of EU, US and China
Total (k vehicle)	64,603	12,551	7,688	19,701	24,663	62%
EV (k vehicle)	295	75	119	75	26	91%
% of EV	0.5%	0.6%	1.5%	0.4%	0.1%	

Source: ACEA, CAAM, ICCT, KAMA

This report aims to quantify sales requirements for EVs to increase average passenger vehicle fleet fuel economy, on top of projected conventional technology improvements, in order to meet stringent 2020 fuel economy standards set in all three markets, termed the “EV gap”. We analyse the potential to achieve these sales levels, understand the impacts of reaching implied levels of EV penetration in terms of electricity generation requirements and CO₂ emissions, and finally discuss how these goals could be realised. We also highlight the latest initiative from New Zealand to showcase what can be done in smaller countries.

Ultimately, closing the gap between projected, business-as-usual vehicle fuel economy and these new, aspirational standards in each market will require the orchestration of multiple policies and technologies, but this analysis shows EVs can and should play a central role towards this effort. Further research is suggested on architecting an environment to facilitate the required levels of EV adoption and defining the role of other technologies.

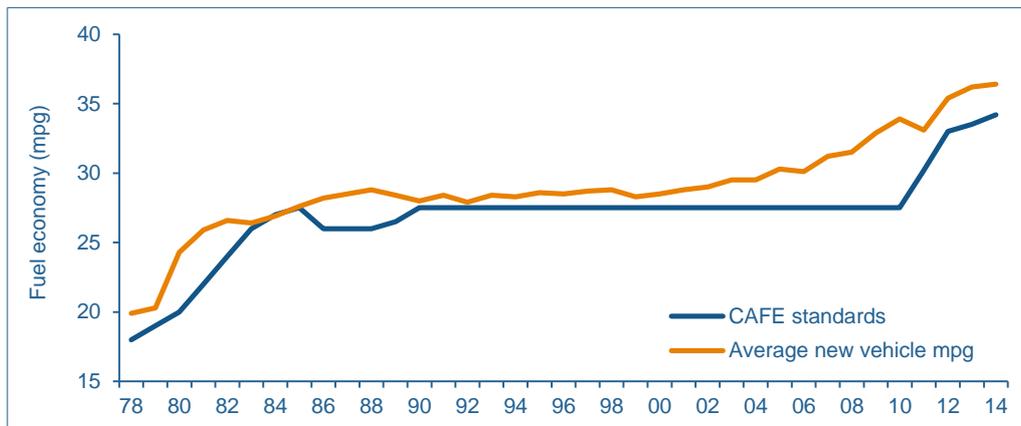
Chapter 1

The tipping point of vehicle emissions standards

AMBITIOUS FUEL ECONOMY TARGETS SET TO FACE CLIMATE CHANGE CONCERNS AND OIL PRICE VOLATILITY.

Facing climate change concerns and recent oil price volatility, regulators across the globe have been emboldened to set increasingly ambitious fuel economy targets over the next five to ten years. Historically, fuel economy standards have been the most effective policy measure in improving efficiency and reducing energy consumption of passenger vehicles. Forcing vehicle manufacturers to meet increasing fuel economy standards (typically based on a vehicle’s spatial footprint) or face fines has driven a 50% increase in average new vehicle mile-per-gallon (mpg) performance since 1980 in the US, and spawned similar regulation in other major car markets.

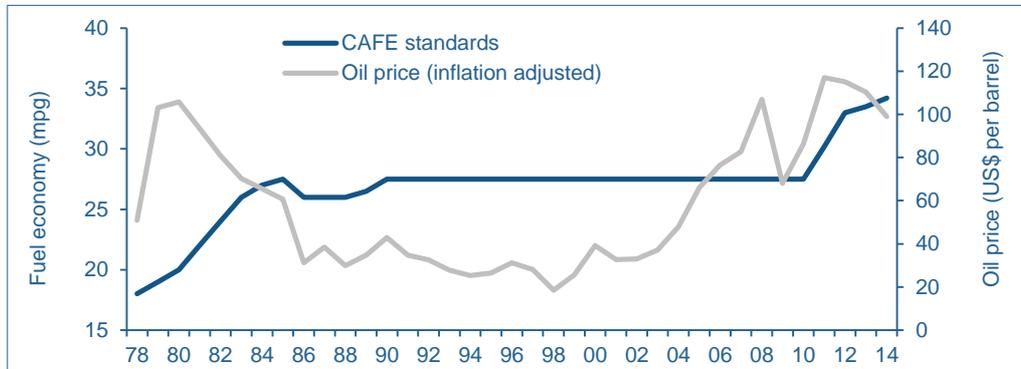
FIGURE 1: US PASSENGER VEHICLE FUEL ECONOMY DRIVEN UP BY INCREASES IN CORPORATE AVERAGE FUEL ECONOMY (CAFE) STANDARDS



Source: NHTSA (2014)

These standards were born in reaction to the oil crises in the 1970s and have consistently been forgotten between oil price and foreign dependency scares. Today, concerns about climate change and CO₂ emissions have become major issues and are often considered as national and global priorities. Oil prices that have averaged over US\$100 per barrel between 2010 and 2014 have driven regulators across the globe to pursue energy independence policies, and set increasingly ambitious fuel economy targets over the next five to ten years.

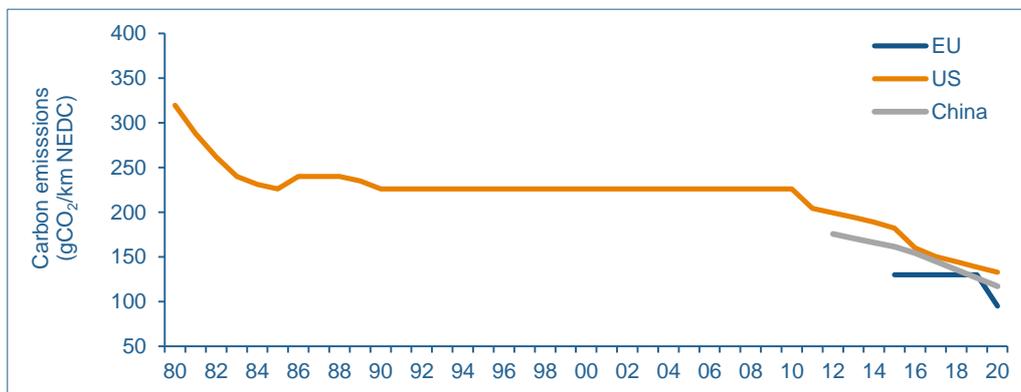
FIGURE 2: UPDATES TO CAFE REGULATION TRAIL OIL PRICE SPIKES



Source: BP (2015b), NHTSA (2014)

The EU, US and China, the world's largest car markets with collective annual demand over 40 million passenger vehicles, have all set fuel economy improvement targets of approximately 30% for cars from 2014 to 2020 (as measured in gCO₂/km) – remarkable for their similarity and ambition. Regulators hope to make a significant impact towards country level CO₂ emissions reduction goals targeting road transport, which is responsible for approximately one quarter of all greenhouse gas emissions in the EU and US as well as 10% in China. Road transport in these region and countries generates over 3 Gt CO₂ every year.

