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DOMESTIC INCENTIVE MEASURES FOR ENVIRONMENTAL GOODS WITH POSSIBLE TRADE
IMPLICATIONS: ELECTRIC VEHICLES AND BATTERIES

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ABBREVIATIONS

Abbreviation	Explanation
..	not available
BEV	battery-electric vehicle — i.e. a vehicle with only an electric motor
billion	10 ⁹
CCS	carbon capture and storage
CKD	completely knocked down — i.e., the unassembled components of a complete vehicle
DOE	Department of Energy
ETS	Emissions Trading System (EU) or Emissions Trading Scheme (NZ)
EU	European Union
EV	electric vehicle
EVI	Electric Vehicle Initiative
FCV	fuel-cell vehicle
FQD	Fuel Quality Directive of the European Union
Gal	U.S. gallon, equal to 3.7854 litres
GHG	greenhouse gas
HEV	hybrid electric vehicle — i.e., a vehicle with both a thermal engine (ICE) and an electric traction motor, but no recharging from the electric grid
HS	HS – Harmonized Commodity Description and Coding System
ICE	internal-combustion engine
IEA	International Energy Agency
kg	kilogramme (1 000 kg = 1 tonne)
kg CO ₂ -eq	kilogramme of carbon-dioxide equivalent
kW	kilowatt (1 Watt x 10 ³)
kWh	kilowatt-hour
LCA	life-cycle assessment
LCR	Local-content requirement
MFN	most-favoured nation
million	10 ⁶
n.a.	not applicable
n.c.	not calculated
P	provisional
PEV	plug-in electric vehicle — i.e., either a BEV or a PHEV
PHEV	plug-in hybrid electric vehicle — i.e., a vehicle configured like a HEV, but which draws part of its energy for traction from the electric grid
ppm	parts per million (by volume)
R&D	research and development
RD&D	research, development and demonstration
THS	Toyota Hybrid System
trillion	10 ¹²
VAT	value-added tax

TABLE OF CONTENTS

ABBREVIATIONS	3
DOMESTIC INCENTIVE MEASURES FOR ENVIRONMENTAL GOODS WITH POSSIBLE TRADE IMPLICATIONS: ELECTRIC VEHICLES AND BATTERIES	6
EXECUTIVE SUMMARY	6
Introduction.....	10
Barriers to the further deployment of HEVs and EVs	12
Policy incentives for the development, adoption, and use of vehicles utilizing electric propulsion.....	17
Organizing framework: the classification of incentives	18
Market-pull policies	18
Technology-push policies	23
Import tariffs	27
Observations on trade and environmental effects	33
Concluding remarks	34
APPENDIX 1. EV-PROMOTION POLICIES IN SELECTED COUNTRIES	35
Association of South-East Asian Nations (ASEAN)	35
Indonesia	35
Malaysia	36
Philippines.....	36
Singapore.....	37
Thailand.....	37
Canada	40
Market-pull policies	40
Technology-push policies	42
Outcomes.....	42
China.....	42
Market-pull policies	43
Technology-push policies	46
Outcomes.....	46
Trade disputes	46
France.....	47
Market-pull policies	47
Technology-push policies	48
Outcomes.....	49
Germany.....	49
Market-pull policies	50
Technology-push policies	51
Outcomes.....	51
India	52
Japan	53
Market-pull policies	53
Technology-push policies	54
Outcomes.....	55
Norway.....	55
South Africa.....	56
Turkey.....	56

United States	57
Market-pull policies	57
Technology-push policies	58
Outcomes	60
BIBLIOGRAPHY	61

Tables

Table 1. Deployment incentives for all-electric and plug-in hybrid-electric vehicles by country	7
Table 2. Electric-vehicle charger capabilities	15
Table 3. Examples of transfers associated with support for the production or consumption of HEVs and electric vehicles.....	20
Table 4. Government programmes and funding for RD&D related to EVs, selected economies.....	24
Table 5. MFN applied tariffs for completely assembled new motor vehicles for passenger transport (as of the end of 2014 or beginning of 2015).....	30
Table 6. MFN applied tariffs for electric accumulators (storage batteries) used for vehicles for transport (as of the end of 2014 or beginning of 2015).....	32
Table 7. Excise tax rates on new passenger vehicles in Thailand, as of January 2015.....	38
Table 8. Comparison of retail prices for domestically produced and imported hybrid-electric vehicles sold in Thailand, local currency units	39
Table 9. R&D expenditure requirements for extending the period of exemption from corporate income tax in Thailand ¹	40
Table 10. Maximum municipal-level incentives for electric vehicle purchases in China as of March 2013	44
Table 11. Bonuses for purchasing or leasing a low-carbon-emitting vehicle in France as of January 2015	48
Table 12. Taxes on conventional and electric vehicles in Turkey	57
Table 13. U.S. Department of Energy's Electric Vehicle RD&D Programme (USD million).....	59

Figures

Figure 1. Global production of automobiles, 2003-13	11
Figure 2. Projected global sales of HEVs and light-duty electric vehicles, 2013-20.....	11
Figure 3. Total GHG emissions in selected countries from using a grid-powered EV, 2013.....	16
Figure 4. Sales in the leading 10 markets for plug-in electric vehicles during 2013	17

Boxes

Box 1. Charging equipment for plug-in electric vehicles	15
Box 2. Types of energy-storage systems used in HEVs and electric vehicles.....	29

DOMESTIC INCENTIVE MEASURES FOR ENVIRONMENTAL GOODS WITH POSSIBLE TRADE IMPLICATIONS: ELECTRIC VEHICLES AND BATTERIES

EXECUTIVE SUMMARY

Propulsion of vehicles by electricity predates by several decades the invention of cars powered by internal-combustion engines. Modern interest in electric propulsion was revived following the dramatic increases in petroleum prices in the 1970s, spawning numerous research and development projects in OECD countries. The first fruits of these efforts were hybrid electric vehicles (HEVs), which are vehicles powered by internal-combustion engines but which can run for part of the time on electric power generated by regenerative braking. Since the launch of the first commercially marketed HEV, in 1997 in Japan, HEVs have grown to command more than 5% of new passenger-vehicle sales in some OECD countries.

Despite the success of HEVs, interest in vehicles that can obtain most of their traction energy from the electric grid — i.e., ones whose batteries can be recharged through plugging into electric mains, or which obtain electrical energy from fuel cells — continues to rise. This is because of the relative simplicity of electric-vehicle drive trains, their low or zero tail-pipe emissions, near-silent operation, and expectations by transport planners that over the long term they will be cheaper to own and operate than vehicles powered by internal-combustion engines or HEVs. The recent rise in global petroleum prices that began in 2003, and concerns about the greenhouse-gas emissions from vehicles, have given new impetus to efforts to develop and improve electric propulsion, though ultimately the total GHGs emissions from such vehicles depend on the mix of fuels used to generate the electricity they use for recharging.

The main aim of this paper is to survey the policies currently in use to support the production and deployment of HEVs and electric vehicles (EVs)¹, from the perspective of their possible implications for international trade. A wide variety of policies are currently being used by nations at the federal or central level and at the sub-national level to accelerate the uptake and use of electric vehicles. These policies are reviewed in detail in this paper and are summarised in Table 1. As is the case with renewable energy, which was examined in a previous report in this series², both developed and emerging economies aspire to be at the forefront of developments in this new industry and have implemented policies aimed at increasing their capacity to develop, manufacture and service electric vehicles. Direct government support has been concentrated in three areas: on improving the capacity and lowering the cost of storage batteries, on

¹ For the purpose of this paper, and consistent with the way the term is defined by the International Energy Agency (IEA), “electric vehicle” is defined here as comprising plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel-cell electric vehicles (FCVs), but not HEVs.

² See the paper by Bahar *et al.* (2013), “Domestic incentive measures for renewable energy with possible trade implications”, *OECD Trade and Environment Working Papers*, No. 2013/01, OECD Publications, Paris.

increasing the scale of deployment of plug-in hybrid electric (PHEV) vehicles and battery-electric vehicles (BEVs), and on developing the infrastructure for recharging electric vehicles. Such support is being provided by several OECD countries but also by governments elsewhere, including the People's Republic of China, India, South Africa, and several governments in South-East Asia.

Table 1. Deployment incentives for all-electric and plug-in hybrid-electric vehicles by country

Type of incentive	Locations
Income-tax credit or deduction for purchase of a BEV or PHEV	Austria, Belgium, Israel, Netherlands (BEV taxis or vans only), United States (federal, Colorado, Georgia, Montana, Oklahoma, South Carolina, Utah)
Grants or rebate on purchase or lease of a BEV or PHEV	Canada (Ontario, Quebec), China (paid to manufacturers), Spain (federal and several regions), Sweden, United Kingdom, United States (California, Hawaii, Illinois, Louisiana, Maryland, Tennessee, Texas)
"Fee-bate" scheme	Austria; Belgium (Walloonia); China; Estonia; France; Ireland; Japan; Luxembourg; Singapore, Spain; Sweden
Reduction in, or exemption from, vehicle purchase or registration tax	Belgium (Flanders), Costa Rica, Denmark, Finland, India, Ireland, Israel, Japan, Malaysia, Netherlands, Norway, Portugal, Romania, Singapore, Sweden, United Kingdom, United States (District of Columbia, Maryland, New Jersey, Washington State)
Exemption from, or reduction in, annual circulation, road, or tonnage taxes	Austria, Australia (Victoria), Czech Republic, Denmark, Finland, Germany, Greece, India, Ireland, Italy, Japan, Latvia, Netherlands, New Zealand, Norway, Portugal, Romania, Sweden, Switzerland (varies by canton), United Kingdom (London), United States (New Jersey)
Discounted or free battery charging	Netherlands, Norway, United States (California, local incentives)
Privileged access to bus or high-occupancy vehicle (HOV) lanes	Korea, Netherlands, Norway, Portugal, Ontario (Canada), United States (Arizona, California, Florida, New Jersey)
Free or reduced charges for parking in public car parks	Denmark, France, Netherlands, Norway, Portugal, United Kingdom
Public procurement preferences	Belgium (Walloonia), Bulgaria, Estonia, France, Italy, Japan, Korea, Portugal, Sweden, United Kingdom, United States (federal and several states)
Government support for the deployment of battery-charging infrastructure	Austria, Canada (BC and Québec), China (in selected cities), Denmark, Estonia, France, Germany, Israel, Italy, Japan, Korea, Netherlands, Norway, Poland, Portugal, Spain, United Kingdom, United States
Income-tax credit, rebate, or grant for private installation of a charger	Belgium, Canada (BC), Denmark, United States (Arizona, Georgia, Maryland, Oregon)

Sources: ACEA (2013); IEA and EVI (2013); Brand et al. (2013), Beltramello (2012); Clean Vehicle Europe (www.cleanvehicle.eu/); Gouvernement du Québec (2012); IA-HEV (2013), Morrow et al. (2010); Ontario, Ministry of Transportation; Tesla Motors (www.teslamotors.com/incentives/AR/); U.S. Department of Energy, Alternative Fuels Data Centre (no date); ACEA (2013); IEA and EVI (2013); Clean Vehicle Europe (www.cleanvehicle.eu/); Weeda et al. (2021); U.S. Department of Energy, Alternative Fuels Data Centre (no date); various news articles listed in the bibliography list of references for this paper.

Compared with many renewable-energy technologies, the market size for plug-in electric vehicles (i.e., BEVs plus PHEVs) and batteries is still relatively small, and many of the technologies are relatively immature. Turnover of the solar photovoltaic industry alone is almost USD 90 billion a year, compared with USD 7-8 billion for PEVs.³ Nonetheless, several OECD countries, and even a few non-OECD countries, have established aspirational targets for electric vehicles, typically to be achieved by 2020 or 2030 but in some cases earlier. Some of these targets cover all forms of electrified transport, while others are specific to plug-in electric vehicles. To help boost the rate of penetration of EVs in their economies, many of the same countries also provide tax incentives and grants to purchasers of qualifying vehicles.

Domestic-content requirements tied to these purchases are exceptional, but do exist. Domestic manufacturers are also sometimes favoured through government procurement, such as in the purchase of postal delivery vehicles. Additional demand is being driven by a number of city-led initiatives to establish fleets of EVs that can be rented for short durations. More broadly, policies requiring automobile manufacturers to increase the average fuel economy of the vehicles they sell, or fuel suppliers to reduce the total carbon-dioxide (CO₂) emissions of vehicles operating in their service area, are creating a market niche that electric vehicles are helping to fill. These market-pull and technology-push incentives exist at both the national and sub-national level.

Domestic markets for HEVs and electric vehicles are also being shaped by border measures, particularly import tariffs, which both favour domestic producers of the vehicles and increase the domestic prices of such vehicles, which has a dampening effect on demand. Whereas import tariffs on technologies used to generate electricity from renewable energy are generally low in most OECD and emerging economies, tariffs on motorised vehicles, including HEVs and electric vehicles, are relatively high, reaching 25% in China, South Africa and Russia, 35% in Brazil, 80% in Thailand, and 100% in India. By contrast, import tariffs on electric accumulators (storage batteries) used for vehicles for transport are relatively low, with few exceeding *ad valorem* rates of 10% in the countries examined in this paper.

All government interventions in the market for vehicles ultimately affect trade, but some do so more directly than others. As the conceptual analysis in the Bahar *et al.* (2013) paper shows, so-called “market-pull policies” will by themselves usually have a stimulating effect on trade, drawing in imports of goods and services to help meet the resulting increased demand. However, some countries have combined market-pull policies with other policies that are intended to ensure that a large share of their domestic demand is met by domestic suppliers. These policies include high tariffs on imports of fully assembled vehicles, local-content requirements, and government-procurement preferences. Such policy combinations may be particularly harmful for the domestic market through raising the domestic price of HEVs and EVs and shielding domestic industries from taking part in world competition. Moreover, they are usually harmful for foreign companies that often cannot overcome barriers to entry introduced by these policies. That is why the World Trade Organization (WTO), in its Agreement on Trade-Related Investment Measures, prohibits the use of measures applied to investments, including local-content requirements, that discriminate against foreign products or that lead to quantitative restrictions. Similarly, the WTO Agreement on Subsidies and Countervailing Measures prohibits subsidies contingent, whether solely or as one of several other conditions, upon the use of domestic over imported goods.

Technology-push policies, which seek to increase the supply of HEVs, electric vehicles and batteries, mostly focus on government support for research, development and demonstration (RD&D) at early stages of innovation, and for product development and manufacturing at later stages. The trade effects of government support for RD&D depend on the details of the policies, how close the funded research or products are to commercial applications, and the generosity of the funding. In industries in which

³ Source of the PV market estimate: Cole (2013); PEV estimate by the authors, based on sales data collected by Jose Pontes and manufactured suggested retail prices for major models.

technology is constantly changing, RD&D can account for a major share of a manufacturing firm's costs. Government assistance — though clearly generating positive externalities through the diffusion of new knowledge — may nonetheless give recipient industries an advantage over their foreign competitors.

Government assistance to manufacturers is more clearly linked to trade outcomes, through exports or import substitution. Incentives for investment in manufacturing of EVs and batteries may lower the market price of these goods on the domestic market, but usually not by the full amount of government support as some of the support will be captured by the producers in the form of super-normal profits. Whether and how trade is affected depends on the particulars of each scheme and the relevant market. The automotive industry's extensive and dispersed global supply chains mean that support for a plant that assembles electric vehicles, for example, may lead to increased imports of batteries and other components. How much foreign firms can benefit from other countries' support for manufacturing will largely depend on the characteristics of the supply chain of the products in question. Whether manufacturing of finished vehicles or batteries are supported, a trade impact may occur through lower-than-otherwise imports of the finished product.

Ensuring that domestic-incentive policies do not violate core trade principles is just as important for HEVs and electric vehicles as it is for other goods. Full transparency on domestic incentives, including through the WTO subsidy-notification process, would be helpful both in keeping trading partners informed and in promoting best practice in the use of domestic incentive measures.

Introduction

Propulsion of vehicles by electricity predates by several decades the invention of cars powered by internal-combustion engines. The first independently manoeuvrable electric carriages appeared in the mid-1800s and by the late 1800s both France and Great Britain were supporting their widespread development (IEA and EVI, 2013). The lead-acid storage batteries available at the time were still relatively unsophisticated, however, and as a consequence the vehicles could travel only a short distance between battery recharges. By the 1910s, gasoline and diesel-powered vehicles eclipsed electric vehicles (EVs) for all but specialised uses, such as indoors where vehicle emissions from internal-combustion engines could pose a danger to health or safety. Interest in electric propulsion was revived following the dramatic increases in petroleum prices in the 1970s, spawning numerous research-and-development projects in OECD countries. The recent rise in global petroleum prices that began in 2003, and concerns about the greenhouse-gas emissions from vehicles, have given new impetus to efforts to develop and improve electric propulsion.

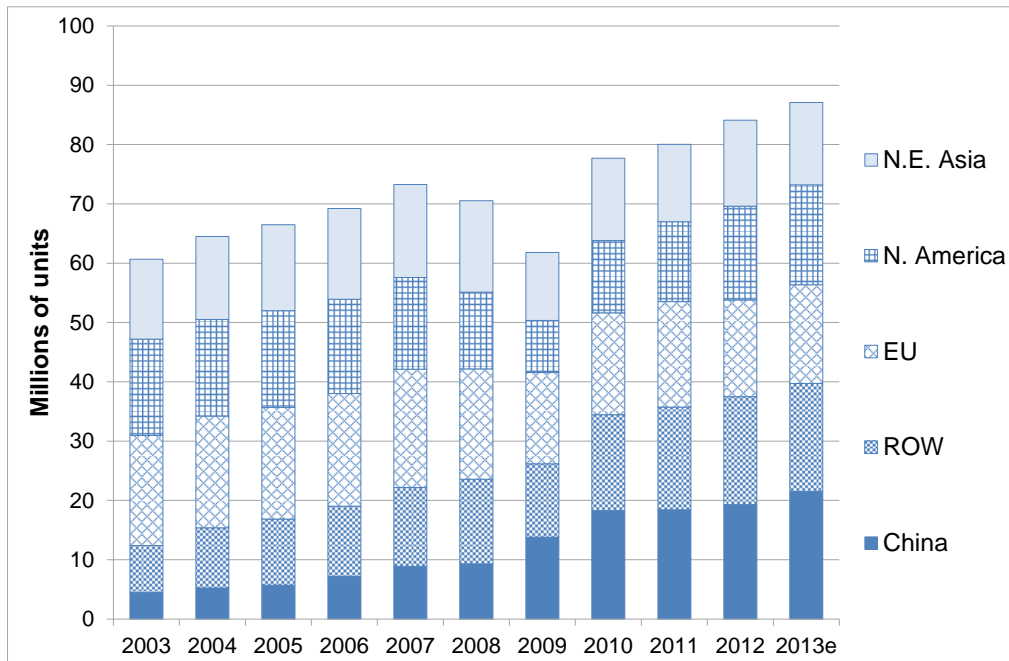
The first fruits of these efforts were hybrid-electric vehicles (HEVs), which are vehicles powered by internal-combustion engines but which can run for part of the time on electric power generated by regenerative braking — a technology that converts a vehicle's kinetic energy during braking into electric energy that can then charge a battery. Some models of HEVs also recharge their batteries or directly power their electric-drive motors with the aid of an electrical generator (a combination known as a *motor-generator*). And many reduce power draw and emissions by shutting down the internal-combustion engine during idling and restarting the engine when needed (a feature known as a *start-stop system*).

Despite the success of HEVs, interest in vehicles that can obtain most of their traction energy from the electric grid — i.e., ones whose batteries can be recharged through plugging into electric mains — continues to rise. This is because of the relative simplicity of electric-vehicle drive trains, their low (in the case of plug-in hybrid-electric vehicles, or PHEVs) or zero (in the case of battery-electric vehicles, or BEVs) tail-pipe emissions, near-silent operation, and expectations by transport planners that over the long term they will be cheaper to own and operate than ICE-powered vehicles or HEVs. Many owners of vehicles with electric propulsion also value the instant torque at low speeds that give some EVs a high-performance quality (OECD, 2014).

HEVs and electric vehicles form part of the much broader market for motorised vehicles for operating on roads. In 2013, global sales of HEVs and EVs are estimated to have slightly exceeded 2 million units, just 2.5% of the total market for all light-duty vehicles of 87 million (Figures 1 and 2). Currently, 9 HEVs are sold for every EV sold in the world. Sales of HEVs are expected to continue to grow, but some forecasters expect that by 2020 combined sales of PHEVs and BEVs will be almost as large as for HEVs.⁴

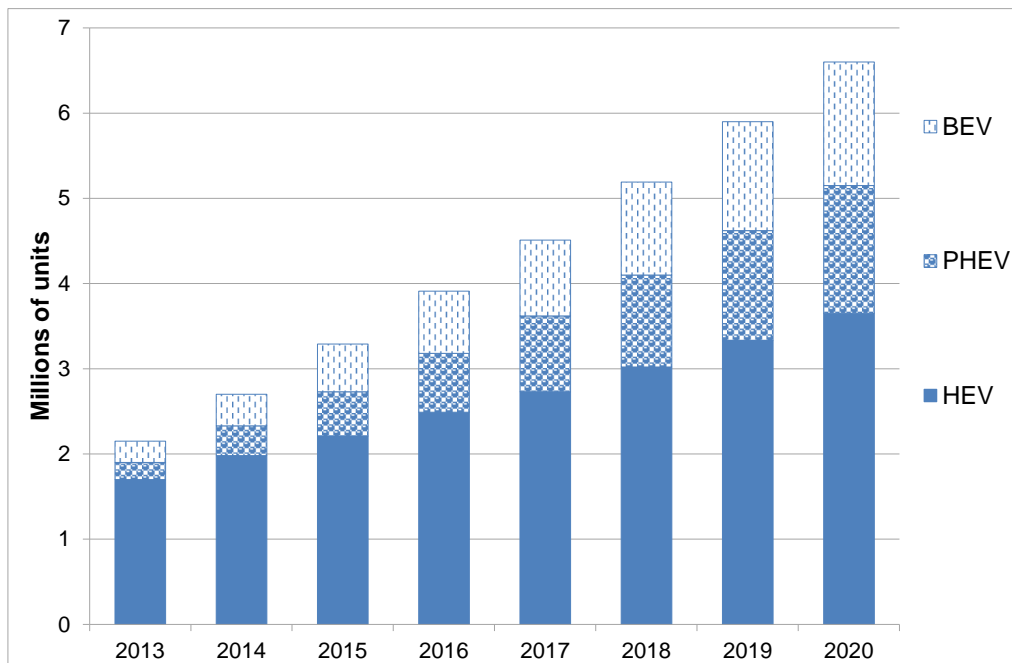
⁴ The market for electric vehicles powered by a fuel cell — a device that converts the chemical energy from a fuel such as hydrogen into electricity through a chemical reaction with oxygen or another oxidizing agent — is much more uncertain. Over 20 prototypes and demonstration models of fuel-cell electric vehicles (FCEVs) have been released since 2009 (www.netinform.net/H2/H2Mobility/Default.aspx); these include automobiles such as the GM HydroGen4, the Honda FCX Clarity, the Mercedes-Benz F-Cell, and the Toyota FCHV-adv. Several manufacturers have announced plans to start selling FCEVs on a commercial scale in 2014 or 2015 (Bullis, 2013).

