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Policy Options for Decarbonising Transportation in APEC

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KEY MESSAGES

- Climate change is an existential threat to the APEC region, and transportation significantly contributes to this problem through its greenhouse gas (GHG) emissions. Vehicle electrification is the most effective and efficient solution to decarbonise transport. This could have quick and measurable impacts on reducing GHG emissions and address climate change.

Policy options for vehicle electrification

- *Vehicle supply regulations*. Setting electric vehicle (EV) sales targets for automakers is a compelling option in promoting EV adoption. And, fuel efficiency and carbon dioxide (CO_2) performance standards are important regulations that directly reduce GHG emissions from vehicles sold to consumers.
- *Vehicle purchase incentives*. Consumer subsidies accounted for a substantial share of total EV sales and were associated with increased demand for EVs. Purchase incentives reduce upfront costs and encourage consumers to make a behavioural change.
- *Provide vehicle usage incentives*. Access to high-occupancy vehicle/carpool lanes, parking incentives and road toll discounts are useful policies to incentivise consumers to use EVs. These solutions lead to greater market share, especially in the nascent stage.
- *Develop charging infrastructure*. Lack of visible charging infrastructure can be a barrier to EV purchase. Investment in charging infrastructure can help grow EV sales, and is especially important in increasing EV market share.
- *Educate, inform and reach out*. Consumer awareness and understanding of EVs and their characteristics are necessary preconditions for potential buyers. Investments in education and awareness programmes and campaigns may accelerate the shift toward vehicle electrification.

Introduction

Climate change is an existential threat to the APEC region. In their 2021 declaration, APEC Leaders made the commitment to 'leverage APEC's role as an incubator of ideas and capacity building to tackle climate change' and 'integrate action on climate change across relevant APEC workstreams'.[1] Transportation is a large part of the challenge, accounting for about a quarter of total greenhouse gas (GHG) emissions worldwide.[2]

The most effective and economically efficient strategy to dramatically reduce GHG emissions from transportation across all economies worldwide is vehicle electrification, combined with clean energy production. This would mean transitioning motorcycles, tricycles, cars, trucks and buses to electricity, primarily relying on batteries but including some use of plug-in hybrid vehicles and perhaps hydrogen fuel cell electric vehicles (collectively referred to as electric vehicles, or EVs).

[1] APEC, "2021 Leaders' Declaration," New Zealand, 12 November 2021, https://www.apec.org/meeting-papers/leaders-declarations/2021/2021-leaders-declaration
[2] "Fact Sheet: Climate Change" (*United Nations Sustainable Transport Conference*, Beijing, 14–16 October 2021), https://www.un.org/sites/un2.un.org/files/media_gstc/FACT_SHEET_Climate_Change.pdf

Full-battery EVs emit no tailpipe GHGs or air pollutants, and, shifting from internal combustion engine vehicles (ICEVs) to EVs can already reduce about a third of emissions from transportation.[3] If the share of renewable energy in power generation increases, then the total magnitude of overall GHG reduction of switching to EVs will be much larger.

The most effective policies for achieving this transition to EVs are performance standards and mandates imposed on vehicle suppliers, coupled with purchase and usage incentives for vehicle buyers, and investments in charging infrastructure, as well as information programmes and campaigns. Demand-side policy strategies, such as restraining vehicle use by dampening demand for cars and increasing the use of transit, bicycling, walking and other types of shared travel modes, complement the switch to EVs and can further reduce GHG emissions.

The transition to EVs is underway in many APEC economies. Given trends in battery costs and efficiency (see Box 1), EVs will eventually be less expensive to own and operate than ICEVs,[4] and will dominate in the next few decades almost everywhere,[5] providing large local air pollution and global climate benefits. Forms of digitalisation such as artificial intelligence and machine learning play a fundamental role in the automation of EV driving,[6] optimisation of battery life and charging times, [7] and advancements in research to produce more powerful and lightweight batteries.[8] This policy brief addresses the biggest challenges that policymakers need to overcome and identifies key policy lessons and opportunities for the transition to EV.

Cheaper, Faster, Cleaner

Over the last three decades, EVs have vastly improved in every way: in cost, performance, efficiency, driving range, styling and availability. Every major automaker now offers a variety of EVs for sale, often at attractive prices, and a few are now selling hydrogen fuel cell EVs (HFCEVs) as well.