FIGURE 3: EU, US AND CHINA FUEL ECONOMY TARGETS



Source: ICCT (2015), NHTSA (2014), TransportPolicy.net (2015)

After enjoying two decades of flat standards, vehicle manufacturers are now required to make continuous improvements well above historical rates of enhancement to placate regulators across the globe. For example, in the US market over the past decade, new passenger vehicle fuel economy has increased 2.2% per annum, but Corporate Average Fuel Economy (CAFE) standards will demand 5.7% annual increase through 2020. As shown in Table 3, manufacturers will face similar discrepancies in the EU and China.

TABLE 3: ANNUAL IMPROVEMENTS IN FUEL ECONOMY: HISTORICAL AVERAGE VS. REQUIREMENT TO 2020

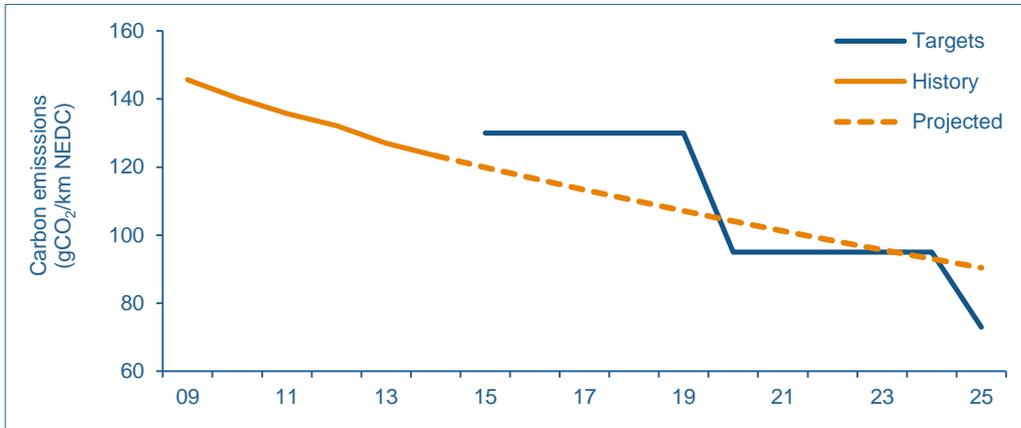
	EU	US	China
Historical average (2004-2014)	2.8%	2.2%	1.9%
Fuel economy standards (2014-2020)	6.1%	5.7%	5.7%

Note: China historical average from 2002-2014; EU standards from 2015-2020
 Source: ICCT (2015)

As a result of this disparity, if fuel economy increases in the new passenger vehicles continue at recent rates of improvement, vehicle CO₂ emission averages in each of these markets will rise above regulation standards by 2020. This could happen as soon as 2020 in the EU and 2017 in the US. These historically based projections are in line with similar estimates from BP (2015a) which forecast 2.1% per annum improvement in fuel economy between 2013 and 2035. Even these fleet improvement forecasts are in jeopardy (of being too optimistic) given recently surfaced uncertainty surrounding diesel technology contributions. (See Figures 4, 5 and 6.)

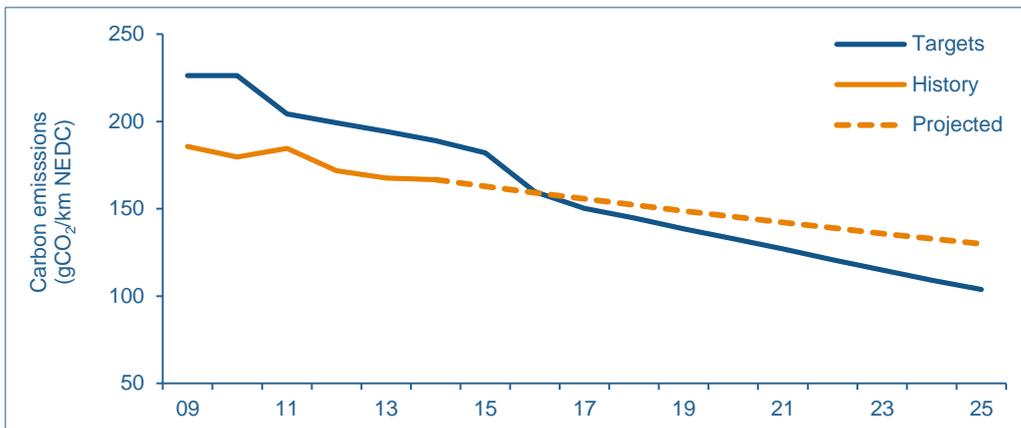
The disappearing cushion between actual new fuel economy and mandated gCO₂/km limits could put some vehicle manufacturers at risk of material penalties in the form of governmental fines. Manufacturers have time to meet these standards, but there is significant work to be done in closing the gap, especially considering the pace of industry change. At 2013 sales volumes and average fuel economies, the leading vehicle manufacturers listed in the Table 4 would collectively face up to €30 billion in fines in 2020 in the EU market alone. Headlines in 2015 have shown that pressure to improve fuel economy – among other factors – have even driven at least one manufacturer to cheat emissions tests.