Figure 1. Global production of automobiles,1 2003-13



1. Total of cars and commercial vehicles (i.e., buses, light commercial vehicles and heavy trucks).
 Data source: Organisation Internationale des Constructeurs d'Automobiles (<http://www.oica.net/category/production-statistics/>).

Figure 2. Projected global sales of light-duty HEVs and electric vehicles,1 2013-20



1. Assuming no change in government incentives in place as of 2Q of 2013 and a 10% and 26% decline in the costs of battery packs for, respectively, HEVs and PHEVs. The price of BEVs is assumed to remain flat, but vehicle range and performance will improve.
 Data source: Navigant Research (2013).

The objectives of this paper are to provide a survey of these various technology-push and market-pull policies, and to discuss their possible trade implications. The paper forms the second in a series intended to examine the trade implications of domestic incentive measures for energy-related goods, following a similar paper on renewable energy (Bahar *et al.*, 2013).

Many different types of policies have been promulgated by governments around the world, especially within the OECD but also in China, India, South Africa and South-East Asia, to promote the manufacturing and deployment of HEVs and EVs. These incentives include tax benefits, regulations, subsidised loans, grants, and investments in research and development (Brand *et al.*, 2013). The paper first reviews the barriers to the large-scale deployment of HEVs and electric vehicles, and then systematically reviews the types of policies that can be used to overcome these barriers should a government choose to do so. Past and current “push and pull” policies are then analysed. Finally, the possible trade implications of these policies are discussed. Summaries of the policies of Canada, China, France, Germany, India, Japan, Norway, South Africa, Turkey, the United States, and the member countries of the Association of South-East Asian Nations (ASEAN) are annexed.

For the purposes of this paper, all three- and four-wheeled vehicles, including light trucks and small autonomous buses, that use electric propulsion as a partial or primary form of traction are of interest.⁵ These include battery electric vehicles (BEVs) that use electric power as the only fuel; plug-in hybrid electric vehicles (PHEVs), which mainly run on electric power but have a back-up gasoline engine; fuel-cell vehicles (FCVs) and hybrid-electric vehicles (HEVs). For all of these vehicles, the battery (or a fuel cell) is one of the most important components of the vehicle, and it is the biggest source of the incrementally higher costs of HEVs and electric vehicles compared with conventional pure gasoline- or diesel-powered alternatives. It is important to clarify at the outset that the barriers, incentives, and policies for BEVs and PHEVs differ rather substantially from those for HEVs because there is no need to plug in an HEV or FCV. HEVs are fuelled by gasoline or diesel (or an equivalent biofuel) and FCVs by hydrogen, whereas BEVs and PHEVs are primarily powered by electricity obtained from the electricity grid, although PHEVs have a back-up gasoline engine.

Barriers to the further deployment of HEVs and EVs

Six types of barriers exist to the further deployment of HEVs and EVs: technical, infrastructure, economic, social, environmental, legal and political. These barriers differ depending on whether or not the vehicle must be plugged in to recharge the battery. In general, the barriers for HEVs are far fewer than those facing BEVs and PHEVs. HEVs have a much greater range than most BEVs and PHEVs, and they face no fuelling-infrastructure barriers. HEVs do not require an investment in batteries as large as is needed for BEVs and PHEVs, and therefore their incremental costs compared with conventional alternatives are smaller. Social perceptions of HEVs are generally positive, and “strong” HEVs (ones that greatly improve fuel efficiency) can lead to vastly improved environmental performance. Political support for HEVs has been widespread.

In Japan, the United States⁶, and Europe, the incremental costs of HEVs are relatively small compared with conventional vehicles, and often they can be recovered during the lifetime of the vehicle due to fuel savings. In some developing countries, such as China and ASEAN member countries, HEVs are expensive from the viewpoint of most consumers. In general, consumers in these countries cannot afford HEVs, or they do not have incentive to buy HEVs because of high import tariffs on the vehicles or the low price of

⁵ The full range of electric propulsion would include electric bicycles and motorcycles at the smaller end, and electric trolley buses and trains at the other. The markets for these, and the policies used to support them, however, are very different from those for cars, light trucks and small buses.

⁶ See, for example, <http://vincentric.com/Home/IndustryReports/HybridAnalysis.aspx>

subsidised fuel. Therefore, sales of HEVs in those countries are small compared with those in OECD countries, which makes it hard for manufacturers to take advantage of economies of scale in the local production of HEV models. In the case of China, the government has taken a strategic decision to promote BEVs instead of HEVs on the assumption that doing so will enhance its automobile industry's technological competitiveness.

For BEVs and PHEVs, the technical barriers and costs remain a primary obstacle to their more rapid deployment. These vehicles currently use lithium-ion batteries, which are still very costly. Despite government efforts around the world to support R&D in advanced battery technology, as well as the substantial grants and loans that they have provided to battery manufacturers, the costs have not come down enough to make BEVs competitive without some government incentives. Battery manufacturers have argued that costs cannot come down without exploiting economies of scale. But without more EVs being sold, demand for batteries has been insufficient and costs have remained stubbornly high. Although there are other technological constraints, batteries remain the most important barrier.

It is often assumed that a lack of a charging infrastructure is a major barrier to the deployment of EVs, but the evidence for this assumption is mixed. Surveys in the United States have shown that, so far, most current BEV or PHEV owners charge at home during the evening hours — especially when they can take advantage of local time-of-use pricing (some utilities offer cheaper rates to EV owners if they charge only during off-peak hours) (Morrow et al., 2008). On the other hand, Sierzchula et al. (2014), in a survey of electric vehicle adoption across 30 countries in 2012, found that EV adoption rates were most strongly correlated with public charging infrastructure among the variables they considered.⁷ Public chargers are particularly important for owners of PEVs living in multi-dwelling units, and those who must commute long distances.

More and more corporations are offering workplace battery recharging, and many municipalities and states are subsidizing the deployment of public charging stations even though it is hard to predict where consumers would like to have them and when they would like to use them. Usage rates of public chargers in the United States appear to be very low (approximately in use only 5% of the time), perhaps because few consumers depend on public charging but rather organise their usage to what can be served by residential and workplace charging. Fast chargers (Level 2) are more likely to be helpful in workplace and public locations since the charge time is substantially reduced, but most of the chargers deployed so far in the United States are of the slower variety (Nissan, 2013). By contrast, Japan leads the world with fast chargers, having installed more than 2800 by the end of 2014 (www.chademo.com).

The perceived barrier of charging infrastructure spurred the firm Better Place to develop the business concept of providing batteries that could be swapped out of EVs in approximately the same time it would take to fill up a tank of gasoline.⁸ But, in a way, this model is even more constraining because it requires the company to provide a comprehensive network of battery-swapping stations, and the EVs must be designed to work with the swapping stations (currently, only one EV model, manufactured by Renault, can do so). Still, it appears that so far most BEV and PHEV owners do not use their vehicles for long trips, and

⁷ Using multiple linear regression analysis, the authors examined the relationship between 14 variables and the share of PEVs in the total light-duty vehicles registered in a country during 2012. The 14 variables related to each country's financial incentives, its environmental regulation and performance, and its urban density; its gasoline, diesel and electricity prices; whether in 2012 it was host to an EV producer's global headquarters or production facility; its per-capita national income, per-capita numbers of vehicles, and per capita charging stations; the percentage of its workforce with at least a tertiary education level; the number of EV models available in 2012; the year (since 2008) that EVs were first sold in the country; and the price of purchasing a Mitsubishi MiEV in the country.

⁸ Better Place went out of business in June 2013, after investing over USD 400 million.

instead use them for predictable trips for which they certainly have adequate range based on residential charging. This means that, for longer trips, owners would need access to a more extensive network of EV charging stations, or good public-transport options. Otherwise, BEVs may end up being purchased mainly as a household's second car.

The costs of charging infrastructure, depending on the type of installation, can be high enough to serve as a deterrent to some residential customers. Most vehicles need no special external charging equipment and their owners instead plug their vehicles into a standard 110 or 220 volt wall socket. However, this method of charging can take 8-16 hours for a full recharge. Faster, Level 2 chargers can reduce the recharging time to 4-6 hours (Box 1). Morris et al. (2014) estimate that costs range from around USD 1 000 for a home AC Level 2 charger to USD 8 000 for a curb-side equivalent, with costs varying considerably around this number depending on how much structural work is needed to prepare the site. A DC Level 3 fast-charger station on a highway corridor can cost as much as USD 50 000. Permitting and delays in electrical upgrades can also deter residential investment in Level 2 or above recharging infrastructure. Governments in many countries subsidise the costs of installing residential, workplace, and public chargers.

Some governments even offer free public charging. Operating costs are certainly much cheaper for BEVs and PHEVs in most developed countries since the cost of refuelling using electricity is much less than refuelling with gasoline. Strong HEVs can go much further on a litre of gasoline than conventional alternatives, so the per-kilometre cost of driving is substantially lower, raising the possibility that owners of HEVs will drive their vehicles further — an illustration of the rebound effect.

The social barriers to greater deployment of HEVs and EVs vary substantially by country and by vehicle type. HEV sales have been strong in the United States and Japan, and public acceptance of HEVs was quick and warm. Public understanding of the advantages and disadvantages of EVs is much more variable, however, and public acceptance more sceptical than it was when HEVs were first introduced to the marketplace. A survey of over 13 000 individuals in 17 countries, carried out by Deloitte Touche Tohmatsu Limited between November 2010 and May 2011 (Giffi et al., 2011), found that the majority of consumers surveyed were either willing to consider the purchase of an electric vehicle or see themselves as potential first movers when it comes to electric vehicle adoption. However, deeper questioning revealed a significant gap between consumer expectations of electric vehicle capabilities and what an electric vehicle could deliver at the time. The authors observe, “Consumers generally felt that EVs should be able to go farther, on less charge time, for a cheaper price than automakers are currently able to offer” (p. 1). Other investigators have also found that the public has difficulty calculating the costs and benefits of owning an EV (Committee on Overcoming Barriers to Electric-Vehicle Deployment, 2013). This is one of the reasons why Natural Resources Canada, in collaboration with the Canadian Automobile Association (CAA), has created a calculator that shows consumers how much they can save on operating costs (<http://electricvehicles.caa.ca/electric-vehicle-cost-calculator/>).

The life-cycle emissions of HEVs and EVs vary substantially from one place to another depending on whether they plug into the grid or not, on the type of battery used in the vehicle⁹, and on how the vehicle and batteries are manufactured.¹⁰ If they plug into the grid, and the grid is supplied primarily by coal-fired power plants that do not capture and store CO₂, then the life-cycle emissions of BEVs and PHEVs can be higher than from conventional gasoline vehicles (Figure 3), and substantially higher than emissions from HEVs running part of the time on liquid fuels (Samaras and Meisterling, 2008; Huo *et al.*, 2010; Faria *et al.*, 2013). This is not the case, however, in countries that cap their total emissions and which include

⁹ Battery production can be very energy- and resource-intensive (see, e.g., Majeau-Bettez et al., 2011; Delucchi et al., 2014)

¹⁰ As for any vehicle, *how* the vehicle is driven can also affect energy requirements and thus emissions.

emissions from electric power generation, but not emissions from the combustion of ground-transport fuels, within the total quota: in that case, additional electric consumption for battery charging has no effect on emissions from the power sector but does displace CO₂ that would otherwise be emitted by the combustion of gasoline or diesel fuel. It is logical, therefore, that among the countries with the highest shares of EVs are those already with low or moderate carbon emissions from their electricity sector (Canada, France, Iceland, Norway, and Sweden), or that are encouraging greater use of renewable energy or are displacing coal with natural gas. In countries with relatively high carbon emissions from electricity generation, and which have not capped emissions from their electric power sector, hybrid-electric vehicles yield lower GHG emissions than BEVs.

Box 1. Charging equipment for plug-in electric vehicles

Charging equipment for BEVs and PHEVs is classified by the rate at which it charges a vehicle's battery. Actual charging times can vary from 0.25 to 20 hours, depending on the capacity and type of battery, the extent to which the battery is depleted, and the type of electrical vehicle supply equipment (EVSE) used (Table 2).

AC (alternating current) Level 1 EVSEs provide charging through a standard AC plug (100-120 volts in Central and North America, some countries and islands in the Caribbean and South America, Japan, and Chinese Taipei, and 220-230 volts in most of the rest of the world). Most PEVs are sold with an AC Level 1 EVSE cord so that the owner need not purchase additional charging equipment. AC Level 1 charging is typically used when there is only a standard electrical outlet available. Based on the battery type and vehicle, AC Level 1 charging adds about 3-7.5 kilometres of range to a PEV per hour of charging time and can take 8-16 hours to charge a fully depleted battery.

AC Level 2 EVSE offers charging through 240 V or 208 V electrical service and requires a dedicated circuit of 20 to 100 amps, depending on the EVSE requirements. Many non-residential units operate at up to 30 amperes, delivering 7.2 kW of power. However, most residential AC Level 2 EVSEs operate at lower levels of power. Based on the vehicle and circuit capacity, AC Level 2 adds about 16-32 kilometres (10-20 miles) of range per hour of charging time, or 4-6 hours to charge a fully depleted battery.

Direct-current (DC) fast-charging equipment, sometimes called DC Level 3, enables rapid charging and so is suitable mainly along heavy traffic corridors and at public recharging stations in large cities. These devices typically require 480-V AC input, however. A DC fast charger can add 100 to 140 kilometres (60-80 miles) of range to a light-duty PHEV or BEV in just 20 minutes. As of 1 April 2014, the EV maker Tesla Motors had installed around 85 public "superchargers" in the United States, and 14 in Europe, for use by Tesla car owners for free.

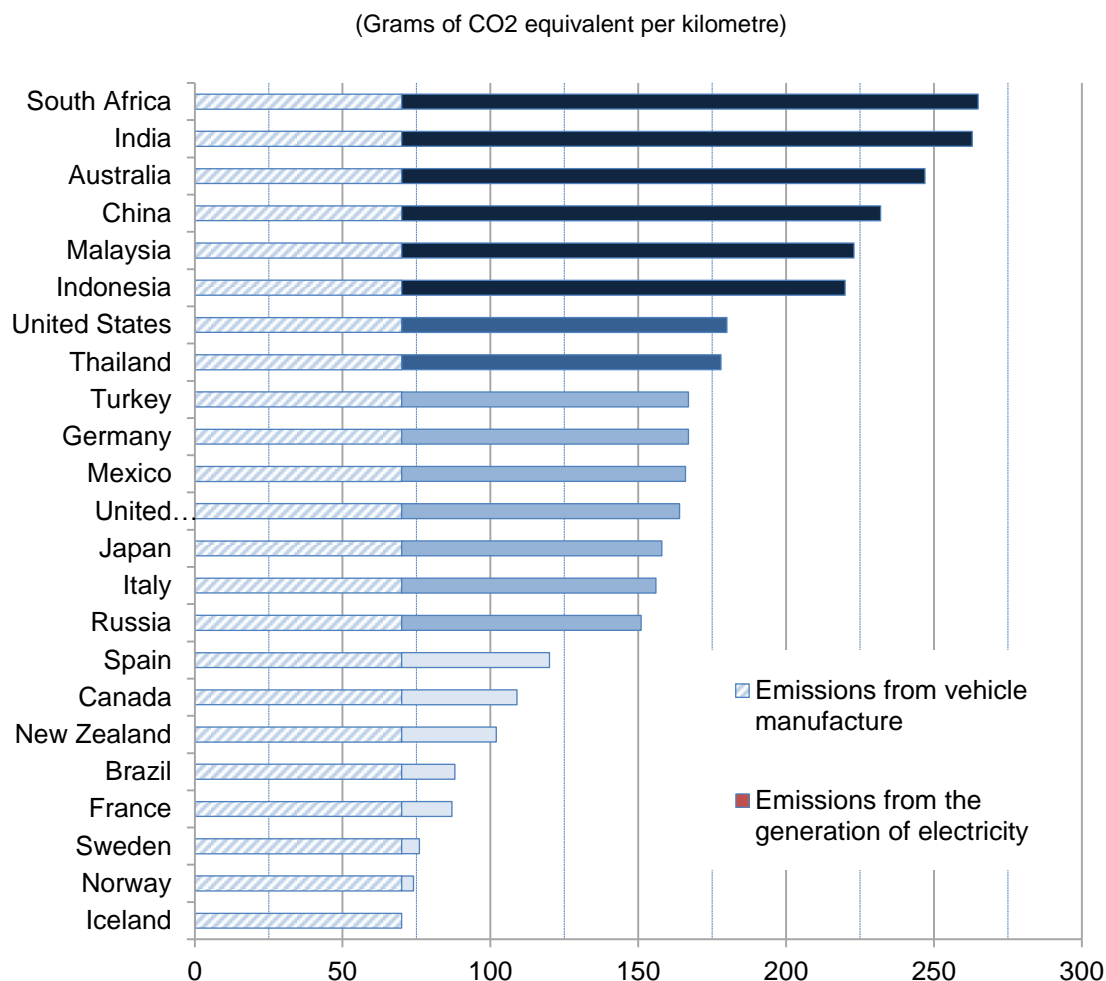
Table 2. Electric-vehicle charger capabilities

Characteristic	Alternating-current chargers		Rapid (DC) chargers
	Level 1	Level 2	Level 3
Voltage	110-120 (or 210-220)	208-240	480
Charge power (kW)	1.8-1.9	≤ 14.4	30-250
Estimated charge time	10-20 hours	3-8 hours	< 30 minutes
Estimated price	~ USD 1 000	USD 500 – 3 000	USD 17 500 – 50 000
Comments	Appropriate for small battery packs such as in plug-in hybrid electric vehicles (PEVs).	Ideal and cost-effective for most EV charging applications.	Most expensive and most stressful for the grid. Shortens battery life.

Source: Adapted from Deloitte Touche Tohmatsu Limited (2011).

Inductive charging equipment, which uses an electromagnetic field to transfer electricity to an EV without a cord, has been recently introduced commercially for installation as an after-market add-on. Currently available wireless charging stations operate at power levels comparable to AC Level 2. Recently, Toyota announced that it will offer wireless charging power-capture devices on their future PHEVs and BEVs. Compatible wireless charging devices will be manufactured by third-party suppliers, under license from WiTricity, the holder of the patents on this technology.

Sources: US Energy Information Administration; Morris et al. (2014); Tesla Motors (www.teslamotors.com/supercharger); WiTricity (www.businesswire.com/news/home/20131205005161/en/Toyota-Licenses-WiTricity-Patent-Portfolio-Wireless-Power)

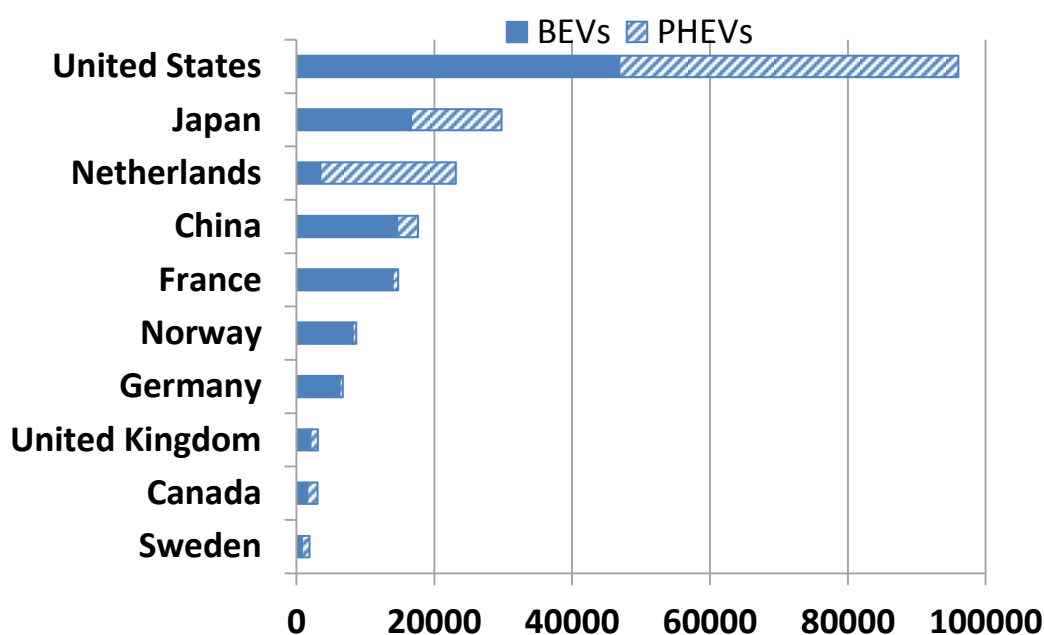
Figure 3. Total GHG emissions in selected countries from using a grid-powered EV, 2013

Note: Assumes for each country that manufacturing emissions average 70 gCO₂e/km over the lifetime of the vehicle (compared with 40 gCO₂e/km for a vehicle powered by an internal-combustion engine only), and that the vehicle's wall-to-wheels energy use is 211 Watt-hours per kilometre — i.e., similar to that of a Nissan Leaf.

Sources: OECD Secretariat, based on data from the UK Department for Environment Food & Rural Affairs (www.ukconversionfactorscarbonsmart.co.uk/) and assumptions used by Wilson (2013).