Aside from being the most effective strategy toward transport decarbonisation, vehicle electrification is also the most economically efficient path to reduce GHG emissions in transport in the long run. At present, battery EVs are somewhat more expensive to produce than gasoline cars, though shrinking battery costs are likely to translate to purchase cost parity with gasoline and diesel cars before 2030.

In terms of total cost of ownership (TCO), the case for EVs is even more compelling. Gasoline-powered vehicles are three to five times more expensive to operate per kilometre relative to EVs in many regions.[9] The lower operating costs are due to EVs providing fuel cost savings and incurring lower maintenance costs. Battery EVs already have the lowest TCO of any powertrain for medium-sized cars bought today (assuming certain conditions, such as similar annual mileage and unchanged electricity and gasoline prices).[10] Further, by 2024 and 2026, respectively, battery EVs are expected to have the lowest TCO for small and large cars. Because EV prices will continue to decrease, EVs purchased in the coming years are expected to save drivers a considerable amount of money.

These recent research findings on TCO and other benefits of EVs are not widely disseminated across potential buyers and, thus, proactive engagement with consumers through education and outreach is an important policy option to consider. Another policy option is consumer incentives. Although the TCO for an EV is less than that for an ICEV in the long run, the large upfront costs with EV purchase cannot be ignored in the short term. Provision of consumer subsidies is necessary to reduce the effective purchase price of EVs.

Indeed, vehicle electrification is the most impactful strategy in terms of dramatically reducing GHG emissions in the transport sector because EVs have lower energy consumption per kilometre and lower carbon emissions compared to ICEVs. Also, through advancements in EV technology, EVs are now financially more attractive relative to ICEVs. Cheaper, more efficient, more energy-dense

[3] D.L. Chandler, "Can Today's EVs Make a Dent in Climate Change?" MIT News, 15 August 2016, https://news.mit.edu/2016/electric-vehicles-make-dent-climate-change-0815
[4] "EVs Will Be Cheaper than Petrol Cars in All Segments by 2027, BNEF Analysis Finds," Transport & Environment, 10 May 2021, https://www.transportenvironment.org/discover/evs-will-be-cheaper-than-petrol-cars-in-all-segments-by-2027-bnef-analysis-finds/
[5] S. Tucker, "EVs Will Dominate by 2033, Study Finds," Market Watch, 12 July 2021, https://www.marketwatch.com/story/evs-will-dominate-by-2033-study-finds-11625769624
[6] M. Lee, "An Analysis of the Effects of Artificial Intelligence on Electric Vehicle Technology Innovation Using Patent Data," *World Patent Information* 63 (2020): 102002, https://doi.org/10.1016/j.wpi.2020.102002
[7] "Algorithm Helps Reduce Charging Times and Improve Battery Life of Electric Cars," Innovation Origins, 24 August 2022, https://innovationorigins.com/en/selected/algorithm-helps-reduce-charging-times-and-improve-battery-life-of-electric-cars/
[8] R. Yang, "Building Better Batteries, Faster," MIT News, 24 August 2022, https://news.mit.edu/2022/pablo-leon-battery-materials-0824
[9] Zero Emission Transportation Association (ZETA), "Electric Vehicles Are Far Cheaper to Drive than Gas-powered Cars" (ZETA, 2022), https://8829857.fs1.hubspotusercontent-na1.net/hubfs/8829857/Zeta%20Report%20July.pdf
[10] Element Energy, "Electric Cars: Calculating the Total Cost of Ownership for Consumers," 2021, https://www.beuc.eu/sites/default/files/publications/beuc-x-2021-039_electric_cars_calculating_the_total_cost_of_ownership_for_consumers.pdf

batteries, and lower TCO due to savings on repair and maintenance, make it feasible to switch from ICEVs to EVs.

Policy Paths from ICEV to EV

Policymakers can support vehicle electrification through vehicle regulations; purchase and usage incentives; charging infrastructure investments; and education and outreach. Here, we outline how these policies can help grow EV markets and look at issues that would need to be considered in designing and implementing these policies.