FIGURE 4: EU FUEL ECONOMY STANDARDS SET TO EXCEED VEHICLE FUEL ECONOMY AT CURRENT RATES OF IMPROVEMENT



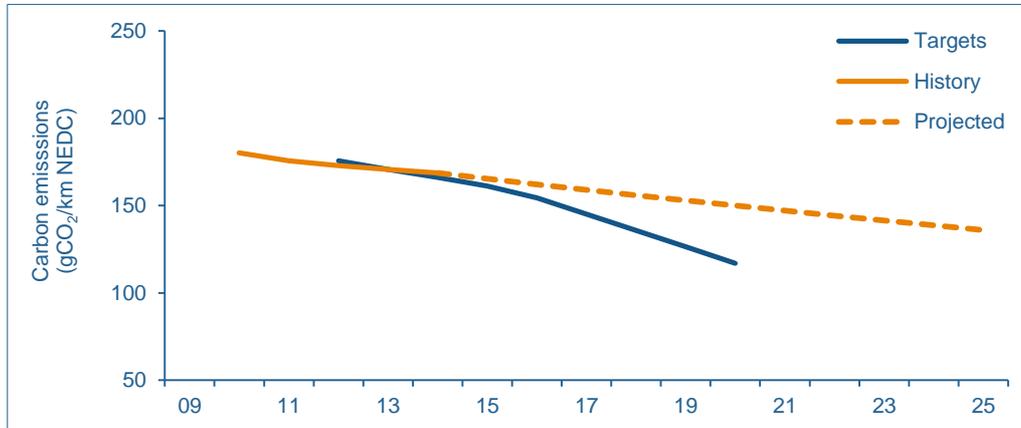
Source: ICCT (2015)

FIGURE 5: US FUEL ECONOMY STANDARDS SET TO EXCEED VEHICLE FUEL ECONOMY AT CURRENT RATES OF IMPROVEMENT



Source: ICCT (2015)

FIGURE 6: CHINA FUEL ECONOMY STANDARDS SET TO EXCEED VEHICLE FUEL ECONOMY AT CURRENT RATES OF IMPROVEMENT



Source: ICCT (2015)

Historically, incremental improvements to ICE technology or inertia between commodity price spikes have been enough for vehicle manufacturers to stay ahead of regulation. This would not be the case for the foreseeable future with regulators placing more stringent improvement requirements on manufacturers. Additionally, amidst a plethora of policy and technology options, EVs represent one of the more promising opportunities for the step-wise improvements in fuel economy required to keep pace with legislation.

EV technology is market-tested (being initially introduced in the late 19th century), displaces emissions inside of urban centres, and positions society for even further reductions in transport emissions as the world transitions to an alternative fuel and renewables based electricity generation mix. Recognising its potential, authors of fuel economy standards in the EU, US and China have all built incentives into their regulations for BEV and PHEV production (in addition to incentives for most economising technology). The mandates only penalise vehicle manufacturers for “tailpipe emissions”, ignoring CO₂ produced by electricity generation required to charge EVs. Additionally, EVs are allowed to be counted multiple times towards manufacturer’s average fuel economy to avoid fines as illustrated in Table 5.

E-MOBILITY: CLOSING THE EMISSIONS GAP

TABLE 4: EU CO₂ EMISSION STANDARDS AND POTENTIAL FINES

Vehicle Maker	Europe ¹⁾ 2013 Passenger Car Registration (vehicle)	2013 CO ₂ Emission (gCO ₂ /km)	2020 CO ₂ Target (gCO ₂ /km)	% Reduction	Estimated 2020 Fines at 2013 Emissions ²⁾ (mil. €)	Fines per Vehicle (€)	Earnings per Vehicle (€)
Renault	801,795	110	91	-17%	1,375	1,715	266
Peugeot	740,786	115	94	-18%	1,404	1,895	(233)
Fiat	572,937	116	87	-25%	1,500	2,617	(108)
Toyota	519,402	116	93	-20%	1,078	2,076	1,088
Citroen	601,624	116	94	-19%	1,195	1,986	(233)
Seat	289,029	119	90	-24%	756	2,617	241
Ford	918,538	122	94	-23%	2,321	2,527	614
Skoda	510,464	125	92	-27%	1,520	2,978	551
Dacia	294,415	127	89	-30%	1,010	3,430	266
Volkswagen	1,547,235	127	95	-25%	4,468	2,888	1,233
Kia	345,824	128	93	-27%	1,092	3,159	1,655
Volvo	230,477	131	106	-19%	520	2,256	250
Nissan	422,036	131	96	-27%	1,333	3,159	528
Opel	822,560	132	97	-26%	2,598	3,159	-
Audi	692,844	133	101	-24%	2,001	2,888	3,379
BMW	640,887	134	101	-24%	1,909	2,978	3,139
Mazda	147,005	134	97	-28%	491	3,339	196
Daimler	688,436	137	102	-26%	2,175	3,159	2,559
Hyundai	419,319	138	97	-30%	1,552	3,700	1,655

Note: 1) Europe = EU + EFTA; 2) 2020 fines allow 5% fleet non-compliance and cost €95 for each gCO₂/km in excess of target

Source: European Environment Agency (2014), 2013 Annual Reports from Audi, Citroen, Daimler, Fiat, Hyundai, Kia, Nissan, Peugeot, Toyota and Volvo

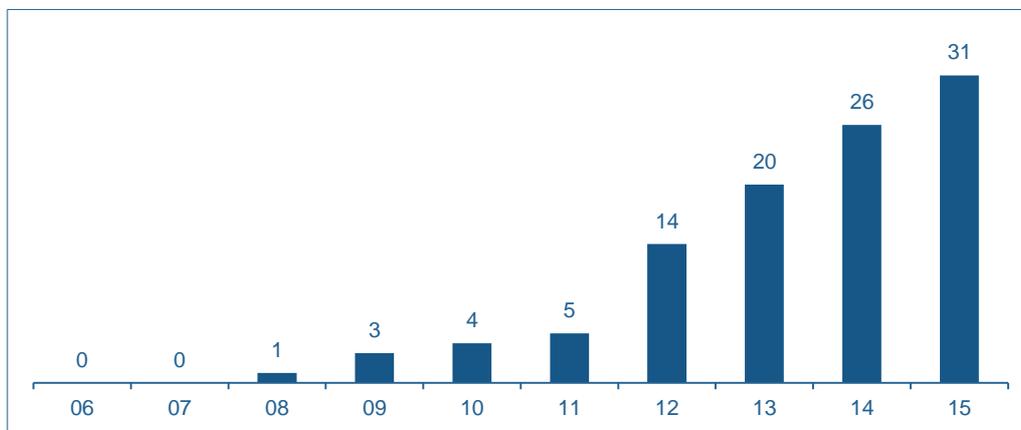
TABLE 5: 2020 CREDIT FOR EV SALES TOWARDS VEHICLE MANUFACTURER'S FUEL ECONOMY TARGETS

	2020 EV credit multiplier	2020 Credited EV emissions (gCO ₂ /km)
EU	1.5 x	0
US	2.0 x	0
China	2.0 x	0

Source: Center for Climate and Energy Solutions (2015a), ICCT (2015)

Growing EV manufacturer’s product portfolios also seem to reflect the expected role of EVs in the face of fuel economy regulations as well as changes in perfection on future consumer sentiment. In 2005, no electric passenger vehicles were available in the US; 34 have been introduced in the decade since (31 available in 2015 with the Tesla Roadster, Th!nk City, and Honda Fit EV being discontinued).