Political support for EVs has varied across time and space. Some governments have proved to be especially keen on EVs, others less so. For example, in his 2011 State of the Union address, U.S. President Barack Obama set a goal of putting one million electric vehicles on U.S. roads by 2015 (U.S. DOE, 2011); and Japan has set a national target for EVs of 15-20% in 2020 and 20-30% in 2030 of national vehicle sales (Sprei and Bauner, 2011). These two countries, plus China, Denmark, Finland, France, Germany, India, Italy, the Netherlands, Portugal, South Africa, Spain, Sweden, and the United Kingdom, in 2010 formed the Electric Vehicles Initiative (EVI), one of the thirteen initiatives to come out of the 2009 Clean Energy Ministerial. Canada joined the EVI in 2013. The 16 members of the EVI, which include 9 of the 10 largest electric vehicle markets in the world (Figure 4), seek collectively to facilitate the global deployment of at least 20 million passenger-car EVs by 2020 (IEA and EVI, 2013). These countries are also expected to account for 83% of global EV sales between now and that year (*ibid*).

Figure 4. Sales in the leading 10 markets for plug-in electric vehicles during 2013



Source: Based on data compiled by Jose Pontes (www.ev-sales.blogspot.ch).

Policy incentives for the development, adoption, and use of vehicles utilizing electric propulsion

Many different kinds of support policies have been designed and implemented around the world to overcome the barriers to EVs, and to promote the development and deployment of HEVs and electric vehicles (Beltramello, 2012). Most of these incentive policies have been fiscal in nature, but market-based, regulatory, informational, infrastructure-creating, and innovation policy tools have been used as well. Governments have also played a convening and co-ordinating role, particularly related to the roll out of infrastructure for battery-charging stations.

Innovation policies aim at “pushing” and “pulling” EVs into the marketplace through a combination of measures, including investments in R&D, demonstration, and the policies identified above that create incentives for the use of EVs. These policies are described in more detail in the next section. The countries that are currently setting the pace for innovation are not necessarily those where actual market penetration is the most advanced (Weeda *et al.*, 2012).

For energy technology innovation, the evidence is strong that a systemic approach is ideal (Grubler *et al.*, 2012). Innovation can result from both “push” and “pull” influences, where technology-push can be thought of as resulting from investments in the inputs (e.g., human capital, funding) of the innovation process, and pull from the market or government-induced demand (Nemet, 2009; Gallagher *et al.*, 2012). Traditionally, innovation was conceived as proceeding through a linear series of stages, beginning with research, moving to development, then demonstration, then diffusion. Over time, it has become clear that the linear model does not aptly describe how innovation occurs in the real world and that there are many feedbacks within the process, and many more stages that matter. The roles of different types of actors (producers, consumers, universities, research bodies, etc.) and institutions, at different stages, have become clearer. All of these aspects, and more, form part of the innovation system for a given technology, sector, or nation.

The innovation system for EVs is exceedingly complex. It includes the producers and consumers of the vehicles themselves, the producers of the various parts and components of EVs (including the batteries), electric utilities, grid operators, and research institutions. Despite Japanese automotive firms having emerged as the forerunners in HEV and EV technology, holding many of the most important patents, neither one firm nor one nation owns all the intellectual property rights to all EV technology. Markets for HEVs and EVs have sprung up, largely as a result of government policy, in numerous advanced and emerging economies, and producers are now serving multiple markets. By taking a holistic approach to innovation and considering the systemic effects of different policy interventions, governments are more likely to enhance the effectiveness of their policies. Designing policies to be consistent, aligned, and stable will avoid sending contradictory signals to the market (Grubler *et al.*, 2012).

Organizing framework: the classification of incentives

There are several ways to examine support measures systematically. Figure 1 provides a two-dimensional framework similar to the one used by the OECD for organising data on support to agriculture and to fossil fuels. The first dimension highlights the formal incidence of a transfer — i.e. which aspect of production or consumption is targeted. The other dimension, transfer mechanism, relates to how the transfer is created. The framework divides incidence into production (corresponding roughly to technology-push) and consumption (market-pull). Measures supporting production are then further divided into several sub-categories, depending on whether they relate to output returns, enterprise income, the cost of intermediate inputs or value-adding factors — labour, land and natural resources, capital, and knowledge creation. Consumption is divided into measures supporting the acquisition of the particular technology — in this case an HEV or electric vehicle — and those that help reduce its running costs.

When discussing support policies, it is standard practice to structure the discussion around incidence, in an order reflecting the degree of influence on market outcomes. Generally, policies that directly bear on the level of production or consumption are considered to affect production decisions to a greater extent than subsidies to value-adding factors, like labour. Government support for research and development (R&D), as long as it is not a form of production support in disguise, is normally considered by economists to be the least distorting. So is support for consumption that does not discriminate against imports — e.g., purchase rebates for electric vehicles. The importance of differentiating among different forms of support according to their incidence is implicitly recognised in the WTO’s Agreement on Subsidies and Countervailing Measures (ASCM), where a distinction is made between those subsidies that are prohibited (e.g. subsidies contingent upon the use of domestic over imported goods — i.e., subsidies with a local-content requirement), and those that are actionable (e.g. subsidies to cover operating losses). Local-content requirements are also addressed in the WTO Agreement on Trade Related Investment Measures (WTO), which deems them inconsistent with the national treatment obligation of Article III:4 of the GATT.

Market-pull policies

As detailed in Appendix 1, many different types of policies are being used by countries around the world to accelerate the deployment of HEVs and EVs and their component technologies. In addition to these are excise taxes and carbon taxes applied to petroleum-based fuels. Probably the most important type of policy is a “market-formation” policy, which creates a new market or greater demand for a given technology (Gallagher, 2014). All of the fiscal, regulatory, and market-based instruments discussed in the following section could be considered market-formation policies.

As Crist (2012) observes, one justification for these market-formation policies is the belief that the shift to low-carbon transport is inevitable and that assisting such a shift to electro-mobility early reduces the overall burden on society that may otherwise result from a late shift. He adds:

The “early-shift” storyline stresses that not only is government intervention in BEVs required (on a sometimes large scale) but that society ultimately benefits due to a reduction of the oil import bill (with beneficial productivity impacts throughout the economy) and an increase in domestic manufacturing and jobs. An alternate storyline may highlight the elevated up-front opportunity costs of reducing energy dependency and greenhouse gas emissions via BEVs as opposed to advanced internal combustion engine vehicles and hybrids.

Incentives for HEVs and electric vehicles and battery-charging infrastructure

BEVs and PHEVs are significantly more expensive to purchase than equivalent conventional vehicles. Reducing this differential is the first incentive measure offered in most programmes to promote the use of electric vehicles. Twelve out of the EVI’s sixteen member governments offer some form of purchase incentive. The main fiscal tools used by governments are tax credits, sales-tax reductions or exemptions, and purchase rebates or grants. In the United States, for example, a federal income-tax credit of up to USD 7 500 is offered to buyers of BEVs and PHEVs, but no longer to HEVs. Differentiated acquisition or registration fees are imposed based on fuel efficiency, vehicle type, or emissions. Rebates have been offered for EVs, and a few countries have experimented with *bonus-malus* or fee-bate regimes, whereby a fee is imposed on inefficient or polluting vehicles, and rebates offered for fuel efficient or low-emission or electric vehicles. Many governments plan to phase out support once a certain sales volume is reached or funds are exhausted, the rationale being that costs should start to fall as the market becomes better established.

The measures detailed above typically result in a reduction in the current investment for an electric passenger car of USD 7 000 to USD 10 000, which covers only part of the price differential with a conventional car. Though the electric vehicle user will be saving on fuel costs as well as maintenance and repair costs, support is also often provided after the vehicle has been purchased, with reductions or exemptions in recurrent costs such as annual or road circulation taxes. This support typically represents USD 500 to USD 1 500 annually per vehicle.

Most countries’ subsidies and tax incentives for the purchase of HEVs or EVs are not made contingent on the use of locally manufactured or assembled automobiles. However, some countries that are starting to provide consumer incentives, such as China, Malaysia, and Thailand, apply import tariffs of 25% or higher on vehicles, meaning that purchasers are likely to favour domestically produced vehicles. Moreover, the structure of the incentives matters. In China’s case, the purchase rebates provided by the Central Government and municipalities are channelled via the manufacturer (see Appendix 1), which means that only car models supplied by firms with production or assembly plants in the country can benefit from the scheme.¹¹

¹¹ The planned scheme in India would also channel the subsidy through the manufacturer.

Table 3. Examples of transfers associated with support for the production or consumption of HEVs and electric vehicles

		Statutory or Formal Incidence (To Whom and What a Transfer is First Given)								
		Production						Consumption		
		A. Output returns	B. Enterprise income	C. Cost of intermediate inputs	D. Costs of production factors				E. Cost of acquisition (vehicle or charging infrastructure)	F. Operating costs
Labour	Land and natural resources				Capital	Knowledge				
Transfer Mechanism (how transfer is created)	I. Direct transfer of funds	Output bounty, export subsidy or deficiency payment	Operating grant	Input-price subsidy	Wage subsidy	Grant or subsidised loan linked to acquisition of land	Grant or subsidised loan linked to acquisition of machinery	R&D carried out by a government institution	Unit subsidy or purchase rebate	Government-subsidy on electricity used for charging batteries
	II. Tax revenue foregone	Production tax credit	Reduced rate of income tax	Reduction in excise tax on input	Reduction in social charges (payroll taxes)	Property tax reduction or exemption	Investment tax credit	Tax credit for private R&D	Reduction in or exemption from registration fee or VAT	Reduction in or exemption from annual vehicle circulation taxes
	III. Other government revenue foregone			Under-pricing of a government-supplied good or service		Underpricing of access to government land or natural resources		Government transfer of intellectual property right	Provision of government-owned property for use by charging station	Free use of (formerly) metered parking spots for EVs
	IV. Transfer of risk to the government		Third party liability limit for producers		Assumption of occupational health and accident liabilities	Credit guarantee linked to acquisition of land	Loan guarantee			
	V. Induced transfers	Price protection via import tariff	Monopoly concession on vehicle sales	Export restriction on key input	Wage control	Land-use control in favour of a particular use	Credit control (sector-specific)	Stronger than standard IPR protection	Regulated price; cross-subsidy	Mandated lower electricity rate for battery charging.

Financial support for the development of charging infrastructure is a standard feature of programmes to promote the use of electric vehicles. Governments have approached non-residential infrastructure deployment in very different ways. Japan has installed more fast chargers than any other country — more than 2800 by the beginning of 2015,¹² but has placed less emphasis on slow chargers, whereas the United States has adopted the reverse approach. In The Netherlands, both types of chargers have been developed in equal measure, resulting in the highest number of charging points per capita worldwide. These efforts represent a large share of public expenditure on electric vehicle support programmes. The EVI estimates that its members had spent some USD 800 million on EV-related infrastructure through the end of 2012 (IEA and EVI, 2013).

Government procurement

Government procurement has formed part of the package of incentive measures in most of the countries that have undertaken programmes to support HEVs or electric vehicles. Indeed, according to the IEA and the EVI (2013), the uptake of electric vehicles in public fleets at the national and local levels is playing a major part in scaling up EV production and promoting mass adoption in many countries. Government procurement policies can create niche markets for EVs, such as when purchased for public buses, airport fleets, garbage-collection fleets, and other municipal vehicles (Kemp *et al.*, 1998). The rationale for procurement is that it serves as a large-scale demonstration programme, helps kick-start the market for electric vehicles and provides a showcase for their reliability, safety and environmental advantages.¹³ Nevertheless, because public procurement generally concerns captive fleets, conditions are more favourable to the use of electric vehicles than for private fleets and individuals (Wang, 2013). In addition, public operators generally have the financing capacity to make the necessary up-front capital investments, as well as having access to funds that can bridge the gap with the cost of conventional vehicles.

Procurement policy guidelines are sometimes expressed, as in France and Portugal, as aiming for a share for electric vehicles in government fleets or fleet renewal. Most other countries' guidelines or requirements allow for more than one type of "clean-energy" technology to meet the quota. In China, participating cities and regions have set minimum numbers of vehicles to be purchased. Japan has set public purchasing requirements for low-emission and electric vehicles since the 1990s, and made them mandatory in its 2000 Green Purchasing Law. A recent survey of the history of electric-vehicle procurement targets and quotas shows that they are often not met, largely because plans proved to be too costly to implement, particularly when financial resources are constrained by cutbacks in public spending (Beltramello, 2012).

The extent to which public procurement has favoured domestic producers of HEVs and EVs is difficult to discern. Certainly the proclivity of governments to purchase vehicles from national manufacturers is borne out by statistics. In the United States, for example, passenger cars made by foreign companies (i.e., other than by one of the "Big Three": Chrysler, Ford or General Motors) registered a 8.3% share of total car purchases by governments (local, state and federal) in 2012, in contrast with a 43.3% share in the fleet segment of the market overall (Polk, 2013a). However, the foreign share of government purchases of HEVs, PHEVs and BEVs in the same year was 49% (Polk, 2013b). In the case of China, the preference is not only for domestic manufactured or assembled vehicles, but "home-grown makes". According to Murphy and Zander (2013), "all 412 sedans, multipurpose and sport-utility vehicles and alternative-energy cars listed as eligible for government purchase" in 2012 by China's Ministry of Industry

¹² Source: www.chademo.com

¹³ Though public procurement is widely used to promote the use of electric vehicles, empirical evidence of its cost-effectiveness relative to market-based instruments is lacking. A full analysis would need to take account of the impact of the demonstration effect, as well as reductions in CO₂ and other emissions.

were indigenous brands owned by Chinese car makers. As of the beginning of 2014, that situation had not changed (Annex 1).

Information and co-ordination

Information policies are aimed at educating potential consumers about the benefits of HEVs and EVs and include labelling programmes, demonstration programmes, and public-education campaigns. A relatively small but important issue is permitting policy, which can strongly affect the ability of firms to install chargers in different types of locations. In several countries, for example, building codes have slowed the approval process for the installation of high-voltage chargers in residences and workplaces.

Governments often play a co-ordination role in terms of planning for public charging infrastructure, extension or expansion of the grid, and for dialogue between vehicle manufacturers and electric utilities. The establishment of EV corridors across different jurisdictions, for example, occasionally requires intervention by central-government authorities. Most governments have formed collaborative partnerships with industry, research entities and other stakeholders, such as local authorities and NGOs, to advance the adoption of electric vehicles by combining expertise, aligning resources and creating common goals.

At the international level, the Implementing Agreement for co-operation on Hybrid and Electric vehicles (IA-HEV) — one of 42 technology collaboration programs of the IEA — has been collaborating since 1993 on, among objectives, producing and disseminating new knowledge and information on hybrid and electric vehicles (IA-HEV, 2013). The IA-HEV serves as a platform for information exchange among its 18 member countries (Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Korea, the Netherlands, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States), and also publishes an Annual Report with statistics and information on national policies.

Regulatory standards and mandates

Regulatory policies are being widely used around the world to require manufacturers to offer vehicles using electric propulsion. Although California tried to implement its Zero Emissions Vehicle (ZEV) mandate in 1990, it relaxed its requirement for ZEVs when it became clear that there was insufficient consumer demand at the time. California's low-carbon fuel standard was assessed by Yeh and Witcover (2012) and found to have imposed a compliance cost of USD 13 per metric tonne of CO₂e, adding one-tenth of a U.S. dollar per gallon (U.S. 0.026 per litre) to the cost of gasoline in 2012. Most governments today either specify performance standards for fuel efficiency or CO₂ emissions. Between 2020 and 2025, Europe, Canada and the United States, and China, will all require that new vehicles emit no more than 120 grams CO₂/km. This standard is roughly equivalent to a fuel efficiency of 5.6 litres per 100 kilometres, or 50 miles per gallon (An, 2011). Such stringent performance standards will likely require a substantial hybridisation of the vehicle fleet, although not necessarily widespread use of BEVs or PHEVs. Furthermore, the interaction of BEVs and PHEVs with policies aimed at reducing CO₂ emissions from vehicles is complicated because the life-cycle emissions of the vehicles depend on the GHG intensity of the grid.

Disincentives for non-electric vehicles

Market-based policies like carbon taxes, gasoline taxes, and cap-and-trade regimes in principle create a disincentive for the use of conventional vehicles and an incentive for the use of alternative vehicles. Indeed, there is plenty of evidence that rising gasoline prices are associated with increased sales of HEVs (Gallagher and Muehlegger, 2011). The evidence is not yet in for BEVs and PHEVs. On the other hand, the carbon taxes applied by a few countries (Denmark, Norway, Sweden, Switzerland) and by the Canadian Province of British Columbia on transport fuels do not strongly affect the prices of petroleum

fuels since the relatively low carbon contents of refined petroleum products translate into a small proportion of the overall retail price, and are often considerably smaller than the proportion of taxes due to excise duty. Gasoline excise taxes have a more direct effect, but in Europe, these higher prices have led consumers to mainly adopt fuel-efficient diesel vehicles rather than BEVs, in part because of the other barriers to EVs cited in this paper. This is particularly the case in countries where excise taxes on diesel fuel are considerably lower than taxes on gasoline, which is true in all OECD countries except the United States.¹⁴

Technology-push policies

Government support for research, development and demonstration (RD&D)

The IEA and the EVI have estimated that public expenditure on RD&D related to electric vehicles in selected countries during 2012 reached at least USD 2.4 billion, with China and the United States being major contributors to global RD&D spending (IEA and EVI, 2013).¹⁵ How much of this expenditure is provided by government varies substantially, but in most countries public funding typically accounts for a large share (Table 4). The U.S. Department of Energy (DOE) has supported a vehicle-technology programme for many years, though its emphasis on electrification has waxed and waned. For fiscal year 2012, the DOE devoted USD 303 million to EVs. A recent survey of large (over EUR 1 million) RD&D projects in European countries found 320 projects running between 2007 and 2015, for a total cost of EUR 1.9 billion, 65% of which is government-funded (Zubaryeva and Thiel, 2013); updates on EV-related RD&D projects in the EU can be found on the on-line EV-RADAR database (<http://iet.jrc.ec.europa.eu/ev-radar/>). Public-private partnerships are common for demonstration projects, which account for 20% of expenditure. In EU Member States, many projects benefit from additional support from the EU. For instance, the EU Green Cars Initiative is a public-private partnership for R&D on infrastructure and technology, with EUR 1 billion allocated since 2009.

Arguably, government support for other inputs into the innovation system, such as the establishment of the U.S. Department of Energy's Critical Materials Hub to develop alternatives to rare earth elements needed for HEVs and electric vehicles, as well as for other clean energy technologies, at Ames National Laboratory, could also count as "technology push" policies. Governments are also supporting the strengthening of the research base for EV-related technologies, by providing scholarships, fellowships, loans for educational purposes as well as grants to colleges and universities to create degree programmes, research laboratories, testing facilities, and so forth. One example is the Integrative Graduate Education and Research Traineeship (IGERT) U.S. federal government fellowship programme. Analytically, it is hard to quantitatively isolate government support for EVs from other energy technologies in this regard, but many governments have invested in the human and technical resources to enable further innovation in EV technologies.

¹⁴ *Taxing Energy Use* (OECD, 2013) provides a graphical explanation of the excise and other taxes applied by OECD countries to various fuels, including transport fuels.

¹⁵ This total does not count expenditure by Japan, which spent around JYP 5.50 billion (USD 55 million) in FY2012, and an estimated JYP 5.29 billion (USD 53 million) in the year ending 31 March 2014.

Table 4. Government programmes and funding for RD&D related to EVs, selected economies

Government and programme	Description	Funding (period)
Austria: Alternative Propulsion Systems and Fuels Programme (A3plus); Electro-mobility programme; Lighthouse technology projects	A3plus brings together government agencies, industry and universities; Electro-mobility demonstration programme in model regions and in 5 Lighthouse projects	A3plus: EUR 4 million in 2012; Electro-mobility: EUR 2.5 million in 2011, plus EUR 6 million for model regions; Lighthouse projects: EUR 5 million in 2012
Belgium: Flemish Government Living Lab Electric Vehicles Programme	Brings together 70 companies, municipalities, research entities and government agencies to test real-life EV innovations	Total funding EUR 16.25 million since 2011
Canada: Automotive Partnership Canada	Brings together research entities and industry to fund several projects related to EVs	Public funding contribution: USD 27 million in 2009-2013; USD 22 million in 2014-18
China: Ministry of Science & Technology	Clean vehicle programme for the 11 th Five Year Plan	RMB 1.16 billion (USD 118 million) over 2006-2010, plus RMB 7.2 billion (USD 1.17 billion) from local government and industry; USD 18 billion from 2011-2020 for R&D (vehicle technology for alternative fuel and low emissions) and possible investment in industry
Denmark: Danish Energy Agency	Demonstration programme for EVs and charging infrastructure; "Test an EV" project for private users	EUR 6.7 million for 2008-2015
EU Green Cars Initiative	Public-private partnership for R&D on infrastructure and technology with main focus on electrification	EUR 1 billion since 2009
Finland: EVE Programme	Support for applied R&D joint projects and private-public partnerships with research entities	EUR 80 million in 2011-2015
France: Agency for Environment and energy Management (ADEME) Demonstration Fund; Vehicle of the Future	Demonstration of research projects typically 10 years away from commercialisation; demonstration projects for charging and EV fleets in urban areas	Approved projects with a total funding of EUR 100 million, with additional funding of up to EUR 150 million scheduled until 2015
Germany: Federal Ministry of Research, National Electro-mobility Development Plan	R&D support towards goal of 1 million electric vehicles by 2020, based on public-private partnerships; demonstration programme with 4 electro-mobility demonstration projects and 220 projects in 11 model regions	EUR 500 million for R&D from 2009, including EUR 38 million for battery R&D; demonstration programme: EUR 200 million, plus EUR 115 million for 2009-2011
India: 12th Five-Year Plan R&D allocation	Partnerships with industry and research entities, as part of National Mission for Hybrid and Electric Vehicles	USD 110 million in 2012-2017
Indonesia: Indonesian Institute of Sciences (LIPI)	LIPI has produced various prototypes of electric buses and city cars. The technology center will become the main location for the design of electric auto components produced by Indonesians.	No data available.
Italy: Industry 2015 Sustainable Mobility Project	Electrification of a range of vehicles from e-bikes to buses	Total cost for 2008-2015: EUR 450 million, of which EUR 180 million in public funding

Government and programme	Description	Funding (period)
Japan	R&D: to improve performance of Li-ion batteries, to develop post-Li-ion batteries, innovative high-performance magnets that do not rely on rare earth minerals, soft magnetic materials with low energy loss, and high-efficiency motors that use these magnets or new materials.	JPY 5.29 billion (USD 52 million) in FY 2013/14
Korea	R,D&D projects on EVs and related technologies	Batteries: USD 270 million; other areas: USD 680 million in 2011
Netherlands: Automotive NL Innovation Centre, Electric Vehicle Technology Research Programme	Focus on supporting projects on intelligent mobility, innovative power-trains, education and knowledge transfer; 9 demonstration projects using 204 EVs	Public funding: EUR 20 million in 2011 for R&D, EUR 10 million for demonstration in 2009-2014
Norway: Transnova demonstration project	Transnova is a government agency funding projects to reduce GHG emissions from transport. It is testing of EVs in local weather conditions, subsidising charging infrastructure demonstration and operating a pilot project for electric taxis.	Overall programme budget EUR 25 million since 2009
Portugal: MOBI.E programme	RENER demonstration network of 1 350 charging points in 25 towns and along main roads	EUR 3.3 million in 2009-2011
Spain: Ministry of Science and Innovation, Inno Plan and CENIT Verde programme; Movele project	Inno Plan: 7 R&D projects; CENIT Verde: brings together 15 companies and 14 research entities to develop technology and components for EV and HEVs; Movele demonstration project for EVs and charging stations.	Inno Plan: EUR 13.8 million from 2009; CENIT: EUR 40 million; Movele: EUR 10 million for 2009-2011
Sweden: Swedish Energy Agency, Strategic Vehicle Research and Innovation Programme	Partnership between government and automotive industry on climate, environment and safety	Government funding of about EUR 50 million since 2009, including joint projects on electric vehicles with Volvo and EUR 1 million on battery R&D in 2012
Thailand: Automotive and Automotive Parts Industry Programme	The programme focuses on supporting the Thai automotive industry in its efforts to design key automotive parts, drives, electric car safety equipment and energy-saving and environment-friendly automotive parts. Key operation plans include developing prototypes and designing technologies and manufacturing electric cars.	No data available.
United Kingdom: Low Carbon Vehicle Innovation Platform (LCVIP); Ultra Low Emissions Vehicles (ULEV) programme	LCVIP promoted UK-based R&D and showcased vehicle technologies through demonstrations and road trials; ULEV programme "to cement the UK's position as a leader" in the development of ULEVs	LCIP channeled funding from government agencies and industry, leveraging GBP 350 million (USD 560 million) between 2007 and 2012; ULEV to receive GBP 100 million (USD 170 million) from 2014-2020.
U.S. Department of Energy Vehicle Technology Budget	Funding related to electric vehicles and batteries	USD 303 million for fiscal year 2012

Sources: • **General:** Weeda et al. (2012); IEA and EVI (2013); Bernhart et al. (2013); • **EU and EU Member States:** Zubaryeva and Thiel (2013) and <http://www.green-cars-initiative.eu/public/>, Gallagher and Anadon (2012); • **Canada:** www.nserc-crsng.gc.ca/Media-Media/NewsRelease-CommuniqueDePresse_eng.asp?ID=428; • **China (2006-2010):** personal communication with Ministry of Science and Technology official (2013); • **Japan:** Kurosawa (2014); • **Thailand:** Laonual (2013); • **United States:** Gallagher and Anadon (2012).

The government role in RD&D for HEVs, electric vehicles and batteries, as with many other technologies, hinges on a wide variety of factors, including local scientific capacity and traditions of public-private interaction. As explained in Annex 1, public funding is not central to the Japanese model of product development. Rather, the Government generally relies on public-private RD&D programmes, typically involving several manufacturers with the government playing the role of an initiator and a facilitator, co-ordinating the efforts of public and private stakeholders around a shared vision and a programme spanning five to ten years. In the case of HEVs in Japan, private industry, most notably Toyota, developed the key technologies seemingly independently from the Japanese government (Okazaki et al., 2012), though the industry benefited from government support for major HEV components through public-private programmes focussed on BEVs (Gallagher, 2012). The same applies to Honda. It was not until 1997 — after commercialisation of the first HEVs — that the government officially began undertaking RD&D related to HEVs. In addition, the government created a rebate for Japanese buyers of hybrid-electric vehicles, which started at JPY 250 000 (USD 2 400) in 1998 and gradually fell to JPY 100 000 in 2006 and ended in 2007 (Anonymous, 2008).

Government support for product development and manufacturing

In addition to financial support for RD&D, many governments provide incentives to manufacturers of HEVs, electric vehicles or batteries for product development and manufacturing. This support is sometimes provided through the same programmes that provide funding for RD&D to push the technology into the market, though usually it is channelled through specific programmes that focus on development at the production stage, detailed product design, manufacturing, technology operation and promotion, as well as investment incentives for equipment manufacturers, mainly in the form of tax breaks. The integration of vehicle and battery is central to the electric vehicle business, and incentive programmes have focused on both components.

A modern passenger car contains over 30 000 parts.¹⁶ Though car manufacturers assemble final vehicles, as much as 70% of the components come from external suppliers. The battery of an electric vehicle typically represents at least 30% of the total final cost of the vehicle, defining its sales price, range and safety. Initially car manufacturers took the lead in developing electric-vehicle projects, with vertical integration and control of the entire manufacturing chain, including the battery. Recently, though, there has been a trend away from this production model toward partnerships with, and outsourcing to, battery manufacturers. For instance, in 2012 Renault-Nissan renounced its plan to produce 100 000 batteries, deciding instead to purchase batteries for its electric vehicles from the Korean manufacturer LG Chemical. Conversely, while some car manufacturers made their way into the battery business and later exited, some battery manufacturers have sought to establish themselves in the electric car industry so as to gain control over a promising market for their batteries. This is the case for instance of French battery manufacturer Bolloré, which now produces the Bluecar® (a BEV) as a showcase for the reliability of its lithium metal polymer batteries. The Chinese manufacturer, BYD, has also followed this development model. This trend is partially a response to the fact that, as the technology of electric propulsion matures, manufacturers focus on software and battery integration to establish a competitive edge.

Government support for battery production has had a major impact on manufacturing and trade. Lithium-ion battery technology was first developed in the United States and Europe, though Japanese companies were the first to commercialise them in the 1990s, principally for electronic products (Kassatly, 2010). Manufacturing capabilities spread to China and Korea, and by the end of the decade Asia accounted

¹⁶ According to CALSTART, a U.S.-based consortium dedicated to promoting advanced transportation, some 70% of an electric vehicle's component parts may differ from that of a gasoline-powered vehicle. The number of moving parts in an electric vehicles are also many fewer. See https://www1.eere.energy.gov/vehiclesandfuels/avta/light_duty/fsev/fsev_gas_elec1.html

for 98% of global production, close to manufacturing sites for battery-dependent portable consumer goods. Since 2000, Asian manufacturers repositioned themselves to capture the market for electric vehicle batteries. In recent years, in recognition of the importance of batteries to the success of electric vehicles, some countries have launched large programmes to support the development of domestic manufacturing capacity. The largest is a U.S. programme that awarded over USD 1.5 billion in stimulus grants to support battery development and manufacturing, starting in 2009, when the federal government identified the battery manufacturing business as a strategic industry to decrease dependence on oil imports and stimulate the economy (CBO, 2012). By the end of 2012, lithium-ion battery production capacity for electric vehicles was five times larger than demand from automakers as a result of disappointing sales of electric vehicles. Recent increases in global sales of electric vehicles are expected to absorb this battery production overcapacity within a few years.

There is intense international competition both in electric vehicle and battery production. Given that battery production currently outstrips demand, the point at which electric vehicle and battery manufacturers can stand alone without government support cannot be predicted. Nevertheless, it is clear that, without government support, it is likely that most batteries (particularly lithium-ion batteries) for electric vehicles might still be sourced in Asia (Canis, 2013). By 2013, lithium-ion batteries were being installed in 94% of PEVs, and the top two manufacturers, Panasonic and AESC (a joint venture between NEC and Nissan), accounted for almost $\frac{3}{4}$ of global sales (Pontes, 2014).

There are in any case two important market factors that favour the creation of a domestic supply chain for batteries for electric vehicles: just-in-time manufacturing practiced by most auto manufacturers and the heavy weight of the batteries, which can make them cheaper to assemble locally rather than to transport from abroad. In the case of countries that manufacture both conventional and electric vehicles, there can be a strong rationale for ensuring that a significant share of vehicle and battery production remains domestic because this is seen as a way of gaining an early leadership position in what are hoped to be growing domestic and export markets, without losing market shares held by conventional vehicles.

Import tariffs

Domestic policies supporting EVs and associated equipment interact with measures applied at the border, particularly import tariffs and non-tariff barriers. When combined with a high import tariff, for example, a policy to stimulate domestic demand for a particular good also becomes a policy to stimulate domestic production of that good.

Some countries have created special tariff lines in their national tariff schedules for vehicles powered primarily by electricity. Of the twenty-five WTO member economies listed in Table 3, accounting for over 98% of global production of passenger cars in 2013, sixteen¹⁷ provide a separate classification (usually as an 8- or 10-digit extension — i.e., “ex out” — of HS 8703.90) for electric vehicles. Of these, only Mexico and Russia levy a (slightly) lower import tariff on new vehicles equipped only with electric motors than they do on new vehicles powered mainly by internal-combustion engines (ICE).¹⁸ Among the same group of countries, only Israel has created a separate “ex out” for hybrid-electric vehicles, providing two codes each under HS 8703.2 and HS 8703.3. These separate codes exist mainly for statistical purposes: the tariffs on HEVs are the same as for pure ICE-powered vehicles.

¹⁷ Canada, China, India, Indonesia, Israel, Korea, Malaysia, Mexico, Norway, Pakistan, Philippines, Russia, South Africa, Thailand, Turkey, and Vietnam.

¹⁸ Several economies, including Russia, apply significantly higher import duties on used vehicles than on new vehicles.

Pakistan is an important exception. In June 2013, Pakistan’s federal tax agency reduced the import duty rates on hybrid-electric vehicles with engine-displacement capacities up to 2500 cubic-centimetres (cc). The import tariff on non-hybrid cars with internal-combustion engines ranges from 50% to 100%, and the tariff applied on electric vehicles (tariff code 8703.90.20) is 50%. The applicable sales tax is 17%.¹⁹ The new policy reduced all applicable duties (import tariff, withholding tax and sales tax) to zero (a 100% concession) on hybrid cars with gasoline engines up to 1 200 cc, and granted a 50% duty concession on hybrid cars with engine capacities between 1201 cc and 1800 cc, and a 25% duty concession on hybrid cars with horsepower between 1801 and 2500 cc. Local automobile assembler paid a 25% import duty, in lieu of the previous 35%, on imported complete knockdown kits.²⁰ On 26 June 2014, however, Pakistan’s federal tax agency amended its Notification No. S.R.O. 499(I)/2013, reducing to 50% the exemption in leviable duties and taxes on hybrid-electric vehicles with engine-displacement capacities of up to 1800 cc, and to 25% the exemption on HEVs with engines larger than 1800 cc capacity.²¹

The main observation evident from the table is that MFN import tariffs for OECD countries on motorised vehicles are generally much lower than those applied by non-OECD countries. Moreover, though not shown, an increasing volume of international trade in motorised vehicles takes place between nations that are parties to a free trade agreement (FTA), and therefore crosses borders duty-free.²² On motor cars and other motor vehicles principally designed for the transport of persons (other than buses) — i.e., vehicles classified under HS 8703 — Japan, New Zealand, and Norway allow imports to enter their countries duty-free. Of these three countries, only Japan is a major manufacturer of EVs. Australia, Canada, Chile, Israel, Korea, Switzerland and the United States apply MFN import tariffs of less than 10%; the EU and Turkey apply MFN import tariffs of 10%; and Mexico applies an MFN import tariff of 20% (except on vehicles under the “Other” category, HS 8703.90). These MFN tariffs are the highest that are applied by OECD countries on other WTO members, however.

By contrast, MFN applied import tariffs set by many of the larger, non-OECD members of the G–20 and ASEAN are considerably higher than those applied by OECD countries. Ignoring HS 8703.10, which generally excludes vehicles designed for operation on public highways, the MFN applied tariffs of the non-OECD countries listed in Table 3 are 25% or higher. In Indonesia they are 40%, in Thailand they are 80%, and in India they are 125% — i.e., the domestic price for an imported motor car is more than doubled by the application of the import tariff. In several of these countries, however, the MFN applied tariffs for large vans and buses (HS 8702) are lower than for motor cars. This relates to the other observation, which is that, apart from the few exceptions noted above, the level of protection provided to motor vehicles is generally uniform whether the vehicle is designed to transport a few or many passengers, and whether it is powered by gasoline, diesel, electricity or some combination of electricity and an electric fuel.

Turning to import tariffs on electric accumulators (the trade term for rechargeable storage batteries) — the heart of and the most expensive single traded component in electric vehicles and in hybrid-electric vehicles (Box 2) — as well as on capacitors, the story is very different (Table 5). MFN applied tariffs are often 0%, are much lower on average across all 25 countries, and are highest in Argentina and Brazil (18% for accumulators, 16% for capacitors). Most countries apply the same *ad valorem* rate on electric accumulators, irrespective of the metallic elements on which they are based, but ten (China, the EU, Mexico, New Zealand, Pakistan, Philippines, South Africa, Turkey, the United States,

¹⁹ <http://www.thenews.com.pk/Todays-News-3-204319-Local-assemblers-to-unveil-new-hybrid-cars>

²⁰ <http://tribune.com.pk/story/564462/businessmen-welcome-duty-relief-on-hybrid-cars/>

²¹ [http://download1.fbr.gov.pk/SROs/20146261363914483SRO567\(I\)-2014.pdf](http://download1.fbr.gov.pk/SROs/20146261363914483SRO567(I)-2014.pdf) (Official Notification S.R.O. 567(I)/2014).

²² In the case of the 2011 Korea-US Free Trade Agreement, Korea will immediately reduce its electric car tariffs from 8% to 4%, and both countries will then phase out their tariffs by the fifth year.

and Vietnam), levy a higher tariff on lead-acid accumulators used for starting piston engines than they do on accumulators using other technologies. China levies an MFN applied tariff of 6% on nickel-metal hydride and lithium-ion accumulators, and 10%-12% on other types of accumulators. Canada, Mexico, and the United States have created separate ex outs for accumulators used as a power source for propelling electrically powered vehicles of subheading HS 8703.90. In Canada's tariff schedule, such accumulators attract a 0% tariff, in contrast with the 7% tariff levied on accumulators imported for other uses; in Mexico's and the United States' tariff schedules, the tariffs vary by technology but not by end use.

Box 2. Types of energy-storage systems used in HEVs and electric vehicles

Various energy storage systems are used in hybrid electric vehicles, plug-in hybrid electric vehicles, and battery-electric vehicles. Each has its advantages and disadvantages relative to the others.

Lead-acid batteries can be designed to deliver high amounts of power and are inexpensive, safe, and reliable. However, low specific energy, poor cold-temperature performance, and short life cycle impede their use in vehicles with large electrical demands. Advanced high-power lead-acid batteries are being developed, but these batteries are used only in commercially available electric-drive vehicles for ancillary loads.

Nickel-metal hydride batteries, offer reasonable specific energy and specific power capabilities. Nickel-metal hydride batteries have a much longer life cycle than lead-acid batteries, are safe and are tolerant of abuse. These batteries have been used successfully in all-electric vehicles and are widely used in hybrid-electric vehicles. The main challenges with nickel-metal hydride batteries are their high cost, high self-discharge and heat generation at high temperatures, and the need to control hydrogen loss.

Most of today's plug-in hybrid-electric vehicles and all-electric vehicles use *lithium-ion* batteries. These batteries have a high power-to-weight ratio, high energy efficiency, good high-temperature performance, and low self-discharge. Chemistries include lithium cobalt oxide, lithium nickel cobalt aluminum, lithium iron phosphate, lithium nickel cobalt manganese, lithium manganese spinel and lithium titanate. Most components of lithium-ion batteries can be recycled. Research and development is ongoing to reduce cost and extend their useful life.

Lithium-polymer batteries with high specific energy, initially developed for electric vehicle applications, also can provide high specific power for hybrid electric vehicle applications. Their costs will need to decline before they become commercially viable, however.

Ultracapacitors store energy in a polarised liquid between an electrode and an electrolyte. Energy storage capacity increases as the liquid's surface area increases. Ultracapacitors can provide vehicles with additional power during acceleration and hill climbing and help recover braking energy. They are also useful as secondary energy-storage devices in electric-drive vehicles, by helping electrochemical batteries to level the power load. Additional electronics are required to maintain a constant voltage due to low energy density.

Sources: www.afdc.energy.gov/vehicles/electric_batteries.html; www.tva.gov/environment/technology/car_batteries.htm

Table 5. MFN applied tariffs for completely assembled new motor vehicles for passenger transport (as of the end of 2014 or beginning of 2015)

Country	Motor vehicles for the transport of 10 or more persons, including the driver:		Motor cars and other motor vehicles principally designed for the transport of persons (other than those of heading 8702), including station wagons and racing cars:			
	With compression-ignition internal combustion piston engine (diesel or semi-diesel)	Other	Vehicles specially designed for travelling on snow; golf cars and similar vehicles	Other vehicles, with spark-ignition internal combustion reciprocating piston engine ¹	Other vehicles, with compression-ignition internal combustion piston engine (diesel or semi-diesel) ¹	Other vehicles, or electric vehicles explicitly, where they are separately identified
HS code:	8702.10	8702.90	8703.10	8703.21-24	8703.31-33	8703.90
Argentina	35%	35%	20%	35%	35%	35%
Australia	5%	5%	5%	5%	5%	5%
Brazil	35%	35%	35%	35%	35%	35%
Canada	6.1%	6.1%	6.1%	6.1%	6.1%	6.1%
Chile	6%	6%	6%	6%	6%	6%
China	25%	25%	25%	25%	25%	25%
EU	10-16%	10-16%	5-10%	10%	10%	10%
India	10%	10%	125%	125%	125%	125%
Indonesia	5-40%	5-40%	40%	40%	40%	40%
Israel	7%	7%	7%	7%	7%	7%
Japan	0%	0%	0%	0%	0%	0%
Korea	10%	10%	8%	8%	8%	8%
Malaysia	30%	30%	30%	30%	30%	30%
Mexico	20%	20%	15%	20%	20%	15%
New Zealand	5%	5%	0%	0%	0%	0%
Norway	0%	0%	0%	0%	0%	0%
Pakistan	20%	0-20%	30%	50-100%	20-100%	50%
Philippines	15-20%	20%	30%	30%	30%	30%
Russia	0-20%	0-18%	5%	25%	25%	0%
South Africa	20-25%	20-25%	0%	25%	25%	25%
Switzerland	0%	0%	————— CHF 12-15 per 100 gross kilogramme ² —————			
Thailand	40%	40%	40%	80%	80%	80%
Turkey	10-16%	10-16%	5-10%	10%	10%	10%
United States	2%	2%	2.5%	2.5%	2.5%	2.5%
Vietnam³	5-70%	5-70%	70%	67-70%	70%	70%

1. Excluding ambulances, prison vans, police vehicles and hearses, vehicles designed for operation using LNG or CNG, and "completely knocked-down" (i.e., unassembled) vehicles.

2. Assuming a range of weights between 1 350 and 2 500 kilogrammes per vehicle (http://cars.lovetoknow.com/List_of_Car_Weights), and border prices of at least CHF 10 000 per vehicle, these specific-rate duties translate to a maximum of CHF 375 per vehicle, or no more than 3.75% on an ad valorem equivalent basis.

3. For some vehicle types, the duty rate is applied according to the duty rate of each part or accessory of the vehicle.

Source: Market Access Database (<http://madb.europa.eu/madb/indexPubli.htm>).

The much lower rate of import tariffs applied by countries on components of HEVs and electric vehicles reflects a common phenomenon, especially in non-OECD countries: tariff escalation — i.e., the practice of charging significantly higher tariffs on finished goods than unfinished goods or components.

Thus, in 2011 India announced that specified parts required for the manufacture of hybrid vehicles would enjoy full exemption from basic customs duty and special countervailing duties. For its budget for 2012-13, the import tariff for specific parts of hybrid vehicles, and of lithium-ion batteries imported for the manufacture of battery packs for supplying HEVs or electric vehicles, was reduced to 6% from 10%.²³ Indonesia and Malaysia, like several other emerging economies that manufacture or assemble automobiles, charge, relatively high (respectively, 40% and 30%) import tariffs on most vehicles under HS 8703, including all-electric vehicles, but a relatively low (10%) import tariff on “complete knocked down” (i.e., unassembled) vehicles.

²³

<http://www.theclimategroup.org/what-we-do/news-and-blogs/india-announces-solar-led-and-hybrid-vehicle-exemptions-in-annual-budget/> and <http://www.dnaindia.com/money/1805677/report-excise-duty-on-suvs-hiked-100pct-import-duty-on-luxury-vehicle>. As of December 2014 Malaysia’s applied MFN tariff on lithium-ion batteries stood at 20%.