FIGURE 7: CUMULATIVE NEW EV MODELS IN THE US MARKET



Source: Union of Concerned Scientists (2015)

Despite growing production projections, EVs have faced serious consumer adoption issues. Manufactures must overcome range anxiety, high capital costs, consumer misconceptions, and other issues impacting sales. In 2014, the available US EV models averaged less than 5,000 sales each (119,000 total sales).

In order to stimulate consumer demand, governments have adopted incentives. A federal subsidy programme for EVs allows for a one-time bonus, depending on the battery capacity of the vehicle, of up to a maximum of US\$7,500 in the form of a tax credit. For the Renault Zoe BEV, the bonus would be US\$7,500 (about €5,400); for the Volvo V60 PHEV, it would be US\$5,400 (about €3,900). In California, there is another subsidy programme at the state level, granting BEV purchasers another US\$2,500 (about €1,800) and PHEV US\$1,500 (about €1,100) in the form of a one-time bonus payment.

E-MOBILITY: CLOSING THE EMISSIONS GAP

EVs only captured 0.7% market share combined across the three passenger car markets. Thus, to date, EVs have yet to realise a material impact to vehicle fuel economy and subsequent transportation CO₂ emissions. The analysis below aims to quantify this “EV gap” and better understand sales requirements for EVs to play a more significant role in meeting fuel economy and emissions reductions goals across European, US and Chinese markets in the near future.

Chapter 2

Quantifying the EV gap

AT CURRENT RATES OF MARGINAL FUEL ECONOMY IMPROVEMENT, VEHICLE MANUFACTURERS WILL STRUGGLE TO KEEP PACE WITH NEAR-TERM EFFICIENCY TARGETS SET IN ALL THREE MARKETS.

Improvements in hybrid technology, new ICE fuels (e.g. hydrogen), vehicle design and other technologies can obviously influence fuel economy, but this exercise aims to illustrate the potential value of EVs and a scenario in which EV sales are largely responsible for increasing average passenger vehicle fuel economy to meet stringent 2020 new standards set in all three markets. In this scenario, observers only witness the same small, incremental improvements in the conventional liquid fuels technology based fleet witnessed over the past decade as outlined in the previous chapter.

At current rates of marginal improvement, vehicle manufacturers will struggle to keep pace with near-term efficiency targets set in all three markets. An ICE-based new car fleet will generate emissions 11%, 12% and 29% (in terms of gCO₂/km) above 2020 regulator-set targets in the EU, US and China markets respectively. The average floor for vehicle fines could outpace average fleet economy as soon as 2017 in the US, and actual performance could already be below the new 2015 standard in China.

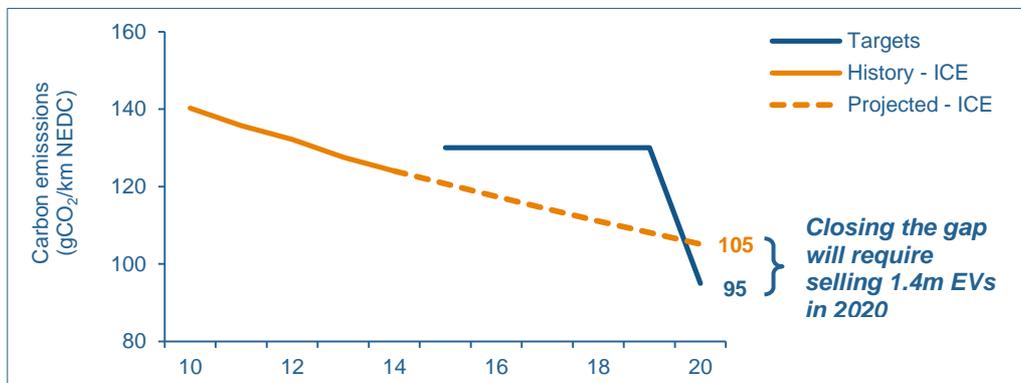
In order to quantify the EV gap, or calculate the number of EVs required to bring total vehicle fuel economy to parity with mandated targets in each market in 2020, the average of non-EV projected 2020 fuel economy and EV fuel economy (established at 0 gCO₂/km in each market), weighted by the quantity of each vehicle type, is set equal to the target overall new fuel economy. The equation can be reduced to the following, which when combined with known forecasts for total market demand (vehicle size), total fuel economy targets (in terms of gCO₂/km), and legacy ICE-based vehicle fuel economy forecasts, allows us to solve for expected EV sales to achieve mandated fuel economy targets:

$$V_{ev} = V_t - \left(\frac{V_t \times FE_t}{FE_{ice}} \right) = V_t \times \left(1 - \frac{FE_t}{FE_{ice}} \right)$$

where V_{ev} = number of EVs (EV gap); V_t = total number of new passenger vehicles; FE_t = total vehicle target fuel economy; FE_{ice} = ICE-vehicle forecast fuel economy.

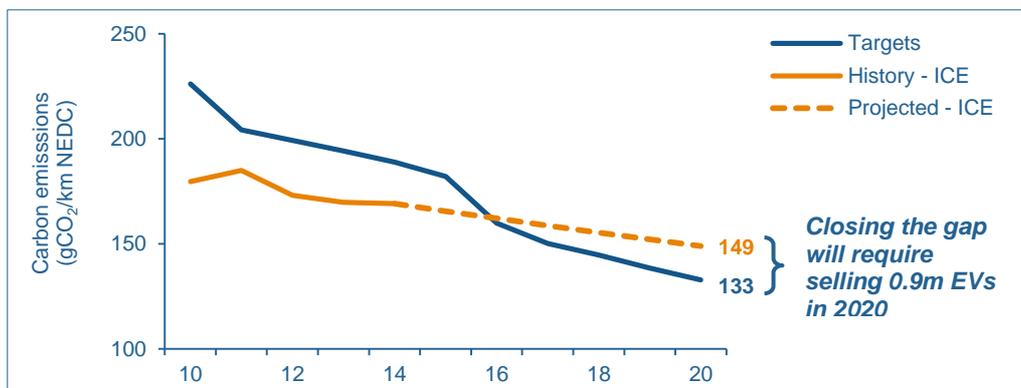
In the EU, this means 1.4 million, 10% of the estimated 14 million 2020 passenger car sales, will need to be EVs in order to lower the fleet blended average below the target 95 gCO₂/km. In the US, the requirement is closer to 0.9 million EV sales (11% of the projected 8 million 2020 passenger car sales) and in China, it is about 5.3 million EV sales (22% of the estimated 24 million passenger car sales). Figures 8-10 below highlight the expected gap in fuel economy between ICE-based passenger vehicle emissions performance and targets, as well as the EV sales required to close the gap for each market.

FIGURE 8: QUANTIFYING THE 2020 EV GAP IN THE EU



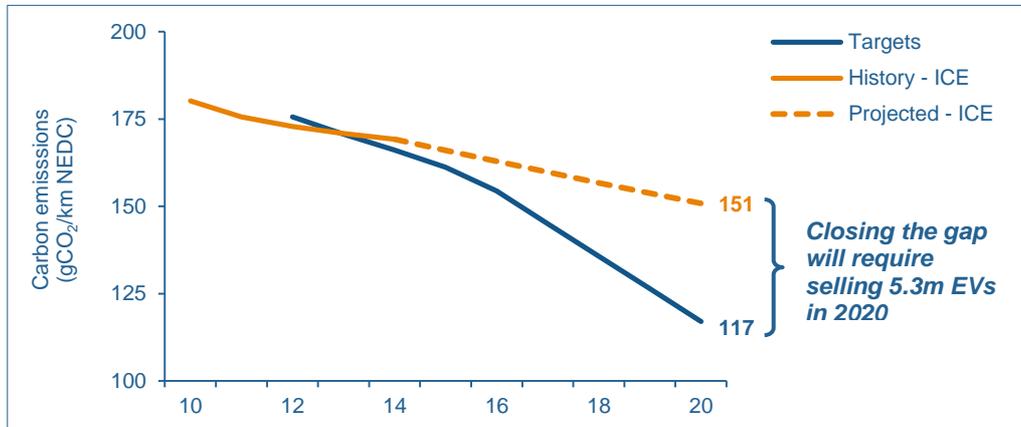
Source: ICCT (2015)

FIGURE 9: QUANTIFYING THE 2020 EV GAP IN THE US



Source: ICCT (2015)

FIGURE 10: QUANTIFYING THE 2020 EV GAP IN CHINA

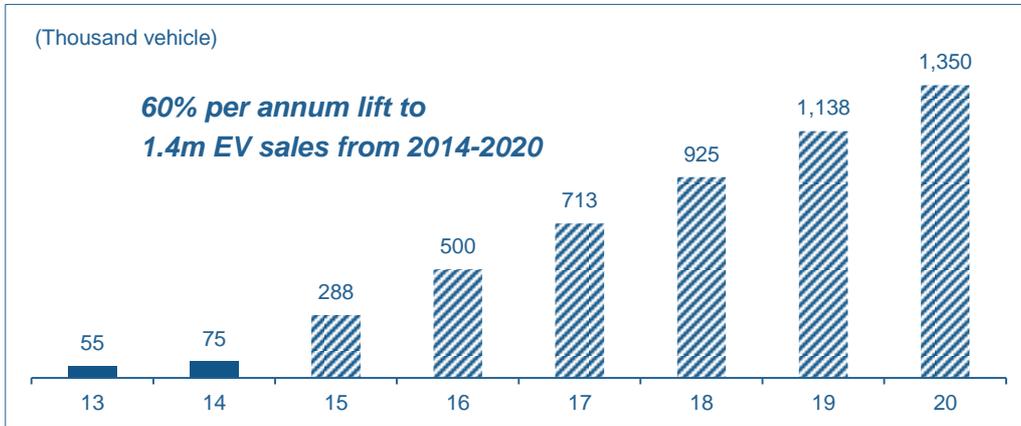


Source: ICCT (2015)

In the EU, this means a significant increase in EV win rates (EV sales / total passenger car sales) between 2014 and 2020. In 2014, 0.6% of passenger car sales are BEVs and PHEVs. Assuming constant market passenger vehicle demand, the win rate will need to reach 10% in 2020, a 60% compound annual growth rate from 2014, to sell 1.4 million EVs. China is in a similar situation with only 75,000 EV sales in 2014.

While EV sales growth over the past several years hasn't been 60%, it has still been exceptional. The current annual growth rate in EV sales in the EU is approximately 40% (2013-2014). Fostering current levels of momentum could mean reaching these adoption targets, and as a result, EVs could deliver a significant portion (if not all) of the fuel economy improvements regulators hope to achieve. Declining EV battery costs could be one of the breakthroughs that provide the catalyst to help fuel sales growth by making EVs cost competitive with ICE vehicles in the next five to ten years. Developing an environment to support this scenario will require significant investment and overcoming the adoption challenges outlined in Chapter 1.

FIGURE 11: HISTORIC AND PROJECTED EV SALES TO REACH 2020 EV TARGETS IN THE EU



Source: ACEA (2015), Electric Drive Transportation Association (2015), ICCT (2015)

Chapter 3

Mind the Gap

BY 2020, EACH ICE TO EV CONVERSION IN THE EU WILL REPRESENT A 63% REDUCTION IN CO₂ EMISSIONS FROM FUEL CONSUMPTION.

Next, the analysis seeks to understand the implications of adding 1.4, 0.9 and 5.3 million EVs per year (the 2020 goal in this EV-driven scenario) to European, American and Chinese roads in terms of electricity generation requirements and actual emissions.

Electricity generation:

In Table 6 below, incremental electricity generation requirements in 2020 to meet demand of new EVs on the road are estimated in each market should they meet fuel economy targets through aggressive adoption of EVs as outlined in the analysis. Assuming 2.5% per annum improvements to EV fuel economy (Wh consumed per km), average passenger vehicle energy requirements of 0.17 kWh/km can be estimated for 2020. Factoring in differences in average distances travelled across the EU, US and China as well as losses for charge/recharge cycle efficiency, battery self-discharge, and transmission efficiency, forecasts for new generation requirements to meet EV demand in 2020 range from 26 TWh in China (which has a less efficient electric grid) to less than 4 TWh in the EU.