Table 6. MFN applied tariffs for electric accumulators (storage batteries) used for vehicles for transport (as of the end of 2014 or beginning of 2015)

Country	Electric accumulators, including separators therefor, whether or not rectangular						Electrical capacitors, fixed, variable or adjustable (pre-set)
	Lead-acid, of a kind used for starting piston engines	Other lead-acid accumulators	Nickel-cadmium	Nickel-metal hydride	Lithium-ion	Other accumulators	
HS code:	8507.10	8507.20	8507.30	8507.50	8507.60	8507.80	8532
Argentina	18%	18%	18%	18%	18%	18%	16%
Australia	5%	5%	5%	5%	5%	5%	0%
Brazil	18%	18%	18%	18%	18%	18%	16%
Canada ²	0%	0%	0%	0%	0%	0%	0%
Chile	6%	6%	6%	6%	6%	6%	6%
China	10%	10%	10%	8% ³	6% ³	12%	0%
EU	3.7%	3.7%	2.6%	2.7%	2.7%	2.7%	0%
India	10%	10%	10%	10%	10%	10%	0%
Indonesia	10%	10%	10%	10%	10%	10%	0%
Israel	12%	12%	12%	12%	12%	12%	0%
Japan	0%	0%	0%	0%	0%	0%	0%
Korea	8%	8%	8%	8%	8%	8%	0%
Malaysia	20-25%	20-25%	20%	20%	20%	20%	0%
Mexico	15%	15%	0%	0%	0%	0%	0%
New Zealand	5-10%	5%	5%	5%	5%	5%	0%
Norway	0%	0%	0%	0%	0%	0%	0%
Pakistan	35%	20%	10%	10%	10%	10%	10-25%
Philippines	15%	15%	3%	5%	5%	5%	0%
Russia	5%	3-5%	5%	0%	0%	0%	5%
South Africa	5%	0%	0%	0%	0%	0%	0-15%
Switzerland	————— CHF 29 per 100 gross kilogramme ¹ —————						0%
Thailand	10%	10%	10%	10%	10%	10%	0%
Turkey	3.7%	3.7%	2.6%	2.7%	2.7%	2.7%	0%
United States	3.5%	3.5%	2.5%	3.4%	3.4%	3.4%	0%
Viet Nam	20-25%	20-25%	20%	0%	0%	0%	0%

1. Assuming a range of weights between 45 and 100 kilogrammes per battery pack, and border prices of at least CHF 1000 per battery pack, these specific-rate duties translate to a maximum of CHF 29 per battery, or no more than 3% on an *ad valorem* basis.

2. Tariff rates shown pertain only to accumulators for use as the primary source of electrical power for electrically-powered vehicles of subheading 8703.90.

3. Relates to tariffs applied specifically to batteries for use in electric vehicles; higher tariffs are applied to batteries intended for other uses.

Source: Market Access Database.

Observations on trade and environmental effects

This paper finds that many OECD countries, and an increasing number of non-OECD countries, are making extensive use of incentives to promote the electrification of road transport. Most of the targeted measures either involve incentives for the purchase of PHEVs or BEVs, or are aimed at promoting the production of such vehicles and associated batteries. While a few countries have announced nation-wide targets for the share of electricity in the energy used for transport, or for the share of electric vehicles in the total private-vehicle fleet, these targets are for the most part only aspirational. There are no government-mandated (i.e., compulsory) numbers or percentages of electric vehicles that have to be sold or purchased, except in some places for government fleets. This is in contrast with measures governments use to promote renewable energy, where strong targets for market penetration (e.g., the share of electricity generated) are common.

Charging excise taxes (and, in a few countries, additional carbon taxes) on liquid transport fuels clearly reduces the relative operating costs of fully or partially electrified vehicles. However, because of their higher up-front capital costs, the exemption from such taxes (so far) on electricity used for propulsion is not generally sufficient to tip the balance towards EVs. Accordingly, governments have provided additional purchase incentives in the forms of grants, tax credits, and exemptions from various taxes normally levied on the purchase price of new vehicles (e.g., VAT, or taxes levied according to weight class or size of the engine). In addition, many governments have subsidised the installation of charging points, and a few have extended miscellaneous benefits, such as free parking, to operators of all-electric vehicles. Government procurement has also played an important role in stimulating demand, especially in the uptake of all-electric vehicles, which are increasingly being used for light duty tasks, such as mail delivery.

The effect on trade of these various policies is likely to have been positive, where no barriers to imports of HEVs or electric vehicles exist. However, such barriers are not uncommon. In particular, import tariffs of 25% or higher are protecting the domestic markets of a number of countries, including in all of the BRIICS and several of the ASEAN countries that assemble or manufacture automobiles. This increases the chance that “market-pull” policies in these countries will mainly benefit domestic suppliers and likely lead to higher overall costs in those countries.

Local-content requirements are a feature in several non-OECD countries, particularly in Asia. These are typically tied to reductions in the excise or luxury taxes normally applied to passenger vehicles, or to purchase subsidies. From the evidence so far, the schemes with local-content requirements have not boosted the market shares of HEVs or PEVs to anywhere near the levels seen in countries with liberal import policies. The uncertainties generated by frequent changes in the policy settings — such as Malaysia’s recent decision to narrow the eligibility of tax exemptions on purchases of HEVs and electric vehicles to locally assembled vehicles — also risk slowing down the rate of market penetration that these vehicles heretofore experienced.

The technology-push policies that countries have adopted appear to be related in part to their technological capacities. Most OECD countries have extensive research, development and demonstration (RD&D) programmes relating to advanced vehicles that they carry out either on their own or in co-operation with other countries. Developing and emerging countries that are unable to invest in RD&D at the early stages of technological development (before their potential competitors) typically provide incentives for foreign companies to set up production within their borders in order to encourage the transfer of technological know-how. In addition, many governments, both in the OECD and among the larger emerging economies, provide assistance to companies that set up facilities to manufacture electric vehicles or advanced batteries. The forms of assistance involve all manner of instruments, ranging from grants and tax holidays to government loan guarantees. In some countries an additional large infusion of assistance was channelled to manufacturers through various economic stimulus packages created in the

wake of the 2008-09 financial and economic crisis. Other assistance packages, especially those provided by sub-national governments, are funded through general economic-development policies. The technology-push policies are often accompanied with market-pull policies to improve the market environment and support the scaling up of the market especially when pervasive market-externalities exist.

The general trade effects of technology-push policies, as described by Bahar *et al.* (2013), apply equally to electric vehicles and batteries as to other high-tech sectors:

Market-push policies such as government support for research and development, can provide a benefit for domestically established firms, but the spill-over knowledge it generates can also benefit suppliers elsewhere, depending on the stage of technological development. Support provided to domestic manufacturing may promote learning by doing, but can also distort trade by reducing the manufacturers' costs and improving their competitive position vis-à-vis foreign manufacturers. If substantial, and the country is a major producer, such support can also end up depressing world prices. In the short run, this benefits consumers of the technologies ..., but it can also precipitate the closure of non-subsidised manufacturers.

Government assistance to manufacturers is more clearly linked to trade outcomes, through exports or import substitution. Incentives for investment in manufacturing of EVs and batteries may lower the market price of these goods on the domestic market, but usually not by the full amount of government support as some of the support will be captured by the producers in the form of super-normal profits. Whether and how trade is affected depends on the particulars of each scheme and the relevant market. The automotive industry's extensive and dispersed global supply chains means that support for a plant that assembles electric vehicles, for example, may lead to increased imports of batteries and other components. How much foreign firms can benefit from other countries' support for manufacturing will largely depend on the characteristics of the supply chain of the products in question. In both cases, a trade impact may occur through lower-than-otherwise imports of the finished product.

Concluding remarks

Compared with many renewable-energy technologies, the market size for electric vehicles and batteries is still relatively small, and many of the technologies are still undergoing rapid change. However, there are a number of major producers of vehicles that are either starting to enter the market or are planning to, which means that inter-firm and international rivalry on the supply side can be expected to increase. In order to avoid future trade frictions, and enable consumers to benefit from the expanded choice engendered by such competition, it is incumbent on countries that are Members of the WTO to avoid adopting policies that contravene the principles of national treatment and non-discrimination.²⁴ Concretely, this means eschewing subsidies contingent, whether solely or as one of several other conditions, upon the use of domestic over imported goods. Countries that are applying high import tariffs on imported electric vehicles may also benefit from following the example of Pakistan by reducing such tariffs unilaterally.

Ensuring that domestic-incentive policies are compatible with WTO subsidy rules is just as important for hybrid and electric vehicles as it is for other goods. Full transparency on domestic incentives, including through the WTO subsidy-notification process, would be helpful both in keeping trading partners informed and in promoting best practice in the use of domestic incentive measures.

²⁴ Especially important are Articles III:4, III:5, and XXIII:1 of the General Agreement on Tariffs and Trade (GATT), Articles 3.1(b) and 3.2 of the Agreement on Subsidies and Countervailing Measures (SCM), and Article 2.1 of the Agreement on Trade-Related Investment Measures (TRIMs).

APPENDIX 1. EV-PROMOTION POLICIES IN SELECTED COUNTRIES

Association of South-East Asian Nations (ASEAN)

The member countries of the Association of South-East Asian Nations (ASEAN) — Brunei Darussalam, Cambodia, Indonesia, Lao People’s Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam — produced collectively around 3.4 million vehicles in 2013, approximately equivalent to the output of Germany or India. Indonesia and Thailand were the leading manufacturers, followed by Malaysia, the Philippines, and Vietnam. The other countries produce no or only small numbers of vehicles. In recent years, several of the ASEAN member countries have introduced consumer incentives for what some call “eco-cars” and others “energy-efficient vehicles”. The original focus of these incentives was on smaller vehicles with fuel-efficient engines but some of the incentives have since been expanded to cover HEVs and electric vehicles. In a few countries, the incentives are available only for vehicles manufactured or assembled locally.

A common feature of all the ASEAN countries that aspire to become important manufacturers of automobiles are their high import tariffs. Malaysia and the Philippines apply MFN tariffs of 30%, Cambodia 35%, Indonesia 40%, Viet Nam 70%, and Thailand 80% on imports of passenger vehicles (HS 8703). On completely knocked-down passenger vehicles, Indonesia and Malaysia apply a lower MFN tariff of 10% (0% for some categories of vehicles imported into Malaysia); for completely knocked-down vehicles, Vietnam applies tariffs according to the duty rate of each part or accessory of the vehicle. By contrast, Brunei and Singapore apply MFN import tariffs of 0% on passenger vehicles, whether the vehicles are completely knocked down (unassembled) or completely built up (assembled).

Free-trade agreements both among the ASEAN members and between other countries and ASEAN as a region or with its individual members have reduced average import tariffs on automobiles and components. By establishing AFTA (ASEAN Free Trade Area), the region has reduced tariffs on the overwhelming majority of goods traded within AFTA, including automobiles and components, to a level of between 0% and 5%; full liberalisation of tariffs is scheduled to take place on 1 January 2015. The Agreement on Comprehensive Economic Partnership among Japan and Member States of the Association of Southeast Asian Nations, signed in March 2008, affords Japanese car companies doing business in the region preferential tariff treatment on auto parts in most or all of the four vehicle-producing countries.²⁵ However, some of the free-trade agreements signed with ASEAN do not extend to automobiles. ASEAN’s free-trade agreement with China, for example, contains exemption clauses for automobiles (Heymann, 2011).

Indonesia

Indonesia, the world’s fourth most populous nation, is also a growing manufacturer of and market for automobiles. In June 2013, the central government issued the Low Emission Car Project Decree (LECPD), which exempts cars that can run more than 28 kilometres on a single litre of fuel (equivalent to 3.57 litres per 100 km) from the luxury tax (Ball, 2013). (Cars that can run 20 to 28 km on a litre of fuel benefit from a 50% reduction in the tax.) Only cars that cost less than IDR 100 million (USD 10 200) qualify for the

²⁵

<http://www.mofa.go.jp/policy/economy/fta/asean/annex1.html>

incentive, however. And, in order to be eligible for the incentive, the vehicles must have been manufactured in Indonesia. This tax reduction is expected to benefit mainly very small ICE vehicles, though in theory it could also benefit low-speed electric vehicles. In 2012, the Government set itself a target for the country to begin the mass production of electric automobiles in 2014 (Tampubolon, 2012). The electric car programme forms part of the Government's efforts to promote fuel-saving vehicles in order to significantly reduce State subsidies for petroleum-based transport fuels.

Malaysia

In its 2011 budget, the *Malaysian* Government granted a full exemption on import tax and a 50% reduction in excise duty for HEVs and PHEVs with 2.0 litre or smaller internal-combustion engines; the incentives were extended again until the end of 2013 in its 2012 budget. Malaysia's third National Automotive Policy (NAP), launched in January 2014, exempted all excise duties and taxes on domestically assembled hybrids until 31 December 2015 and until 31 December 2017 for BEVs (Mohamed, 2014). Currently, the only company that benefits from this policy is Honda Malaysia — 34% owned by the DRB-Hicom Group²⁶ — which assembles completely knocked-down (CKD) versions of its Jazz hybrid-electric passenger car. The ending of the duty preferences on imported completely built-up hybrid vehicles subjects them to an import duty of 30% and excise duties of between 65% and 105% (depending on the engine displacement of the car). In 2013, almost 19 000 HEVs were sold in Malaysia, accounting for 2.85% of total vehicle sales. In the case of the German manufacturer, Audi, its A6 Hybrid made up 61% of the cars it sold in Malaysia during that year. With the change in policy, the purchase price of an A6 Hybrid is expected to increase by around 25% (Say and Mahalingam, 2014).

In addition to consumption incentives, the Malaysian Government has also offered incentives for the domestic assembly or manufacture of hybrid-electric and battery-electric vehicles and components. Companies that assemble or manufacture such cars can be given "Pioneer Status", which means that they would then be eligible for a 100% exemption from corporate income tax for 10 years, and a 100% investment tax allowance on qualified capital expenditure incurred within the first five years. Licenses to assemble automobiles are not automatically granted, however. Companies that manufacture "critical" or "high value-added" parts and components supporting the manufacturing of hybrid or battery-electric vehicles (including electric motors, electric batteries, and battery management systems) can also qualify for Pioneer Status and hence benefit from tax exemptions and credits similar to those afforded to licenced HEV and PEV assemblers and manufacturers. To be eligible for the incentives applying to parts and component manufacturers, a company had to submit its application to the Malaysian Investment Development Authority (MIDA) by 31 December 2014.²⁷

Philippines

The *Philippines* hopes to have one million electric vehicles on the road by 2020, a dramatic increase from the approximately 500 electric vehicles — mostly electric tricycles (E-trikes) and E-jeepneys — operating in the country as of early 2014 (Santos, 2014). Most of these were manufactured locally following the granting in 2012 of a USD 400 million loan by the Asian Development Bank that is intended to facilitate the replacement of 100 000 municipally owned petroleum-powered tricycles with electric ones and to reinvigorate the Philippine's infant electric-vehicle industry (ADB, 2014). The 2020 forecast expects the number of E-trikes to reach 350 000 and electric jeepneys 50 000, with the remaining 600 000 being electric cars.

²⁶ DRB-HICOM also assembles ICE-vehicles for Honda, Isuzu, Mercedes-Benz, Suzuki, TATA Motors, and Volkswagen.

²⁷ <http://www.mida.gov.my/env3/index.php?page=manufacturing-sector-2>

In order to help domestic manufacturers, the Government created special, 0% tariff lines for “components, parts and/or accessories, imported from 1 or more countries for assembly of motor vehicles by participants in the Motor Vehicle Development Program with certificate from BOI [Philippine Board of Investments] for the assembly” of electric vehicles, hybrid-electric (with gasoline or diesel fuel) vehicles, flex-fuel (bioethanol or biodiesel) vehicles, compressed natural gas (CNG) vehicles, or vehicles powered by hydrogen or another alternative fuel. No government incentives are currently offered for the private purchase of electric vehicles, but the Electric Vehicle Association of the Philippines (EVAP) recently called on the government to pass legislation that would “grant fiscal incentives such as exemption from excise tax and lowering of import tax, as well as non-fiscal incentives such as preference in vehicle registration and parking, setting up of a green lane, and exemption from number coding” (Santos, 2014).

Singapore

A recent analysis of four types of vehicles that might be used as taxis in densely-populated *Singapore* concluded that BEVs could provide an effective means for reducing GHG emissions from its transport sector (Reuter et al., 2014). However, mild hybrid-electric vehicles running on compressed natural gas seem to be a very practicable, near-term solution for mobility, also with low life-cycle GHG emissions.²⁸

Singapore has nonetheless been cautious in its embrace of electrified transport. In June 2011 the country’s Energy Market Authority and its Land Transport Authority co-lead a multi-agency EV Taskforce to assess different electric-vehicle prototypes and charging technologies to determine their feasibility in Singapore. Among other results, the programme led to the installation of over 100 public and private charging stations, including three quick-charge stations, installed around the city-state (Watts, 2014). Uptake of electric vehicles has been slow, however. A SGD 20 000 (USD 16 000) offset against a car’s Additional Registration Fee (ARF), which increases progressively with the original manufacturer’s value, is available on vehicles that emit no more than 100 grams of CO₂ per kilometre; cars with high carbon emissions incur a corresponding ARF surcharge (Singapore Land Transport Authority, 2014). The semi-annual road tax also favours electric over petroleum-powered vehicles. However, remaining taxes on electric vehicles, which do not differentiate between purely electric and other low-emissions alternatives, make electric vehicles among the most expensive options on the Singapore market. For example, an electric vehicle selling for around SGD 88 000 (USD 70 000) before taxes would cost roughly twice that amount once taxes are added.

Thailand

Thailand, which suffers from high levels of urban air pollution, could achieve a small reduction in energy consumption in the transportation sector, and a 14% reduction in GHG emissions from Thailand’s road transport by 2030 (compared with 2008 emissions), according to a recent analysis by Saisirirata et al. (2013). Already, several domestic companies, such as Electric Vehicles (Thailand) Co., Ltd. (www.evthai.com) and Clean Fuel Energy Enterprise Co., Ltd. (www.c-fee.com), sell a wide range of light, open-sided, all-electric vehicles (sometimes called electric rickshaws) with top speeds of around 35 to 50 kilometres per hour. These are currently used mainly by resorts and on non-urban roads.

Thailand’s main policy for promoting cleaner vehicles is its Eco-Car programme, the first phase of which was introduced in 2007. Under the programme, differentiated excise taxes were introduced for vehicles depending on their engine’s displacement capacity and what kind of fuels they use (Table 7). Hybrid-electric vehicles, fuel-cell vehicles and battery-electric vehicles not exceeding 3 000 cubic centimetre (cc) engine displacement were assigned an excise tax rate of 10%, compared with up to 50% for

²⁸ The analysis covers emissions during the manufacturing processes and considers also upstream emissions from fuel and electricity production.

a comparable gasoline-powered passenger car, or 20% for a passenger-carrying pick-up truck with a displacement of less than 3 250 cc. The actual applied excise tax (AET) is not the same as the published rate (ETR) but is calculated according to the following formula:

$$\text{AET} = \text{ETR} / (1 - (1.1 * \text{ETR})), \text{ where the ETR is expressed as a decimal.}$$

Table 7. Excise tax rates on new passenger vehicles in Thailand, as of January 2015

Car category	E20-compatible vehicles ¹		Other cars	
	Excise rate	Effective excise rate	Excise rate	Effective excise rate
Normal, gasoline-powered cars	25-50%	34.5-111.1%	30-50%	44.8-111.1%
Eco-Cars				
— Hybrid, fuel-cell and BEVs	10%	11.2%	10%	11.2%
— < 1300 cc and Eco-Car approved	17%	20.9%	17%	20.9%
— Natural-gas-powered vehicles	not applicable	not applicable	20%	25.6%

1. Vehicles capable of running on gasoline fuel blends containing up to 20% ethyl alcohol (ethanol) by volume.

2. Ranges correspond to engine displacement and HP rating, with the highest values corresponding to vehicles with 3-litre or greater engines and greater than 220 HP.

Sources: Thai Visa Forum (www.thaivisa.com/forum/topic/435479-taxes-on-cars-in-thailand/) and Thailand Excise Department (<http://www.excise.go.th/home/index.htm>).

Because of the manner in which excise taxes on automobiles are applied in Thailand, however, the difference in total tax burden between a domestically produced and imported Eco-Car can be significant. Domestically produced cars are charged excise tax based on the ex-factory price of the vehicle, an interior tax (10% of the excise tax), and VAT (7% of the total of the ex-factory price, excise and interior tax, and the dealer's margin). Imported vehicles are first charged an import duty of 80%, and then the other taxes are charged in addition on the basis of the C.I.F. price plus import duty. The cumulative effect of the different taxes can raise the retail price of an imported HEV by 68% above the price of its domestic equivalent (Table 8).

Effective 1 January 2016, Thailand will move to a new structure for its excise taxes on vehicles that takes into account CO₂ emissions (Admin, 2014). For non-hybrid sedans and other vehicles with no more than 10 seats, a cylinder capacity of no more than 3 000 cc and CO₂ emissions of no more than 150 grams per kilometre (gCO₂/km), a 30% excise tax will apply. The tax will be 35% if vehicular emissions are between 150 and 200 g CO₂/km and 40% if they exceed 200 gCO₂/km. The rates are reduced by five percentage points for automobiles using E85 or natural gas. Hybrid-electric cars with a cylinder capacity of no more than 3 000 cc and emitting no more than 100 gCO₂/km will be taxed at 10%. The tax rate is doubled, to 20%, if the vehicle's emissions are between 100 and 150 gCO₂/km, 25% if its emissions are within the 150-200 gCO₂/km range, and 30% if its emissions exceed 200 gCO₂/km. As is the case currently, much lower excise-tax rates will apply to pick-up trucks — ranging from 3% for trucks with no space behind the driver to 15% for the largest, double-cab pick-up trucks, even those emitting more than 200 gCO₂/km.

Table 8. Comparison of retail prices for domestically produced and imported hybrid-electric vehicles sold in Thailand, local currency units

Example	Ex-Factory price or C.I.F. price	Import duty = 80% of column a	Excise tax, at an effective rate of 11.24% of columns a + b	Interior tax = 10% of column c	Dealers' profit = 20% of column a	VAT = 7% of the sum of columns a through e	Retail price = sum of columns a through f
	(a)	(b)	(c)	(d)	(e)	(f)	
Small, B-segment HEV							
— Domestically produced	565 000	—	63 483	6 348	113 000	52 348	800 180
— Imported	565 000	452 000	114 270	11 427	113 000	87 899	1 343 595
Luxury, C-segment HEV							
— Domestically produced	1 271 000	—	142 809	14 281	254 200	117 760	1 800 050
— Imported	1 271 000	1 016 800	257 056	25 706	254 200	197 733	3 022 495

Sources: • **Domestically produced:** Thai Visa Forum (www.thaivisa.com/forum/topic/435479-taxes-on-cars-in-thailand/);
• **Imported:** OECD Secretariat calculations.

Thailand's Eco-Car programme is also attempting to stimulate local production. Phase Two of the programme was unveiled in October 2013.²⁹ Eco-Cars produced for the domestic market must: consume no more than 4.3 litres of fuel per 100 kilometres, comply with the Euro 5 standard (UNECE Reg.83(06) Rev.4 or higher), and emit no more than 100 gCO₂/km. Various passenger-safety standards also apply. Qualifying applicants to the programme benefit from an eight-year exemption on corporate income tax, exemptions of import duty on machinery, and up to a 90% reduction of import duties on raw materials and essential parts for a period of two years (TBOI, 2013). Applicants for the incentives had to propose an integrated package by 31 March 2014 that involves vehicle assembly, engine manufacturing and car-part manufacturing or sourcing, and a minimum investment, excluding cost of land and working capital, of THB 6.5 billion (USD 200 million), or THB 5 billion (USD 160 million) for companies already participating in the Eco-Car 1st Generation scheme. Actual production must reach at least 100 000 units a year from the fourth year onwards and would have to start by 2019. At least four out of the following five engine parts, as well as the process of manufacturing them, must be included in the project: cylinder head, cylinder block and crankshaft. Because one of the criteria relates to producing the components of a vehicle's internal combustion engine, BEVs would not qualify. In the event, the investment-promotion scheme attracted 10 carmakers, committed to making a total investment value of THB 138.9 billion (USD 4.3 billion) with an expected production capacity of 1.5 million units (TBOI, 2014). Whether any of the vehicles will use hybrid-electric technologies remains to be seen.

Thailand has not ignored the production of components for HEVs and PEVs either. In 2012 it began offering eight-year exemptions from corporate income tax (with a cap) for investment in the manufacture

²⁹ The first phase of the programme secured investments of THB 28.8 billion (around USD 900 million) and a combined annual production capacity of 635 000 units from five vehicle manufacturers: Honda, Mitsubishi, Nissan, Suzuki, and Toyota (Malaysia Automotive Institute, 2014). None of those vehicles were PEVs or HEVs.

of vehicle parts involving advanced technologies, including batteries for HEVs, PHEVs, and BEVs, as well as traction motors “for automobiles such as hybrid or fuel-cell cars” (Kaewsang, 2013). Producers of these and other qualifying products can extend the number of years of exemption from corporate income tax depending on the share of R&D expenditures in their total revenues (Table 9).

Table 9. R&D expenditure requirements for extending the period of exemption from corporate income tax in Thailand¹

Share of R&D expenditures in total revenues	Alternative spending minimum (THB millions)	Alternative spending minimum (USD millions)	Years of additional exemption from corporate income tax	Cap on exemption?
1%	150	4.65	1	Yes
2%	300	9.30	2	Yes
3%	450	14.95	3	No

1. Available only to industrial activities in Group A1, A2, and A3 (as designated by the Thailand Board of Investment's classification).

Source: Kaewsang, 2013.

In the Formulation of its Five-Year Investment Promotion Strategy for 2015-2019, Thailand's Board of Investment has given priority to strengthening the automotive supply chain “by promoting the manufacture of engines, high-tech auto parts and auto parts for new automobile models (*hybrid and electric vehicles*) as well as important supporting industry — e.g. the manufacture of machinery, metal products and parts”, and co-ordinating with other agencies “to create new automotive product champion[s] — e.g. *electric vehicles*, large-sized motorcycles.” (Asawachintachit, 2013; emphasis added)

Canada

Canada's automotive industry is integrated with the U.S. industry, providing components for EVs manufactured by Chrysler, Ford, and General Motors. In addition, Canada is home to several independent manufacturers of electric utility vehicles and of conversion kits for existing internal-combustion vehicles (e.g., the Volkswagen Beetle and the Ford Ranger). In 2010, Natural Resources Canada (NRCAN), in collaboration with industry and other government agencies, released an EV technological roadmap (evTRM), which envisages 500 000 or more electric vehicles on Canadian roads by 2018. The evTRM identified a number of strategic initiatives needed to support that target, including research into improved energy storage and other components for EVs and efforts to increase public awareness and education.

Market-pull policies

At the federal level, the government applies a “green levy” on all new and imported used passenger vehicles (cars, sport-utility vehicles (SUVs) and vans) put into service after 19 March 2007, according to their weighted-average fuel consumption.³⁰ This levy ranges from CAD 1000 for vehicles with a fuel consumption of 13.0-13.9 litres per 100 kilometres to CAD 4000 for those that consume 16 litres or more per 100 kilometres. This levy acts as a disincentive to the purchase of vehicles with poor fuel economy and thereby indirectly favours purchases of fuel-efficient vehicles, including HEVs and PEVs.

³⁰

<http://www.riv.ca/CostConsiderations.aspx>.

The federal government also operates several outreach and education programmes related to electric vehicles.³¹ For example, since 2012 NRCan has participated in the AJAC Eco Run Challenge, which demonstrates a broad spectrum of fuel-efficient vehicle choices, including HEVs, PEVs and cars using advanced conventional technologies.³² During the annual International Auto Show in Toronto, Ontario, it provides information to visitors and answers questions about fuel consumption values reporting for all types of vehicles. NRCan also presents the annual Most Fuel Efficient Vehicle Awards to showcase the most fuel-efficient vehicle in each class.³³ And, in collaboration with the Canadian Automobile Association (CAA), NRCan has created a calculator that shows consumers how much they can save on operating costs, and with CrossChasm to develop an application that provides a listing of all charging stations in Canada (<http://electricvehicles.caa.ca/>). In addition to these efforts, Canada's ecoTECHNOLOGY for Vehicles (eTV) Programme provides educational material on a dedicated website.³⁴

Under its guidelines for implementation, the federal-government's Policy on Green Procurement³⁵ recommends hybrid-electric vehicles and fully electric vehicles (among vehicles that use alternative fuels) under "Vehicles used for Personnel Transportation and/or Service Delivery".³⁶ In the fiscal year ending 31 March 2012 (the latest year for which data are available), the federal government acquired 47 hybrid gasoline-electric vehicles among the 3 707 vehicles it acquired in total (Treasury Board of Canada Secretariat, 2012).

Purchase incentives for PEVs are offered by two provinces in Canada.³⁷ Since 1 July 2010, residents of Ontario have been eligible for a rebate ranging from CAD 5000 to CAD 8500 on the purchase or lease of a new, highway-capable, plug-in hybrid electric or battery-electric vehicle.³⁸ Quebec's Drive Electric Programme provides rebates on PEVs ranging from CAD 4000 to CAD 8000. In each province, the amount of the rebate is calculated according to the capacity of the vehicle's electric battery; total applicants are limited to 10 000; and the vehicle must be included on the list of eligible vehicles.³⁹ Québec in addition

³¹ <http://canmetenergy.nrcan.gc.ca/transportation/hybrid-electric/2620>; See also <http://oee.nrcan.gc.ca/node/6680>

³² <http://www.ajac.ca/eco-run/background.asp>

³³ <http://oee.nrcan.gc.ca/cars-light-trucks/buying/most-efficient-vehicles/17257>

³⁴ <http://www.tc.gc.ca/media/documents/programs/EN-EV-Primer.pdf>

³⁵ Paragraph 3 of Canada's Alternative Fuels Act (S.C. 1995, c. 20) specifies that, from 1999, "where it is cost effective and operationally feasible, seventy-five per cent of motor vehicles operated by all federal bodies and Crown corporations will be motor vehicles operating on alternative fuels" (<http://laws-lois.justice.gc.ca/eng/acts/A-10.7/page-1.html>). Alternative fuels are defined as "including, without limiting the generality of the foregoing, ethanol, methanol, propane gas, natural gas, hydrogen or *electricity* when used as a sole source of direct propulsion energy." (Emphasis added.)

³⁶ <http://www.tpsgc-pwgsc.gc.ca/ecologisation-greening/achats-procurement/eas-gsp-eng.html#a1>

³⁷ Several additional incentives were available until recently. Prior to 1 April 2013, the Province of Prince Edward Island offered a rebate on personal revenue tax of up to CAD 3000 on hybrid vehicles purchased or leased between 30 March 2004 and 31 March 2013. From 1 December 2011, the Province of British Columbia's *LiveSmart BC* programme also offered rebates (of up to CAD 5000) on the purchase of an eligible PEV, fuel-cell-powered vehicle or compressed natural gas vehicle; but the programme exhausted its funds (CAD 14.3 million) as of February 2014.

³⁸ <http://www.mto.gov.on.ca/english/dandv/vehicle/electric/electric-vehicles.shtml>

³⁹ See, respectively, <http://www.mto.gov.on.ca/english/dandv/vehicle/electric/ev-vehicle-list.shtml> and <http://vehiculeselectriques.gouv.qc.ca/english/rabais.asp>

offers a CAD 500 rebate on the purchase of an HEV⁴⁰, and a CAD 1000 rebate on the purchase of a low-speed electric vehicle authorised to operate on Québec roads.⁴¹

Currently, there are no incentives in Canada for installing charging stations. Until the end of 2013, Ontario offered a grant of up to CAD 1000, or 50% of the total purchase and installation cost (whichever was lower), to be applied to eligible Level 2 charging stations. In British Columbia, rebates of up to CAD 500 per eligible electric vehicle charging station were available to B.C. residents who owned or leased a PEV that was eligible for a Clean Energy Vehicle Program point-of-sale vehicle incentive (see note 19); the funds were exhausted, however, in March 2014. In addition, for a brief period during 2013, property owners of multi-unit residential buildings and mixed-use residential buildings could apply through the *LiveSmart BC* programme for grants covering 80% of the eligible costs (up to CAD 4500 per station) of procuring and installing an electric vehicle charging station.

Technology-push policies

Canada's main technology-push policies are funded through its Automotive Partnership Canada (APC) programme. The programme brings together research entities and industry to fund several projects related to EVs; total funding during the four years through 31 March 2013 was CAD 27 million. Renewed funding of CAD 18.1 million was provided for a five-year research project being carried out by a team at McMaster University working in collaboration with Chrysler Canada. The project is focussing on developing the next generation of electrified powertrains.

Outcomes

Canada experienced 54% year-on-year growth in its PEV sales in 2013, and a doubling in 2014. In total, around 10 000 PEVs (excluding low-speed vehicles) had been registered in Canada as of the end of 2014. Hundreds of public recharging stations, mainly Level 2, had been installed, from Vancouver Island to Newfoundland. An electric vehicle can now drive across Canada following more than 7000 km of the Trans-Canada Highway, from Victoria, British Columbia almost to St. Johns, Newfoundland, and be assured of having access to a public battery-recharging station.

China

China has made a major push toward electric vehicles in manufacturing, technology development, and the creation of consumer incentives. Given the country's heavy reliance on coal for electricity supply, the main environmental benefits for China could be slightly cleaner air in some cities, and a reduction in noise pollution. However, according to a recent analysis by Ji *et al.* (2012), replacing gasoline cars with electric vehicles in China with its current electricity supply mix would result in higher CO₂ emissions and increased mortality risk from PM_{2.5} in most Chinese cities. The Chinese government views a shift to electric vehicles to be beneficial to China's energy security as well. In its "Energy-Saving and New Energy Automotive Industry Development Plan for 2012-2020, the State Council set a target for "pure electric vehicles and plug-in hybrid electric vehicle production and sales" of 500 000 a year by 2015, and a domestic production capacity of 2 million by 2020 (Government of China, 2012). The target for cumulative production and sales of all "new energy vehicles" (NEVs) — China's term for electric vehicles and hydrogen-powered vehicles — by 2020 is more than 5 million.

⁴⁰ Only hybrid vehicles registered since 1 November 2013 are eligible for a rebate at the time of purchase. This section of the programme will remain in force through 2016, or until 15 000 rebates for HEVs have been granted.

⁴¹ <http://www.livesmartbc.ca/incentives/transportation/#cevinbc>

Recently, the Chinese government has said that it is considering modifying taxes, including import tariffs, to encourage greater deployment of electric vehicles in the country. However, as of May 2014, the specific details were still under development (China News Network, 2014).

Market-pull policies

The central government has subsidised the deployment of electric vehicles since 2009. On 17 September 2013, China's Ministry of Finance (MoF), together with the Ministry of Science and Technology (MoST), the Ministry of Industry and Information Technology (MIIT), and the National Development and Reform Commission (NDRC) — the “Four Ministries” — jointly issued a new policy aimed at increasing efforts to promote the purchase of NEVs through the year 2015. According to the Notice, the central government will provide, based on certain technical requirements, up to RMB 35 000 (USD 5 600) for the purchase of a plug-in hybrid-electric vehicle, RMB 60 000 (USD 9 700) for an all-electric passenger vehicle, and RMB 500 000 (USD 80 500) for an electric bus.⁴² Originally, the subsidies were to be reduced by 10% in 2014 and by 20% in 2015. However, in February 2014 the envisaged subsidy reductions were revised, to respectively 5% and 10% — i.e., RMB 31 500 and RMB 54 000 for a PHEV and a BEV in 2014. Moreover, the subsidy was raised to RMB 57 000 for BEVs sold in highly industrialised target areas such as the Beijing-Tianjin-Hebei region, the Pearl River Delta region, and the Yangtze River Delta. Crucially, the subsidy payments are being distributed to domestic *manufacturers* (on a quarterly basis) in advance and the subsidies then paid by the manufacturers directly to consumers. The government is also considering waiving the 10% tax on purchases of new PEVs.

In order to be able to enjoy a central-government subsidy, an EV has to be among the models registered on the “Energy Conservation and New Energy Vehicle List” produced by the Ministry of Industry and Information Technology (MIIT). So far, no foreign-made electric vehicles have made it onto the list (Wang, 2013; Murphy and Zander, 2013).

Some local governments in 25 pilot cities also provide matching subsidies on top of the central government subsidies, mostly to support the purchasing of vehicles used for public transportation (e.g. buses and local state-owned taxi companies). It has been alleged that some local governments have imposed “buy local” provisions so that the local EV firms benefit at the expense of other EV companies elsewhere in China and around the world (Zeng, 2013). Starting in 2013, the Chinese government began allowing six cities to experiment with subsidies to individual consumers who purchase EVs (Table 9). In these six cities, the local government can provide purchase incentives on top of those provided by the Central Government. Some municipalities also offer free license plates to owners of electric vehicles. To qualify for the subsidies, minimum battery-capacity requirements apply: at least 10 kWh for a PHEV and at least 15 kWh for a BEV.

With the issuance of the aforementioned Notice by the Four Ministries, the pilot cities and regions now in addition have specific targets to meet, and restrictions intended to reduce the tendency of local and regional governments to favour vehicles made within their own jurisdictions (Kandi Technologies Group, 2013):

⁴² Notice No. 551 of 2013, “Regarding the Continuous Promotion and Application of New-Energy Vehicles for the years from 2013 to 2015”. The Notice required any city interested in becoming a Pilot City submit a detailed “new-energy vehicle promotion implementation plan” and to the Four Ministries by 15 October for their evaluation and final approval. (http://jjs.mof.gov.cn/zhengwuxinxi/tongzhigonggao/201309/t20130916_989833.html).

1. From 2013 to 2015, there shall be at least 10 000 new energy vehicles added cumulatively in each Large Pilot City or Region, and at least 5 000 new energy vehicles added cumulatively in each of other cities or regions.
2. At least 30% of these new energy vehicles shall be non-local brands. Local and regional governments shall not set barriers or disguised restrictions on vehicles from other regions.
3. When procuring new vehicles, government agencies and public organisations shall favour new-energy vehicles. For new or replacement vehicles used in public transportation, by government agencies, or for waste management, at least 30% of them shall be new-energy vehicles.
4. The local government shall have issued specific policies and measures of vehicle purchase, public transportation operation, supporting infrastructure construction, and other aspects for new energy vehicles.
5. The pilot cities are subject to an annual inspection and evaluation. Pilot cities, which fail to complete the annual promotion objectives, will be eliminated from the subsidy programme.

Any city that meets the above requirements can apply to become a pilot city and qualify to receive the subsidies. This policy is expected to expand the geographic area previously covered by policies used to promote new-energy vehicle purchases in China.

Table 10. Maximum municipal-level incentives for electric vehicle purchases in China as of March 2013

Municipality	Plug-in hybrid-electric vehicles (PHEVs)		Battery-electric vehicles (BEVs)	
	RMB	USD	RMB	USD
Beijing	Not available	—	60 000	9 770
Changchun	40 000	6 515	45 000	7 330
Hangzhou	Not known	—	Not known	—
Hefei	Not yet announced	—	Not yet announced	—
Shanghai	20 000	3 260	50 000	8 140
Shenzhen	30 000	4 890	60 000	9 770

Data source: Dr. Wang Lifang of the Institute of Electrical Engineering at the Chinese Academy of Sciences during an interview with Kelly Sims Gallagher, March 2013.

The situation in Beijing is illustrative of both the opportunities and the barriers to greater penetration of electrified vehicles in China's internal market. In order to address traffic congestion and pollution, Beijing's Transport Commission restricts the numbers of licenses granted to new vehicles each year through a lottery system.⁴³ Some 1.84 million Beijing residents applied to license new gasoline-powered vehicles in 2014, more than 10 times the yearly quota, which itself was reduced to 150 000 from the previous quota of 240 000 vehicles in 2013. A separate quota of 20 000 license plates was established for new-energy vehicles in 2014, with half of them available to individuals. During its first bi-monthly round of approvals, announced at the end of February 2014, only 1 428 individuals had applied for the 1 666

⁴³ "Regulation of the number of passenger cars in Beijing Interim Provisions", Implementing Rules (2013 Amendment).

new-energy vehicle plates on offer⁴⁴ (Bloomberg News, 2014). The Transport Commission has said that it will increase the total annual quota to 30 000 in 2015 and to 60 000 in 2016 and 2017. Beijing's plan is for 200 000 new-energy vehicles on the road by the end of 2017 (Li, 2014).

In January 2014, Beijing announced a revised schedule of municipal purchase subsidies for BEVs. These are in addition to the ones available from the central government. Vehicles with a range of 80-150 km qualified for a RMB 31 500 (USD 5 070) subsidy; those rated at 151-250 km for a RMB 45 000 (USD 7 250) subsidy; and those rated at more than 250 km for a RMB 54 000 (USD 8 700) subsidy (Beijing News, 2014).

Inadequate availability of charging points is often cited as a major barrier to greater adoption of PEVs in Beijing. There were about 70 charging stations in Beijing at the end of 2013, most of them serving taxis, buses, and other public vehicles (Wu, 2014). Beijing obliges carmakers to equip each buyer of a PEV with a personal charging point. But in order to do so the buyer must have access to a dedicated parking space, which in Beijing costs on average more than RMB 200 000 (USD 32 000). Moreover, parking spaces are often so far from an owner's electrical box that it is impractical to meet the installation requirements (Wu, 2014). To remedy these problems, the Municipal Government, in co-operation with Beijing Electric Power Company, said it would establish 1000 new charging facilities in the city and nearby suburbs during 2014. Unlike most of the current ones, which are available only to taxis and buses, these would be accessible by private car owners (Luo, 2014). In addition, early in 2015, the state-owned electric utility, State Grid, completed the installation of 50 fast-charging stations (one every 25 km) along a 1260 km route between Beijing and Shanghai; these stations can be used by vehicles produced by the Chinese carmakers BYD and BAIC Motor; Dongfeng-Nissan; and BYD's joint venture with Daimler (Mitchell, 2015).

To sell PEVs in Beijing, carmakers must obtain permission to do so from city officials. The authorities also require that non-local carmakers must be able to respond within 30 minutes in the event that one of their vehicles breaks down. Moreover, they must sell no fewer than 1000 cars within the first two years of being granted permission to sell or risk having their permission revoked. According to Wu (2014), as of March 2014 only two companies had been authorised to sell electric cars in the capital, and six others were awaiting approval.

The U.S. electric car maker, Tesla, plans to be one of the first foreign companies to market electric vehicles in Beijing. As part of that plan, it envisages establishing a network of free charging stations in China, enabling owners of its cars to travel between major eastern cities. In January 2014 it announced it would begin selling its Model S saloon in China at a price starting at RMB 734 000 (USD 120 000) and soon thereafter it began taking orders for its vehicle. Over the course of the year it shipped 4 761 electric cars to China (Murphy, 2015). As of March 2014, even though the Model S is a BEV, it did not qualify for Beijing's fast-track electric-vehicle license. Prospective Tesla customers must therefore apply to obtain a license plate through the normal lottery process, which can involve years of waiting (Perkowski, 2014). Neither are Tesla cars eligible for government purchase subsidies. By contrast, soon after Tesla launched its Model S in China, the City of Shanghai announced that it would waive the cost of its license plates, which would normally be about USD 16 000 per car for a Model S. This makes the Model S more competitively priced than gasoline-powered automobiles from other makers of luxury cars (Dalal, 2014).

During the 22nd Session of the Joint Commission on Commerce and Trade between the United States and China (Chengdu, China, 2011), China asserted that, "It does not and will not require foreign automakers to transfer technology to Chinese enterprises nor to establish Chinese brands in order to invest and sell in China's fast-growing market. China also confirmed that foreign-invested enterprises are eligible on an equal basis for electric vehicle subsidies and other incentive programs for electric vehicles" (USTR,

⁴⁴ That is to say, $1666 = 50\% \text{ of } 20\,000 \times (2/12)$.

2011). Nevertheless, as Murphy and Zander (2013) point out, in late 2012, before he became president, the then Chinese Communist Party chief Xi Jinping called on local officials to “ride in home-grown cars,” adding “it gives a bad impression that Chinese officials ride in foreign brands.”⁴⁵

Technology-push policies

China is already the largest EV bicycle producer and consumer, accounting for approximately 90% of the global market. The Chinese government R&D program for clean, light-duty vehicles initially focused approximately equally on fuel-cell-powered vehicles, BEVs, and HEVs. As of 2008, 970 invention patents had been applied for through the State Intellectual Property Organization (SIPO) based on the research of the Chinese government’s Energy-Saving and New Energy Vehicle Programme (Ouyang, 2009). In its 11th Five Year Guideline (covering the period 2006-10), however, the Government’s emphasis shifted strongly to BEVs. This shift can be attributed to China’s continued weakness in innovative capabilities with respect to conventional automotive internal-combustion technology, as well as a recognition that HEV technology is out of reach due to patents owned by foreign firms. As a result, the Government’s current strategy is to de-emphasise the internal combustion engine and focus on developing EV capabilities.