TABLE 6: CALCULATION OF INCREMENTAL ELECTRICITY GENERATION REQUIREMENTS IN 2020

Implied electricity generation requirements estimate	EU	US	China
Energy efficiency per EV in 2020 (kWh/km)	0.17	0.17	0.17
Average vehicle distance travelled per annum (km)	11,500	22,000	21,000
Base annual electricity requirements per vehicle (kWh)	1,955	3,740	3,570
Charge/recharge efficiency	85%	85%	85%
Self-discharge efficiency	90%	90%	90%
Grid transmission efficiency	94%	94%	94%
Actual generation per vehicle (kWh)	2,719	5,201	4,965
2020 EV requirements (vehicle)	1,350,000	867,000	5,275,000
Total 2020 incremental generation requirements (TWh)	3.7	4.5	26.2

Source: Green Car Congress (2015), Union of Concerned Scientists (2015), US Federal Highway Administration (2015), Vermont Energy Investment Corporation (2013), WB (2015)

E-MOBILITY: CLOSING THE EMISSIONS GAP

This is equivalent to the annual electricity demand of nearly 734,000 houses in the EU, 367,000 houses in the US, and over 17 million homes in China (Chinese homes only consume 1,500 kWh per annum compared to over 12,000 kWh in the US, based on 2013 data from the World Energy Council). However, each of these EV electricity demand estimates represents less than 0.5% of 2014 total electricity generation in their respective markets.

Consequently while the increased electricity generation requirement introduces concerns regarding the ability of local grids to support the higher demand for power, it is expected that this can be accommodated by utilities and municipalities with proper planning and balancing capabilities at the local level as EVs gradually reach these densities. Additionally this analysis does not take into account nascent smart grid energy management technologies such as vehicle-to-grid (V2G) programmes and dynamic time of use (TOU) pricing that may become common practice by the year 2020. Such programmes will allow utilities to streamline their operations through peak load levelling, and serve as a buffer for less stable renewable power sources such as wind energy. Should V2G technology and TOU rates enter mainstream adoption, the projected additional electricity burden will likely be reduced.

CO₂ emissions:

In this 2020 scenario, the overall impact to transport CO₂ emissions in each market is still relatively small as these EVs represent a tiny fraction of the entire passenger road fleet. However, on a per car basis, the reduction in CO₂ emissions is significant when comparing ICE tailpipe emissions to electricity generation. Based on US EIA, EC, and China Energy Outlook estimates of 2020 electricity generation sources, realising a 60-70% actual reduction in annual CO₂ emissions per car transitioning from ICE to EV should be expected based on the market.

In the US, the 870,000 new EVs would prevent the release of 2.0 Mt CO₂ every year. The calculation of CO₂ emissions reductions in all three markets is shown below in Table 7.

TABLE 7: CO₂ EMISSIONS DELTA IN CONVERSION FROM ICE TO EV

Vehicle emissions analysis ¹⁾	EU	US	China
2020 EV requirements (vehicle)	1,350,000	867,000	5,275,000
Actual generation per vehicle (kWh)	2,719	5,201	4,965
Blended 2020 emissions (gCO ₂) per kWh generation	164	195	243 ²⁾
Total annual emissions for target EV adds (t CO ₂)	601,732	880,693	6,375,779
Average vehicle distance travelled per annum (km)	11,500	22,000	21,000
Estimated 2020 ICE emissions performance (gCO ₂ /km)	105	149	151
Total emissions if EVs were ICE's at 2020 emissions estimate	1,632,317	2,840,716	16,707,570
Delta / CO ₂ savings (tCO ₂)	1,030,585	1,960,024	10,331,791
% reduction per car	63%	69%	62%
Total 2020 passenger car sales estimate	14,000,000	8,000,000	24,000,000
100% ICE fleet 2020 emissions estimate	16,927,735	26,211,914	76,015,484
% reduction for total new passenger car fleet	6%	7%	14%

Note: 1) It is known EVs result in more manufacturing emissions than ICE vehicles, but vehicle manufacturing emissions are not considered here; 2) Based on China's eco-friendly energy strategy scenario developed by Xu (2014)

Source: EC (2003), PBL Netherlands Environmental Assessment Agency (2014), US EIA (2015), Volker Quaschnig (2015), Xu (2014)

CASE STUDY: THE EMERGENCE OF ZERO EMISSION VEHICLE (ZEV) REGULATION IN THE US

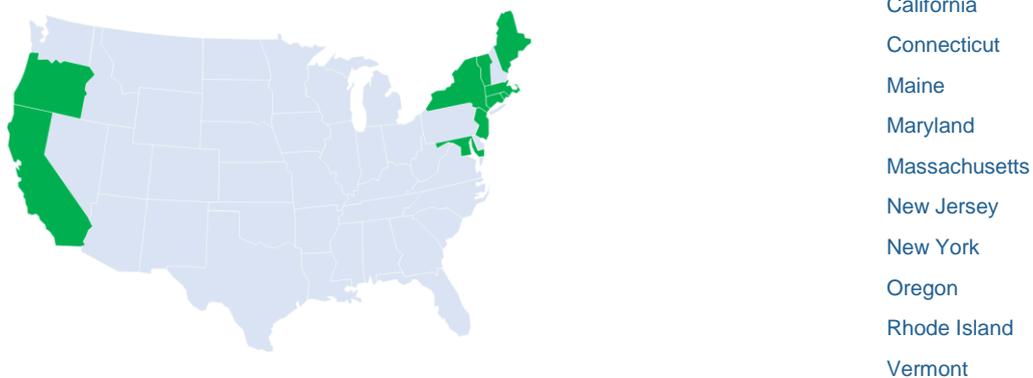
As this analysis explores the promise of pursuing a specific technology in order to reach passenger vehicle emissions targets, it is worth pausing for a moment to understand the historical context that can be gleaned from “technology-forcing” regulation. The World Energy Council’s Trilemma report has detailed one such programme: California’s ZEV mandate.

The ZEV mandate was designed to achieve federal air quality standards by mandating that major car manufacturers make available for sale prime movers with zero tailpipe pollutant emissions (this category is primarily muscle-powered, electric and fuel cell vehicles). As discussed in the Trilemma report, the programme faced serious challenges in the 1990’s after overestimating the potential of EVs and underestimating improvements in conventional technology, and as a result, underwent major modifications. However, by 2014, the market share of California’s EV was more than double that of the rest of the US (3.2% in California compared to 1.5% across the US).

Additionally, since 1990, ten US state markets have introduced or are considering legislation that will ultimately levy fines on sales of the most efficient combustion-based prime movers if sellers aren’t simultaneously offering competitive ZEVs. Continued adoption of the mandate will only strengthen the value proposition of EVs for manufacturers relative to other technologies.

It is important to understand this context in analysing cases for aggressive EV adoption. Technology-forcing regulation can have substantive impact on adoption, but optimistic goals must be tempered by reality. Translating this quantification of EV requirements to policy goals required careful consideration of externalities and creating an environment for EVs to succeed (compared to California in the 1990’s).