Along with support for R&D, the Chinese government has embarked on a substantial demonstration programme for electrified cars and buses. For the 2008 Beijing Olympic Games, 595 “new energy vehicles” were used, carrying a total of 4.4 million passengers. The 2009 National Games in Ji’nan also demonstrated 100 new energy vehicles, and the 2010 World Expo in Shanghai demonstrated 1125, including 390 electric passenger vehicles and buses. Prior to 2009, the main demonstration city for EVs was Shenzhen. In 2009, the Central Government began establishing large-scale demonstrations in many more cities, with an emphasis on vehicles used in public transport. The central and local governments both subsidise the purchase costs of these vehicles. The programme goals are to improve the performance of the vehicles, to contribute to cost reduction and additional diffusion, and to industrialise R&D more quickly. Thirteen cities were included in the first batch of demonstration cities in 2009, and twelve new cities were established in 2010.

Outcomes

As of March 2013, there were approximately 28 000 electric vehicles registered in China, of which about 80% were public buses, not including electric bicycles, which numbered 135 million as of 2010 (Jie and Hagiwara, 2013). Since then, the market has boomed. According to the China Association of Automobile Manufacturers, sales of PEVs grew three-fold in 2014, reaching 74 763 units, of which 48 605 were pure electric vehicles and 29 894; all but a few of these vehicles were made locally.⁴⁶

Trade disputes

In the wake of an unrelated dispute with Japan, in 2010 the Chinese government imposed export restrictions on rare earth minerals (as well as tungsten, and molybdenum), which are used as raw-material

⁴⁵ More recently, on 10 July 2014, China’s Ministry of Industry and Information Technology and the U.S. Department of Energy signed a Memorandum of Understanding on Electric Vehicle and Industrial Energy Efficiency Co-operation in Beijing. Under this framework, the two sides commit to conduct co-operation in the fields of electric vehicles and related technologies, as well as on improving the energy efficiency of electrical appliances. See: <http://www.state.gov/r/pa/prs/ps/2014/07/229239.htm>

⁴⁶ Source: <http://www.caam.org.cn/AutomotivesStatistics/20150114/0905144510.html>. These numbers do not include sales of low-speed small electric cars, sales of which are estimated to have been around 200 000 in 2013, as due to safety and environmental concerns the central government does not recognise these vehicles as new-energy vehicles (Xueqing, 2014).

inputs to drive motors for hybrid and electric vehicles.⁴⁷ China imposed three types of restrictions: (i) duties (taxes) on the export of various forms of those materials; (ii) an export quota on the amount of those materials that can be exported in a given period; and (iii) certain limitations on the enterprises permitted to export the materials.⁴⁸ In response, the United States, followed by the European Union and Japan, filed a challenge with the WTO in March 2012 alleging that China's export restrictions were these measures are inconsistent with Articles VII, VIII, X and XI of the GATT 1994 as well as China's obligations under various paragraphs of the Protocol of Accession, and that the effect of these restrictions was to reduce the domestic price for these materials in China, while increasing the price everywhere else since China produces the majority of rare earths. On 26 March 2014, the panel's issued its report, which broadly supported the arguments of the complainants. Both China and the United States subsequently lodged appeals. On 7 August 2014, the Appellate Body issued its findings. Crucially, it found that "the Panel did not err in its reasoning regarding the signals sent to foreign and domestic consumers by China's export quotas on rare earths and tungsten, or in rejecting China's argument that, by virtue of these signalling functions, China's export quotas on rare earths and tungsten 'relate to' conservation." The WTO's Dispute Settlement Body (DSB) adopted the Appellate Body report and the panel report, as upheld by the Appellate Body report, and China agreed to implement the DSB's recommendations and ruling in a manner that respects its WTO obligations.

France

France, an EV manufacturing country, has set an overall target of 2 million registered HEVs and electric vehicles in 2020, with 400 000 public charging points and 4 million private ones. To meet this target, a 14-point plan was devised in 2009 and is being implemented, covering a broad range of market-pull and technology-push measures. These measures concern all the issues related to the deployment of electric vehicles, ranging from RD&D and improving charging infrastructure to public procurement and developing electric car-share systems. Most of the measures detailed below form part of, or result from, this National Plan for the Development of Rechargeable Electric and Hybrid Vehicles.⁴⁹

Market-pull policies

Between 2007 and 2012, a "fee-bate" system (bonus-malus) based on vehicle CO₂ emissions granted up to EUR 5 000 for the purchase of new electric and plug-in hybrid cars (which qualified because they emit less than 60g of CO₂/km), and up to EUR 2 000 for hybrids (emitting between 60g/km and 125g/km). The incentive scheme has since been modified several times; Table 11 shows the situation as of January 2015. In addition, electric cars are exonerated from the tax on company cars.

⁴⁷ The specific rare earth of concern was neodymium which, when alloyed iron and boron to form a Nd₂Fe₁₄B tetragonal crystalline structure, produces the strongest type of permanent magnet commercially available. The electric motor of each Toyota Prius requires approximately one kilogramme of neodymium.

⁴⁸ http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds431_e.htm

⁴⁹ http://www.developpement-durable.gouv.fr/IMG/pdf/dossier_de_presse_vehicules_ecologiques.pdf

Table 11. Bonuses for purchasing or leasing a low-carbon-emitting vehicle in France as of January 2015

Emissions (CO₂/km)	Amount of bonus
Less than or equal to 20 grammes	27% of the purchase cost (VAT included), and eventually the cost of the battery if it is leased, up to a limit of EUR 6 300
Between 21 and 60 grammes	20% of the purchase cost (VAT included), and eventually the cost of the battery if it is leased, up to a limit of EUR 4 000
Between 60 and 90 grammes	EUR 0 for a vehicle ordered or leased in 2015 EUR 150 for a vehicle ordered or leased before 2015 under the condition that the invoice or the first rental payment, occur before 31 March 2015
Greater than 90 grammes	EUR 0

Source: <http://vosdroits.service-public.fr/particuliers/F18132.xhtml>

Some local authorities are providing additional financial support to users of electric vehicles through purchase grants. For instance, in Paris the municipality offers a grant of EUR 4 000 for rechargeable hybrid taxis and EUR 7 000 for electric taxis, capped at 20% of the cost of the vehicle. Six French cities also offer grants for the purchase of e-bikes.

The Plan for the Development of Rechargeable Electric and Hybrid Vehicles provides 50% grants to local authorities to help provide a basic charging network in urban areas, for both standard and fast charging facilities. Fast charging points installed in petrol stations can benefit from a 30% grant. The budget for these grants was EUR 50 million in 2013.

France has a significant public-procurement strategy, dating back to the 1990s, when the French government agreed with Renault, PSA, and Electricité de France on a target of 10 000 electric vehicles by 2000. Though this aspirational target was not met, the objective of increasing the share of electric and hybrid vehicles in government fleet renewals has been gradually increased from 10% in 2005 to the current 25%, which was already exceeded in 2013. The central purchasing agency, UGAP, in partnership with the national postal service La Poste organised a group of 20 public and private companies to order a large enough number of electric vehicles from French manufacturers to ensure that costs could be brought down to levels closer to those of conventional vehicles. Bids for some 21 300 vehicles were attributed to several manufacturers who are providing the vehicles between 2012 and 2015. UGAP was able to widen its range of electric vehicles on offer and in 2013 it ordered 13 000 light duty vehicles (Renault Kangoo and Peugeot Ion), as well as 2 000 hybrid Toyota Yaris, and 2 600 Renault and Mia electric cars. Many of these vehicles are being taken up by La Poste, which announced in 2012 its intention to purchase 10 000 electric vehicles by 2015, plus 10 000 e-bikes (Beltramello, 2012).

Technology-push policies

France is providing support for RD&D in electric vehicles, batteries and charging infrastructure through a range of programmes. About EUR 100 million has been allocated as part of a programme devoted to emission reductions and low-carbon vehicles in four innovation clusters: Mov'eo, Id4Car,

Vehicles for the Future, and Lyon Urban Truck and Bus (IFA, 2012). This comes in addition to technology-push programmes launched under the umbrella of the 2009 Plan for the Development of Rechargeable Electric and Hybrid Vehicles, which has channelled substantial support for RD&D in batteries and charging infrastructure. Examples include some EUR 70 million for charging infrastructure demonstration projects as well as several large-scale demonstration for EV fleets in urban areas, notably the western suburbs of Paris and Strasbourg (Finpro, 2010).

Autolib', a municipal car-share system, was created in the Paris area in 2011, using electric Bluecars provided and operated by Bolloré, which also manufactures the lithium metal polymer batteries. Autolib's vehicles (the Bluecar®) are assembled in Turin, Italy by Pininfarina and its lithium-metal polymer (LMP) batteries are produced by Bolloré at factories located in Brittany, France and Boucherville, Québec, Canada. As of April 2014 the number of rentals reached 3.5 million, with 120 000 clients for 2 200 Bluecars, making Autolib' the world's largest electric car-share programme (Holland, 2014). Ultimately the programme will run 3 000 cars for about 1 000 charging stations (each with on average 4-5 charging points). The rationale for Autolib' is first and foremost to provide a large-scale demonstration project for Bolloré electric vehicles and batteries, boosting production to reduce costs, improving reliability and attracting new customers. In addition, it is hoped that Autolib' could reduce traffic and congestion by removing as many as 22 000 conventional cars, though it is not yet clear how many Autolib' users might have instead used public transport.

The establishment of the Autolib' programme cost EUR 180 million, two-thirds of which were provided by Bolloré which in turn benefitted from a EUR 130 million loan from the European Investment Bank in 2011. The remainder was invested by local and regional authorities, and the State (Xerfi, 2012). The City of Paris's own investment was EUR 35 million, along with a number of parking spaces. Bolloré is paying back the city's investment out of subscription revenues and through a parking space leasing arrangement (Holland, 2014). Public funding was targeted at contributing EUR 50 000 to each charging station (which can be used by all electric vehicles) and any annual operating costs over and above EUR 60 million. Annual operating costs are currently estimated at EUR 80 million, and the scheme is expected to break even at about 80 000 premium subscribers, which could be reached by 2015 — three years ahead of the original schedule.

Outcomes

In 2013, sales of hybrid-electric vehicles grew by 60%, attaining 46 785 units for the year, of which 32 799 had gasoline engines and 13 986 diesel engines; sales of HEVs slumped in 2014, however, to 39 500 (Jacqué, 2015). In addition, 16 222 plug-in electric vehicles were sold in France, of which 15 045 were BEVs (among which 491 Twizy electric quads and 4 485 utility vehicles) and 1 177 PHEVs.⁵⁰ France accounted for around 7% of global sales of PEVs in the same year. The development of the Autolib car share system represented a large part of the increase in sales of electric vehicles in 2012, but for just 7% of country-wide sales in 2014. By the end of 2014 the total number of HEVs and EVs registered in the country is estimated to have reached around 250 000.⁵¹

Germany

Germany, which has Europe's largest car industry, is a relative late-comer to the EV market, in terms of both supply and uptake. Though some manufacturers, notably Daimler, have operated R&D programmes relating to EVs for several decades, significant policy support for the promotion of EVs was

⁵⁰ <http://ev-sales.blogspot.fr/2015/01/france-december-2014.html>

⁵¹ Authors' estimate, extrapolating from www.france-mobilite-electrique.org/les-ventes-de-voitures-electriques-en-france.291.html

set in motion in 2007 by Germany's climate-change strategy (BMUB, 2007). In August 2009, the Federal Government set a target of one million electric vehicles on the road by 2020 as part of its National Electromobility Development Plan for the decade ahead (BMVI, 2009). The plan's objective is to ensure that Germany takes the lead in electric mobility by strengthening the technological capabilities of its vehicle manufacturing industry and supporting the development of a market for EVs.

A major characteristic of Germany's strategy to promote EVs is the emphasis on collaboration between government departments, within the private sector and through public and private forums, to foster co-ordination across all aspects of electric mobility.⁵² The most important of these forums is the National Platform on Electromobility (NPE), a partnership created in 2010 as a 150-member group of energy, information and communications technology, and automotive industry representatives, as well as researchers, academics and NGO representatives (NPE, 2011). The platform acts as a framework for public-private co-operation, designing and promoting strategies to meet the target of one million electric vehicles through the government's National E-Mobility Programme, launched in 2011 (Bundesregierung, 2011).

Market-pull policies

Since May 2011, EVs have been exempt from annual road tax for ten years from the date of first registration up to May 2015, after which the exemption has been shortened to five years (ACEA, 2013). This represents an annual saving of EUR 300 to EUR 500 for a middle-range car. The private use of a company vehicle is treated as taxable income and taxed at a flat monthly rate of 1% of the vehicle's list price. As a result, EVs were penalised, since their price can be as much as twice that of a conventional car. In June 2013 a law was passed with retroactive effect to 1 January 2013 allowing private users of company cars to offset the list price by EUR 500 per unit of battery size expressed in kWh, with a ceiling of EUR 10 000 (corresponding to a 20 kWh battery) and an annual reduction of EUR 50 per kWh in the amount offset. This measure should help promote the purchase of EVs by corporate customers, which account for about one-third of sales of new vehicles in Germany.

A key measure announced in the National E-Mobility Programme is the introduction of EVs into government car fleets. By 2015, 10% of new government vehicles should emit less than 50g of CO₂ per km, which means that for larger vehicles even HEVs would not meet the limit. Public-procurement budgets for 2014 and 2015 were increased accordingly, to allow for more expensive EVs to be purchased by government departments.

The programme also recommends that EVs be granted special access and parking rights in city centres, though such measures have not yet been introduced. The legal changes necessary are under review by the Federal Government, in co-operation with the Länder. The use of bus lanes or special traffic lanes will be considered in 2015 on the basis of the results of pilot projects underway in several regions and urban areas.

⁵² These include the *Ressortkreis Elektromobilität der Bundesregierung*, an inter-ministerial council bringing together the federal ministries for transport, research, energy, economics and technology, and environment) involved in electric mobility policy; and the *Nationale Plattform Elektromobilität* (NPE), which serves as a forum for all actors in e-mobility to meet and co-ordinate their position. The NPE formulates policy recommendations for the government every two years in its progress reports. Thematic networks have also been established to develop and implement specific strategies, such as a national network for training and education, for the coordination of battery research and the development of long-term scenarios on future e-cities. See Bär (2012).

Technology-push policies

The National E-Mobility Programme covers R&D as well as demonstration and pilot projects. As part of the 2009 Economic Stimulus Package, EUR 500 million of public funding was provided for electric mobility R&D between 2009 and 2011, including EUR 38 million for battery R&D. Most of the initial funding went to large car manufacturers (Hildermeier and Villareal, 2011). A further EUR 1 billion was allocated by the Federal Government to R&D between 2011 and 2013, matched by EUR 3 billion from industry. The automotive industry has pledged to invest EUR 12 billion in alternative drive-train development between 2013 and 2016 (Verband der Automobilindustrie, 2013).

There are two demonstration schemes in the National E-Mobility Programme: regional showcases to test e-mobility in real-life conditions, and technological flagship demonstration projects. Eight test regions chosen in 2008 (Munich, Stuttgart, Rhein-Ruhr, Leipzig-Dresden, Berlin, Bremen-Oldenburg, Hamburg, and Rhein-Main) benefited from EUR 130 million of public funding over four years. For instance, in the Rhein-Main region, 15 demonstration projects between 2009 and 2011 involved 490 EVs, 260 charging stations, a car-sharing system, projects for commercial and delivery vehicles as well as buses, e-scooters and a hybrid train. Many of these projects centred on the city of Frankfurt-am-Main, leading to the adoption by the municipality of an electric mobility plan, with 26 projects covering several aspects of electric mobility, from infrastructure development to marketing and publicity (Roese, 2012).

Funding for the showcases was then concentrated on four largely urban electro-mobility demonstration projects, with public funding of EUR 180 million between 2012 and 2015. These projects emphasise fostering co-operation between EV manufacturers, energy utilities, municipalities and researchers, with user involvement. The four projects are: “Living Lab BW E-Mobil” (Baden-Württemberg), “International showcase for e-mobility” (Berlin and Brandenburg), “Our horse power becomes electric” (Lower Saxony) and “E-mobility connects” (Bavaria and Saxony).

In addition, some 230 flagship demonstration projects have been launched covering a wide range of topics, including linking e-mobility with information and communication technology, mobility concepts, charging infrastructure and grid integration, recycling and resource efficiency, energy systems and storage, and drive-train technologies. Funding for these demonstration projects amounted to EUR 600 million between 2009 and 2013, of which about half has been provided by the automotive industry and energy utilities.

Outcomes

The important position held by the German automotive industry, notably in the premium segment which is considered an important source of technological innovation, is reflected in its ranking among the top global patentees for electric vehicle technologies for several decades, with a marked increase since 2007 (Hasic and Johnston, 2011; Bär, 2013). The last two years have seen a noticeable surge in German manufacturing of EVs, with 12 models from full-electric small cars to medium segment long-distance vehicles and light commercial vehicles on sale in Germany by the end of 2014.

The total stock of registered electric vehicles in Germany is estimated to have exceeded 20 000 by the end of 2014 (Kane, 2014). Sales were small until 2012, when registrations of BEVs and PHEVs reached 3 857, with the Smart ForTwo Electric Drive (“Smart ED”) and the Opel Ampera accounting for almost half. In 2014, sales reached 13 237, led by the BMW i3, with 17% of the market.⁵³ Most of the charging

⁵³ <http://ev-sales.blogspot.fr/2015/01/germany-december-2014.html>

infrastructure (more than 3000 public charging points⁵⁴) has been built as part of the pilot projects of the National E-Mobility Programme.

Germany's strategy supporting electric mobility has been different from that adopted for instance in Japan or the United States, where the broad goal has been to gain experience and advance market maturity by getting electric vehicles on the road. The approach chosen in Germany has been characterised by a lengthy phase of collaborative RD&D and market preparation up to 2014, followed by a market roll-out scheduled to take place between 2014 and 2017, and the rapid development of a mass-market by the end of the decade (NPE, 2012). Germany, unlike many other European countries, does not subsidise the purchase of electric vehicles, focusing instead on a large financial support programme for RD&D.

While some of the support measures it has advocated have been introduced, the NPE has expressed reservations about whether the target of one million electric vehicles could be reached in the absence of a purchase subsidy, which it estimates would have to be at least EUR 5 000 (Fraunhofer ISI, 2013). At a high-level meeting with representatives from industry and research on electric mobility, in October 2012, the Ministers of Transport and of the Economy re-stated that purchase subsidies were not being considered at the present stage of the National E-mobility Programme (Handelsblatt, 2012). With few German EV models available until 2014, any subsidies would have mainly benefitted foreign manufacturers of EVs, though the NPE is hoping sales of company cars will be boosted by the recent change in taxation of corporate EVs, with German EV manufacturers also targeting export markets.

India

In India, the only EV currently on the market is the Mahindra e2o, manufactured in Bangalore by Mahindra Reva Electric Vehicles, and introduced in March 2013. Mahindra plans to introduce a second model, an electric version of its Verito sedan, in 2014 (Gartner, 2013). However, demand for pure electric vehicles is inhibited by the instability of India's power grid, which witnesses many regions suffering daily power outages – increasing the risk that owners needing to recharge their vehicle's batteries could be left stranded. As for HEVs, fewer than 1 800 were expected to be sold in India in 2013. By contrast, more than 500 000 electric bicycles, scooters and motorcycles are expected to have been sold in India during the same year, a number that the market research firm, Navigant, expects will rise to more than 1.1 million by 2018 (Gartner, 2013).

In 2010 the Ministry of New and Renewable Energy launched a provisional, two-year scheme offering buyers incentives of up to 20% on the ex-factory prices of electric vehicles. It did not extend the scheme, however, which expired on 31 March 2012. The City of Delhi also offers a 15% subsidy on the base price of an electric vehicle and a refund of the local VAT (which is 12.5%). And it reduces the road tax normally paid by vehicle operators by 50%.

In August 2012, the Government of India published its National Electric Mobility Mission Plan 2020 (NEMMP 2020), which envisages, among other initiatives, encouraging the development of electric vehicles so that by 2020 some 5-10% of vehicles on the road will be electric-powered. Paragraph 6.2.4. of the Plan states:

In addition; in order to encourage manufacturers having higher level of localization content, *the possibility of having distinguishing/gradation localization criterion* for getting higher level of demand incentives (in terms of quantity of vehicles covered or the amount of incentive provided) can also be explored. Further, the possibility for range of other enablers to fast track investments will also be seen. [Emphasis added.]

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<http://chargemap.com/stats>

Details of the planned support measure were finally announced in April 2014. Subject to approval by the next government, a subsidy will be paid to domestic manufacturers of a wide range of HEVs and electric vehicles, from bicycles to buses. Pay-out of the subsidy requires first proof that excise tax was paid on the vehicle when it is offered for sale, and then that the vehicle has been registered by its owner (Patel, 2014). The government's aim is to cover 30-40% of the price differential between an electric or hybrid vehicle and a corresponding vehicle powered by an internal combustion engine (Bhattacharya, 2014). The actual subsidy paid will be based on factors such as the vehicle's operational range, battery capacity, and factory-gate price. If the subsidy is passed on fully to buyers, light commercial vehicles powered by electric motors should enjoy a discount of about INR 1 lakh (USD 2000), and electric passenger cars priced more than INR 7.5 lakhs (around USD 12 400) will benefit from the maximum discount for that category of INR 1.5 lakh (USD 2500). In total, the government expects to disburse about INR 12 000 crore (almost USD 2 billion) through the programme over six years (Patel, 2014).

Japan

Japan has played a major role in the development of EVs over several decades, notably with the world's first commercial hybrid car, the Toyota Prius in 1997. Some 18 000 were sold within a year in Japan, and 3 million had been sold worldwide by mid-2013. Incentive measures geared toward supporting EV manufacturers and users date back to the early 1970s. They have been renewed regularly as national strategies and programmes were updated to keep pace with technological and market changes. The government's current target for the share of EVs in the vehicle fleet is 15% to 20% by 2020, and 20% to 30% by 2030.

Market-pull policies

Japan actively supports markets for EVs by providing a range of subsidies to purchasers of EVs. The government has been offering financial support for EVs since its first incentive programme in 1996, which has been extended regularly over the years. Since the 2009 Green Vehicle Purchasing Promotion Measure, grants are offered covering half the price differential between an EV and an internal combustion engine vehicle, capped at JPY 850 000 (USD 8 500). The total budget for grants for EVs and PHEVs as well as chargers amounted to JPY 30 billion (USD 300 million) in FY 2011. In addition, EVs are exempt from acquisition tax, which means a savings of over JPY 500 000 (USD 5000) relative to similarly priced gasoline vehicles. EVs are also exempt from weight tax, bringing a further JPY 45 000 (USD 450) saving. These support programmes mean that the price of a Mitsubishi i-MiEV is reduced from about JPY 4 million to JPY 3 million (USD 40 000 to USD 30 000) and that of a Nissan Leaf from about JPY 3.8 million to JPY 3.2 million (USD 38 000 to USD 32 000). The list of eligible EVs includes both domestically produced and foreign cars. For company cars, tax breaks are possible, as well as loans for corporate fleets.