FIGURE 12: US ZEV REGULATED MARKETS IN GREEN



Source: Centre for Climate and Energy Solutions (2015b)

Chapter 4

Bridging the gap

DECISION MAKERS SHOULD RECOGNISE AN ALIGNMENT OF INCENTIVES BETWEEN UTILITIES AND EV MANUFACTURERS.

In the scenario outlined above, in which EV technology becomes the primary driver of accelerating vehicle fuel economy improvements, actually meeting emissions targets by 2020 could require reaching annual sales of nearly 1.4 million EVs in the EU, 0.9 million in the US, and 5.3 million in China. EVs are growing off of a small base, but this could be achieved given momentum behind consumer adoption and continued regulatory support.

The EV-centric analysis intrinsically does not examine other options for reducing emissions of the world's passenger vehicle fleet including hybrid technology, down-weighting technology, off-cycle credit, aerodynamic improvements and alternative fuel sources, many of which may only provide an avenue to sustain the small, incremental improvements seen in ICE-dominated vehicles for the past decade.

Future sales will likely illustrate a range of adoption across these technologies among consumers, but as illustrated above, with enough support, EVs could feasibly reach the level of sales required to deliver the transport fuel economy objectives alone across all three markets. Understanding this influence of one specific technology is critical for decision makers to understand when considering different policy and technology subsidy options (e.g. ZEV) to achieve their goals.

Turning towards realising the 2020 EV sales targets, these decision makers should recognise an internal alignment of incentives and policies, especially given self-imposition of the regulation and goals. Norway has seen particular success in improving the proliferation of EVs through friendly transit policies and through financial incentives that allow EVs to compete with ICE passenger vehicles when all costs are considered. Norway is in a special situation where there are no domestic automobile manufacturers to protect, in addition its cost of electricity generation is particularly low due to the prevalence of hydro power sources. That being said, its model of tax breaks, subsidies and preferential treatment of EV drivers on the road has led to EVs capturing over 20% of new vehicles sold in 2015. Norway was the 4th biggest EV market in the world in 2015 – behind China, the US and the Netherlands.

Additionally, decision makers have the opportunity to encourage alignment between EV manufacturers and utility companies. Facing significant regulatory control in many locations, large capital programmes, and demand side

management (DSM) programmes designed to help consumers use less electricity (and consequently spend less on power), utilities recognise EVs represent one of their largest growth opportunities, especially in more mature EU and US markets. The burgeoning market is also more than just incremental energy demand. It's an opportunity to diversify the portfolio and branch into new revenue streams. Charging infrastructure, consumer education services and novel commercial offerings (e.g. time of use pricing) will all be needed to support sales of nearly 1.4 million and 0.9 million EVs in the EU and US respectively in 2020.

Faced with limited prospects to grow throughput and revenue, utilities may be willing to invest in this space. Bringing capital to collaboration with vehicle manufacturers, utilities can provide the catalyst required to overcome some of the stickiest barriers to consumer adoption of EVs – vehicle prices, range anxiety and charging infrastructure access.

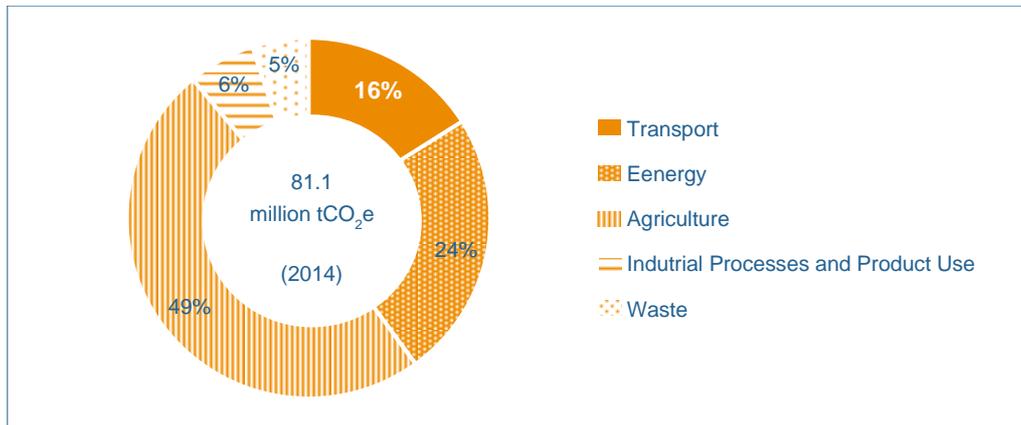
Further analysis is required to factor additional externalities into this case for aggressive EV adoption (e.g. cost of establishing infrastructure, subsidies outlook). However, given the potential for EVs to play a central role in achieving looming policy goals, decision makers should seize the opportunity to bring vehicle manufacturers and utilities together to work towards closing the EV gap.

CASE STUDY: NEW ZEALAND'S EV INITIATIVE

New Zealand has a vibrant market-led economy with a rapidly increasing population and a high economic growth rate. It has an energy market that is generally free of subsidies and a broad policy commitment to signal costs and trade-offs so that consumers can make the best choices about the use of resources – from energy fuels to capital.

New Zealand also has an abundance of natural resources generating over 80% electricity from renewable sources. However, this renewable advantage belies an energy problem – rapidly growing transport emissions. The transport sector causes around 16% of the New Zealand's greenhouse gas emission as shown in Figure 13. These emissions have risen by 60% since 1990 (2.1% annual).

FIGURE 13: NEW ZEALAND'S EMISSIONS BY SECTOR



Source: New Zealand Government (2014)

In July 2015, the government announced a target to reduce total greenhouse gas emissions to 30% below its 2005 level by 2030. By leveraging off its high percentage of electricity from renewable sources, New Zealand has the significant opportunity for EV to make the transport sector cleaner and more energy efficient.

In January 2016, New Zealand had only 1,015 EVs out of 3.1 million registered light vehicles. Committing to support the uptake of EVs, the government has recently announced a new EV package. The implications of this new EV policy is to avoid direct subsidies but deal with market failures – like the lack of information about or supply of new technologies such as EVs.

This is fundamentally different to most other countries with high levels of EV uptake where governments have chosen to subsidise the market in order to achieve wider policy goals such as decarbonisation.

The New Zealand government, in partnership with the business sector, has developed a package of measures including the goal to double the number of EVs in New Zealand every year to reach approximately 64,000 by 2021. So for 2020 the government target would be approximately 32,000 EVs.

In 2015, the BusinessNZ Energy Council (BEC) created two New Zealand specific scenarios of future energy, consistent with the international picture described by the World Energy Council's long-running scenario work in 2013. These describe a predominantly market-led future, "Kayak", with 2,500 EVs in 2020 and a government-led alternative, "Waka", with 41,050 EVs in the same year. Compared to the analysis set out in the BEC 2050 Energy Scenarios report, the government's 2020 target falls between Kayak and Waka scenarios but looks to achieve outcomes more akin to, if not more optimistic than, Waka where relatively high oil and carbon prices drove EV uptake.

The new EV policy will not just allow EVs to use the bus lanes and high-occupancy vehicle lanes on the State Highway, but also include elements such as one million NZD annually for nation-wide EV information and promotion campaign over five years, an extending of the road user charges exemption on light EVs plus a new road user charges exemption for heavy EVs until they make up 2% of New Zealand's light vehicle fleet (approximately 62,000 EVs today) and a fund of up to 6 million NZD annually to encourage and support innovative low emission vehicle projects. The package also seeks ongoing collaboration between the government and the private sector to arrange bulk purchases as well as the establishment of EVs leadership group.

Government agencies will coordinate activities to support the development and roll-out of the public charging infrastructure. A key element of this coordination will be to encourage EV charging during off-peak periods to minimise the use of electricity from non-renewable sources, and avoid the need for electricity transmission and distribution investment to meet a growing EV electrical load. New Zealand's flexible wholesale and retail market design including a carbon price which applies to electricity generation (current carbon price is around 14 NZD per tCO₂e) should help retailers design products which incentivise EV charging at the most efficient time.

The EV package signals an initial step to reduce greenhouse gas emission in New Zealand's transport sector. This package is a significant initiative to encourage private consumers to experience the benefits of driving EVs and express their desire to limit global warming.

(Contributed by BusinessNZ Energy Council, the New Zealand Member Committee of the World Energy Council)

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GLOSSARY

ACEA	European Automobile Manufacturers Association
BEV	Battery Electric Vehicle
CAAM	China Association of Automobile Manufacturers
CAFE	Corporate Average Fuel Economy (US fuel economy standard for passenger vehicle fleet)
EC	European Commission
EIA	Energy Information Administration
EU	European Union
EV	Electric Vehicle
HEV	Hybrid Electric Vehicle
ICCT	International Council of Clean Transportation
ICE	Internal Combustion Engine
KAMA	Korea Automobile Manufacturers Association
mpg	mile-per-gallon (average distance travelled per gallon of fuel)
NEDC	New European Driving Cycle (driving cycle that assesses emission levels and fuel economy)
NHTSA	National Highway Traffic Safety Administration
PHEV	Plug-in Hybrid Electric Vehicle
V2G	Vehicle-to-Grid (electric vehicle batteries serve as excess power storage that utilities can draw on during peak demand hours)
WB	The World Bank
Wh	Watt hour (kWh - kilowatt hour, TWh - terawatt hour)
ZEV	Zero Emission Vehicle

REFERENCES

- ACEA (2015), New Electric Vehicle Registrations in the European Union.
- Anair, Don (2015), "Blog the Equation," The Equation, Union of Concerned Scientists.
- Audi AG (2014), 2013 Annual Financial Report.
- BP (2015a), Energy Outlook 2035.
- BP (2015b), Statistical Review of World Energy 2015.
- BusinessNZ Energy Council (2015), New Zealand Energy Scenarios - Navigating Energy Futures to 2050.
- Center for Climate and Energy Solutions (2015a), Federal Vehicle Standards.
- Center for Climate and Energy Solutions (2015b), ZEV Program.
- ChinaAutoWeb (2015), 2014 EV Sales Ranking.
- Daimler (2013), Annual Report 2013.
- EC (2003), EU-25 Energy and Transport Outlook to 2030, Part IV.
- Electric Drive Transportation Association (2015), Electric Drive Sales Dashboard.
- European Environment Agency (2014), Monitoring CO₂ Emissions from Passenger Cars and Vans in 2013.
- Fiat (2015), 2013 Annual Report.
- Geely Sweden AB (2013), Annual Report 2013.
- Green Car Congress (2015), European LEAF Owners on Average Drive 50% More per Year than European ICE Average.
- Huo, Hong, Qiang Zhang, Kebin He, Zhiliang Yao and Michael Wang (2012), "Vehicle-use intensity in China: Current status and future trend," The International Journal of the Political, Economic, Planning, Environmental and Social Aspects of Energy.
- Hyundai Motor Company (2014), Annual Report 2013.
- ICCT (2014a), China Phase 4 Passenger Car Fuel Consumption Standard Proposal.
- ICCT (2014b), CO₂ Emissions from New Passenger Cars in the EU: Car Manufacturers' Performance in 2013.
- ICCT (2015), Global Passenger Vehicle Standards: Info & Tools.
- New Zealand Government (2014), New Zealand's Greenhouse Gas Inventory 1990-2014 (Ministry for the Environment).
- NHTSA (2014), Summary of Fuel Economy Performance.
- Nissan Motor Company (2013), Annual Report 2013.

- PBL Netherlands Environmental Assessment Agency (2014), Trends in Global CO₂ Emissions - 2014 Report.
- Peugeot SA (2014), Annual Report 2013.
- Quaschnig, Volker (2015), "Specific carbon dioxide emissions of various fuels," Renewable Energy and Climate Protection.
- Toyota Motor Corporation (2013), Annual Report 2013.
- TransportPolicy.net (2015), EU: Light-duty: GHG.
- Union of Concerned Scientists (2015), How Clean Is Your Electric Vehicle?
- US EIA (2015), Annual Energy Outlook 2015.
- US Federal Highway Administration (2015), Annual Miles per Driver by Age Group.
- Vermont Energy Investment Corporation (2013), "Assessment of level 1 and level 2 electric vehicle charging efficiency," Transportation Efficiency Group.
- WB (2015), Electric Power Transmission and Distribution Losses (% of Output), World Development Indicators.
- World Energy Council (2011a), Global Transport Scenarios 2050.
- World Energy Council (2011b), Policies for the Future - 2011 Assessment of Country Energy and Climate Policies.
- World Energy Council (2011b), Policies for the Future - 2011 Assessment of Country Energy and Climate Policies.
- World Energy Council (2013), World Energy Scenarios - Composing Energy Futures to 2050.
- World Energy Council (2016), World Energy Issues Monitor 2016.
- Xu, Xiaojie (2014), "China energy outlook 2020," Institute of World Economics and Politics, Chinese Academy of Social Sciences.
- Yang, Zifei and Hui He (2014), "China's fuel efficiency standard for cars: On track to meet 2015 goals - As long as enforcement isn't required," ICCT blog.

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