Local government has also been providing support for the use of EVs, though some of this support was suspended following the Great Eastern Japan Earthquake of March 2011 as a result of concern about electricity supply. For instance, Kanagawa Prefecture provided a grant of up to JPY 300 000 (USD 3 000) over and above the grant provided by the central government for the purchase of an EV. A range of other measures are available in some areas, such as reduced parking fees and expressway tolls. For Tokyo and Aichi-ken residents, the road tax (JPY 29 500 per year) is waived for up to five years, while it is halved in other areas of Japan.

The development of charging infrastructure also benefits from substantial public support. As early as 1993, Japan adopted a national plan for 1 000 charging stations (ECO-station project). In fact charging stations grew at a much slower pace. Plans were renewed from 2009 with the deployment of the CHAdeMO, a fast-charging standard backed by Japanese automotive original equipment manufacturers

and battery manufacturers. Under the 2009 Green Vehicle Purchasing Promotion Measure, grants are available to cover half the cost of installing a charger. In 2013, as part of a national plan (Project to Promote the Development of Charging Infrastructure), a new target was set to increase the number of fast chargers to 4 000 and that of standard chargers to 8 000. Japan has become a world leader in fast charging networks, with more than 2800 fast chargers installed at the beginning of 2015. Some JPY 100.5 billion has been earmarked to fund the new charging infrastructure which will be developed through prefectures and municipalities. Toyota, Nissan, Honda and Mitsubishi have agreed to bear part of the cost of the installation and maintenance of this infrastructure. Major retailers have also agreed to contribute to building charging stations at stores across Japan. For instance, the retailer AEON announced in July 2013 that it plans to install 500 fast chargers and 650 standard chargers at 490 of its stores at a total cost of JPY 3 billion, of which two-thirds will be subsidised by the government.

One of the pillars of Japan's EV strategy has been public procurement (Perdiguero and Jimenez, 2012). As early as the 1995 Environment Conservation Programme, the government aimed to replace at least 10% of its fleet with low-emission vehicles including EVs by 2000. In fact, only a few EVs were in use in 2000, largely because the government bodies involved found it unaffordable to purchase costlier low-emission vehicles in a time of deep economic recession (Beltramello, 2012). The policy approach was changed and the public procurement of EVs was legislated. The Green Purchasing Law came into effect in 2001 and made it mandatory to replace all government vehicles with low-emission vehicles by 2004. These procurement programmes are designed to be technologically neutral, as they cover HEVs and EVs as well as natural-gas vehicles, and about 60% of vehicles have in fact been HEVs. The larger prefectures and municipal authorities have also implemented procurement programmes in favour of EVs. EV car-sharing schemes have been set up in several areas, notably Tokyo, Yokohama and Okinawa, though these schemes are small-scale since they number under 100 electric vehicles each.

Technology-push policies

Japan's industrial and R&D policy has been strongly supportive of EVs over several decades, in accordance with Japan's long-standing policy to develop low-emission vehicles, exploiting its comparative advantage (for instance batteries developed for its large electronics industry) and encouraging its manufacturing industry to invest in an area of strategic national interest. The Ministry of Economy, Trade and Industry first developed a five-year research strategy for EVs in 1971, and has since followed up with a series of programmes providing funding for RD&D in a broad range of projects relevant to EVs. In the last decade the emphasis has been on lithium-battery technology and PHEV feasibility. Between 2005 and 2009, RD&D support also focussed on infrastructure projects and developing fast chargers (IEA-EVI, 2013). Several programmes were led in partnership with Fuji Heavy Industries, Tokyo Electric Power Corporation, Toyota, Nissan and Mitsubishi. One of the major outcomes has been the CHAdeMO charger system.

Generally, the government relies on public-private RD&D programmes, typically involving several manufacturers with the government playing the role of an initiator and a facilitator, co-ordinating the efforts of public and private stakeholders around a shared vision and a programme spanning five to ten years. Public funding is not central to these efforts and the actual role of technology-push policies such as government support for RD&D and for product development and manufacturing can be difficult to pinpoint, even in retrospect.

The history of the development of HEVs in Japan, which stretches back to the 1970s, illustrates this point (Gallagher, 2012). Private industry, most notably Toyota and Honda, developed HEVs seemingly independently from the Japanese government, though the industry benefitted from government support for major HEV components through public-private BEV programmes. It was not until 1997 (after Toyota produced its first commercial HEV) that the government officially broadened its programme to encompass

RD&D for HEVs. Meanwhile, a public-private R&D programme focused on improving batteries from 1992 and different combinations of battery and vehicle manufacturers joined forces to develop and produce advanced batteries for BEVs, with benefits for HEV development from government support for electronic controls, permanent magnet motors and nickel-metal hybrid battery programmes.

Outcomes

Japan's stock of PEVs was close to 75 000 at the end of 2013 (IEA and EVI, 2013). It was the world's second-largest market for BEVs in the world, with 16 615 vehicles, the majority of which were Nissan Leafs. Japan dropped to third place in the market for PHEVs (after the United States and the Netherlands), with 13 146 sold in Japan in 2013 — twice the number sold in 2012 — boosted by the plug-in versions of the Mitsubishi Outlander and the Toyota Prius. Japanese companies account for a large share of EV related patents, with Toyota holding over 4 000 patents worldwide — about 40% of the total (Millard et al., 2012). Japan also dominates the market for EV lithium-ion batteries, with half of global sales, and is a leader in patents related to lithium-ion batteries filed internationally (Canis, 2013).

Norway

The government of Norway has made a firm commitment to electric vehicles, motivated mainly by the desire to reduce the GHG emissions of its transportation fleet. Because Norway's electricity generation is almost 100% hydroelectric power, a transition to electric vehicles would decarbonise the transportation sector almost entirely. Thirty-three percent of Norway's GHG emissions currently come from the transport sector, of which 19% from road transport alone (Statistics Norway 2013). The goal of the Norwegian Parliament is for 50 000 zero-emission vehicles to be registered in the country by 2018; and the Norwegian Electric Vehicle Association wants to double that number by 2020. Only one small company, Buddy, manufactures electric cars in Norway, and only to order.

To achieve these goals, various tax exemptions and benefits have been introduced at different points in time. Since 1991, the Norwegian Government has exempted EVs from purchase taxes (on average slightly above NOK 100 000 for ordinary cars for personal use), and since 2001 they have also been exempt from VAT (25%) upon purchase. The government also grants EVs free access to toll roads (worth on average around USD 1 400 annually) and bus lanes, and allow them to park for free in municipal parking lots (worth around USD 5 000 annually). In Oslo, EVs in addition have access to free public charging at 466 parking spots (Doyle and Adomaitis, 2013). According to the new government's political platform, the tax-exemption schemes are scheduled to last through 2017 and then be phased out. One study (Doyle and Adomaitis, 2013) has estimated that the various benefits amount to up to USD 11 000 over the lifetime of an electric vehicle, or approximately USD 1 400 per year. Some (e.g., Doyle and Adomaitis, 2013) have criticised the incentive programmes because it encourages families to purchase an EV as a second car (mainly for daily commuting), relying on their gasoline- or diesel-powered vehicle for longer-range trips. Nonetheless, studies have shown that, even in families for which that is the case, overall emissions are thereby reduced. Moreover, with an ever-expanding network of charging points, the share of EVs used for longer journeys is expected to increase.

As of the end of 2014 there were over 40 000 electric cars registered in Norway (a country with a population of 5 million), and sales of 100%-electric vehicles accounted for 14% of total passenger car sales during the year, a higher fraction than in any other country in the world (Shahan, 2014; Pontes, 2015). In addition there were 1400 charging stations (over 5 000 charging points) in Norway, of which around 140 were fast-charging stations. (Source: <http://nobil.no/index.php/nyheter/89-statistikk-fra-nobil>.) Norway's capital now has the highest EV density of any capital city.

South Africa

With 6 million vehicles on its roads, South Africa leads the continent in automobile ownership. The country also hosts plants operated by several multinational vehicle manufacturers (BMW, Ford General Motors, Mercedes Benz, Nissan, Renault, Toyota and Volkswagen), as well as component manufacturers (e.g., Arvin Exhaust, Bloxwitch, Corning, Senior Flexonics).⁵⁵

In May 2013, the South African Government released a “Road Map for Electric Vehicles in South Africa” (DTI, 2013). The Road Map aims to create “an environment in which electric vehicles can be operated on the South African roads” and to support “the development and production of EVs (and components thereof) in South Africa”. It sets out several “strategic interventions” for the industry, including both demand stimulation and investment support. Though details of these policies have not yet been revealed, it is expected that they will include personal income-tax rebates for purchasers of EVs, a reduction in the VAT applied to EV sales, and reduced vehicle-registration charges.

On the supply side, in November 2013 the Government announced plans to amend its Automotive Investment Scheme (AIS) of the Automotive Production and Development Programme (APDP)⁵⁶ in order to enable EVs and related components to qualify for support. Plants that exceed an annual production quota of 5 000 units will receive reimbursements from the Government of 35% of their production costs over three years (Greve, 2013; Pickworth, 2013). As of November 2013 no electric vehicles were being manufactured in South Africa. However, one major South African manufacturer of automobile parts, Metair, is hoping to develop electric vehicles based on lead-acid batteries, of which it is already a leading world producer (Pickworth, 2013).

Turkey

Turkey is home to several subsidiaries of leading multinational automobile manufacturers, but still has an ownership ratio of 1 car per 10 inhabitants. (By comparison, the ratio of cars to inhabitants in Germany is 1:2.) Despite that, according to Ustaoğlu and Yıldız (2012), Turkey intends to become a leading manufacturer of EVs for Europe and for the global market.

Already, on 5 February 2013, Derindere Motor Cars (DMA), a subsidiary of Toyota, had unveiled Turkey’s first commercially available BEV, at a listed price of TL 120 000 (USD 68 000). The vehicle’s HVH 250 engine is supplied by US-based company, Remy International, and the lithium-ion batteries come from Japan and were repurposed from Toyota’s HEV lines. The car is built using the body of a Toyota Corolla sedan. DMA claims that the vehicle has a range at in-city speeds of 280 kilometres, and can be recharged using a simple adaptor system that fits into a standard electrical outlet. A full charge, which takes around eight hours, costs TL 6 (USD 4), compared with the TL 70 (USD 47) it would cost in Turkey for the gasoline that would be required to run that same distance in a vehicle rated at 5 litres per 100 kilometres (Blaser, 2013).

Several municipalities in Turkey have also taken actions to promote BEVs. Many of these initiatives are the result of agreements with the Renault-Nissan Alliance. These focus on the establishment of charging points for BEVs that since 2011 have been manufactured in the Renault’s automobile plant at Bursa Oyak. Some 92 Renault Fluence ZE were sold in Turkey the following year, according to the web site EV-Sales (www.ev-sales.blogspot.ch/search/label/Turkey). Parties to the agreements also work

⁵⁵ <http://www.southafrica.info/business/economy/sectors/automotive-overview.htm#.UooTJpKvOfI#ixzz210EiiS2O>

⁵⁶ The overall aim of the APDP is to increase the annual volume of vehicles manufactured in South Africa to 1.2 million by 2020.

together to develop projects for fleets, public spaces and urban areas, and to review regulations relating to EV charging points (Lukas, 2012).

Since 2011, Turkey has offered a reduced special consumption tax on battery-electric vehicles and small battery-electric motorbikes (Table 12); light duty trucks, trucks, buses, large motorbikes and HEVs and PHEVs do not qualify for the reduction. This is the main incentive available to consumers. Turkey also charges a lower rate for electricity usage during the night than during the day, which would facilitate low-cost home charging of EVs at night.

In February 2013, Turkey's Minister for Science, Industry and Technology announced that the country's Scientific and Technical Research Council (TÜBİTAK) will provide grants to electric car producers covering up to 100% of the costs of conducting R&D related to electric vehicle propulsion. Turkish universities are expected to collaborate with private and public-sector players in this endeavour. As a start to ensure market demand, the Science, Industry and Technology Ministry has also promised to buy 200 electric cars over the next five years (Anatolia News Agency, 2013). In March 2014, the Government announced the six finalists — all Turkish automakers — vying to build the first all-Turkish electric car. The winner or winners of the project, to be announced in April 2014, will receive a 100 million (USD 47 million) grant from the government (Anonymous, 2014).

Table 12. Taxes on conventional and electric vehicles in Turkey

Vehicle type	Conventional engine		Electric motor only	
	Engine Cylinder Volume (cm ³)	Special Consumption Tax (%)	Electric Motor Power (kW)	Special Consumption Tax (%)
Passenger vehicle	<1600	37	<85	3
	1600-2000	60	85-120	7
	>2000	84	>120	15
Motorbike	<250	8	<20	3
	>250	37	>20	37

Source: Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes (IA-HEV), <http://www.ieahev.org/by-country/turkey-policy-and-legislation/>

United States

Market-pull policies

The U.S. Department of Energy's (DOE's) main programme for demonstrating and promoting the early deployment of electric vehicles is its Clean Cities programme, which claims to have avoided the consumption of 52 million gallons (17 billion litres) of petroleum in 2012 (Johnson, 2013). More than 12 000 BEVs and 141 000 HEVs and PHEVs on the road were deployed with help from Clean Cities efforts. The Clean Cities programme has also worked to establish charging stations, and in 2012 more than 20 000 EV charging stations were deployed (Clean Cities, 2012). The demonstration and infrastructure aspects of the Clean Cities programme are designed to be "enabling" for the deployment of EVs.

The major policy designed to create demand for EVs in the marketplace is the U.S. federal tax credit for the purchase of BEVs or PHEVs. This policy grew out of the Energy Policy Act of 2005, which created

an income tax credit of up to USD 2400 for hybrid-electric vehicles, depending on the overall fuel efficiency of the vehicle. Introduced in the American Recovery and Reinvestment Act (ARRA), more generous incentives were established for BEVs and PHEVs (Beltramello, 2012). For a full BEV, the maximum tax credit that can be earned is USD 7500, and the minimum credit for a qualified vehicle is USD 2500. The tax credit is reduced according to the size of the battery, and models will cease to be eligible for the rebates in the calendar quarter after its manufacturer has surpassed 200 000 cumulative vehicles sold. There is also a tax credit equal to 30% of costs (up to USD 1000) for private consumers and businesses (up to USD 30 000) who invest in infrastructure (e.g. charging stations).⁵⁷

At the sub-national state level, many other types of incentives exist all around the country. In California, one of the states most supportive of EVs, the California Energy Commission has made grants for EV charging stations out of its Alternative and Renewable Energy Fuel and Vehicle Technology Program. Funds come from a surcharge on vehicle and boating registrations. There is also a rebate of USD 2500 for BEVs and USD 1500 for PHEVs.

Manufacturers of EVs also benefit from California's Zero Emission Vehicle (ZEV) regulation, which requires large volume and intermediate volume manufacturers to bring to and operate in California a certain percent of ZEVs.⁵⁸ Qualifying ZEVs include battery electric and fuel-cell vehicles, clean plug-in hybrid electric vehicles, clean hybrid-electric vehicles, and clean gasoline vehicles with near-zero tail pipe emissions. A vehicle manufacturer's ZEV requirement is based on a percentage of all passenger cars and light-duty trucks from 0 to 8 500 pounds (3 850 kgs), brought to and registered to operate in California. Manufacturers whose vehicles are operated in California generate varying credits based on vehicle type; other parties that do not have ZEV requirements can also generate credits. These credits are transferable, enabling, for example, the California-based manufacturer of BEVs, Tesla, to earn as much as USD 35 000 extra in credits on for every luxury Model S electric sports car it sells (Hirsch, 2013).

In some U.S. localities, EVs are permitted in carpool lanes, no matter how few passengers they are carrying, and some utilities provide discounts to consumers who charge their vehicles during off-peak hours. In Nevada, EVs are exempt from paying public parking meters and from emission inspections. Colorado has an income-tax credit equal to 75% of the "cost premium" (up to USD 6 000) for a BEV or PHEV purchase (Plug In America, 2013).

In October 2013 the Governors of eight U.S. states (California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont) signed a memorandum of understanding (MOU) to co-ordinate their implementation of policies that would make zero-emission vehicles (ZEV) — namely electric cars and hydrogen-fuelled vehicles — more available to the mass market (Government of California et al., 2013). The agreement (which expires in 2025) includes purchase targets for state fleets relating to both ZEV vehicles and corresponding recharging and refuelling stations. Collectively, the states aim to have at least 3.3 million ZEVs on the road in their states by 2025 and to work together to establish a fuelling infrastructure that will adequately support this number of vehicles. The states also agreed to provide public access to recharging and refuelling stations established for government fleets. State contracts with auto dealers and car-rental companies will, to the extent possible, include commitments to use ZEVs "where appropriate".

Technology-push policies

The DOE, under the Obama Administration, has prioritised RD&D on electric vehicles. The DOE's "EV Everywhere Grand Challenge Blueprint", released in January 2013, sets out three technical targets:

⁵⁷ See <http://www.fueleconomy.gov/feg/taxevb.shtml>

⁵⁸ <http://www.arb.ca.gov/msprog/zevprog/zevcredits/zevcredits.htm>

(1) cutting battery costs from USD 500/kWh to USD 125/kWh; (2) eliminating almost 30% of vehicle weight through the use of light materials; and (3) reducing the cost of electric drive systems from USD 30/kW to USD 8/kW (DOE, 2013). In his 2011 State of the Union speech, President Obama originally set a goal of 1 million electric vehicles by 2015, but in early 2013, DOE Secretary Chu acknowledged that the goal would be difficult to meet despite his Department's major investments in electric-vehicle technology and infrastructure (Rascoe and Seetharaman, 2013). The Energy Efficiency and Renewable Energy (EERE) Vehicle Technology programme budget reached USD 303 million for the FY 2012 enacted budget.⁵⁹ In its FY 2013 request, the Administration asked for a 30% increase, to USD 397 million (Table 13). The DOE has also provided support for demonstration programs (EV Project, Clean Cities), and a small amount of support for research on behavioural and public acceptance.

Table 13. U.S. Department of Energy's Electric Vehicle RD&D Programme (USD million)

Component	FY2011	FY2012 enacted	FY2013 request
Batteries	103	118	204
Vehicle systems, simulation, and testing	43	47	56
Materials	47	40	48
Outreach and deployment	33	39	34
Advanced combustion engine R&D	56	58	55
Total	282	303	397

Source: Data source: U.S. Department of Energy, Congressional Budget Request 2013, Vol. 3, February 2012

The U.S. Government has also provided substantial support in the form of loans, loan guarantees and grants to advanced battery manufacturers as well as U.S. automobile manufacturers who are producing EVs and HEVs. The Title 17 Innovative Loan Guarantee Program provided USD 170 million in FY 2011, but it is not clear how much was spent on electric vehicles. The Advanced Technology Vehicles Manufacturing Loan Program spent USD 10 million in FY 2011 and USD 6 million in FY 2012. As part of the 2009 American Reinvestment and Recovery Act, the Obama Administration granted USD 2.4 billion to accelerate the manufacturing and deployment of the next generation of U.S.-made batteries and electric vehicles through grants to 48 new advanced battery and electric-drive component manufacturers in over 20 states (Canis, 2013). Recipients included Johnson Controls, A123 Systems, EnerDel, Toda America, and General Motors (U.S. DOE, 2011a).

Some advanced battery manufacturers received additional incentives from states and cities. For example, in 2011, Polaris Industries (the parent company of Global Electric Motors) received almost USD 100 000 for training from the State of Iowa, and USD 450 000 tax credits and rebates from the State of Michigan; Michigan provided another tranche of tax credits and rebates, worth USD 595 000, to the company in 2012.⁶⁰ The State of Michigan was even more generous in the case of the advanced battery maker, A123 Systems. In 2009 and 2010 it provided hundreds of millions of U.S. dollars to the company, as described on the web site of the non-governmental organisation, Good Jobs First⁶¹:

⁵⁹ The U.S. federal fiscal year runs from 1 October through 30 September of the following year. Thus FY2012 refers to the period from 1 October 2011 through 30 September 2012.

⁶⁰ <http://www.goodjobsfirst.org/subsidy-tracker>

⁶¹ <http://www.goodjobsfirst.org/subsidy-tracker/mi-a123-systems-now-owned-wanxiang>

The subsidy package [in 2009] included up to USD 100 million in Michigan Business Tax Battery Credits; up to USD 25.3 million in MEGA [Michigan Economic Growth Authority] tax credits; two USD 10 million Centers of Energy Excellence grants; a USD 4 million low-interest forgivable loan; a USD 2 million grant; and USD 1 million in Southwest Michigan Community Alliance job training assistance. The company also stood to receive additional subsidies by virtue of being located in a Renaissance Zone, but the value cannot be determined. In addition to the state subsidies, A123 received a USD 249 million federal Recovery Act grant.

An additional USD 136 million in tax credits and grants was provided in 2010. In 2012 the company filed for bankruptcy and later sold its assets to the Chinese-owned Wanxiang Group. Michigan State officials ultimately took the position that the tax credits could not be transferred to Wanxiang.

Outcomes

Between December 2010 and November 2012, cumulative sales of PEVs in the United States were just over 60 000 vehicles, a total that is approximately twice as large as HEV sales were at the end of their introductory period (December 1999 through November 2001); by February 2014 the number had grown to triple that amount: 190 000. One contributing factor is that the BEV and PHEV tax incentives are considerably larger in real terms than HEV tax incentives were at the time they were introduced. In 2013, sales of HEVs in the United States are likely to exceed 500 000 units, and combined sales of BEVs and PHEVs were just under 100 000 units.⁶² In 2012, various government units (local, state, and federal) purchased a total of 3 431 electric vehicles, 82% of which were HEVs, 10% PHEVs, and 8% BEVs (Polk, 2013b).

⁶²

<http://www.electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952> and http://www.greencarreports.com/news/1089443_plug-in-electric-car-sales-for-2013-almost-double-last-years

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