Reform vehicle supply regulations

Around the world and in the APEC region, many economies have regulations that explicitly or effectively require automakers to sell EVs. These regulations include fuel efficiency performance standards, carbon dioxide (CO_2) emissions performance standards and zero-emission vehicle (ZEV) sales mandates.

If the fuel efficiency and CO_2 emissions standards set by governments are ambitious, automakers would likely have to sell EVs to comply with the standards; strong CO_2 emission standards essentially require the sale of EVs. In some cases, these regulations go further by awarding extra regulatory credits to further encourage EV sales, for instance, by counting an EV as two vehicles. The US federal Corporate Average Fuel Economy (CAFE) standards [11] and the European CO_2 standards[12] have used EV multipliers in this way at various times.

Sales mandates and strong performance standards

A more direct way to increase EV sales is through a sales mandate. EV mandates were first introduced in California, and they are now in place in China; Korea; 14 other US states and two Canadian provinces. Such regulations set EV sales targets for automakers as a share of their total sales; for instance, 35 percent of vehicle sales in California must be EVs (for each automaker).

Most fuel efficiency and CO_2 performance standards, as well as EV mandates, allow credit trading (as well as banking). If an automaker exceeds their requirements, they can sell their excess credits to other automakers who fall short of their requirement. If automakers do not reach their target through vehicle sales or credit purchases, they are charged fees for non-compliance. These credits can be valuable. Tesla, for instance, earned about USD 20,000 in credits from California for each Model S they sold in the mid-2010s. These credits were earned by exceeding the ZEV requirements in California, as well as the federal CAFE and GHG performance standards. The trading provisions provide flexibility to automakers, but also motivate innovation and early investments.

These direct supply-side regulations – stringent CO_2/GHG standards and ZEV mandates – are emerging as some of the most successful policies for accelerating EV sales and reducing GHG emissions. In Europe, for example, EV sales surged by about 70 percent in 2021, an increase that was partially due to the new CO_2 emissions standards implemented along with the expansion of purchase incentives in the region.[13]

ZEV mandates are compelling because they provide regulatory certainty and a clear pathway for automakers, and because they send clear signals to the many entities in the EV ecosystem that EVs are indeed on the way. It gives these other entities the justification, motivation and focus to act. These include electric utilities, which would need to invest in and support the installation of chargers at homes and workplaces and in public spaces; local governments, which would need to provide permits for charging stations and could provide parking incentives for EVs; and car dealers, who would need to educate their sales staff about EVs, provide charging facilities and update their marketing strategies.

Vehicle supply regulations are thus vital to promoting vehicle electrification and to further decarbonising the transport fleet in APEC. More than 30 automakers have already declared their intention to phase out combustion vehicles by 2040, some by 2030,[14] and regulation would be a big part of their ability to achieve the targets. But that would not be sufficient. Automakers have, appropriately, urged that regulatory requirements be matched by incentives and by investments in charging infrastructure to increase EV adoption. The potential

[11] National Highway Traffic Safety Administration (NHTSA), US, "Corporate Average Fuel Economy," accessed 24 August 2022, https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy

[12] European Commission, "Climate Action: CO_2 Emission Performance Standards for Cars and Vans," accessed 24 August 2022, https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

[13] L. Paoli and T. Gül, "Electric Cars Fend Off Supply Challenges to More than Double Global Sales," International Energy Agency (IEA), 30 January 2022, https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales

[14] Department for Transport, UK, "COP26 Declaration on Accelerating the Transition to 100% Zero Emission Cars and Vans," Gov.uk, updated 1 August 2022, https://www.gov.uk/government/publications/cop26-declaration-zero-emission-cars-and-vans/cop26-declaration-on-accelerating-the-transition-to-100-zero-emission-cars-and-vans

of these policy options to move the needle on the EV transition will be explored further in the next subsections.

Offer vehicle purchase incentives

Even with EVs reaching parity with gasoline and diesel vehicles in terms of TCO, purchase incentives would still be needed because, in reality, consumers rarely make vehicle purchase decisions based on TCO. Consumer purchase decisions are impacted by how they value vehicles, which includes their emotional, functional and social perceptions of vehicles.[15] Incentives can encourage consumers (and fleet managers) to purchase EVs.

Research on EV incentives from Europe, Asia and North America has found that most incentives help increase EV adoption and adoption intention, including studies that focus on APEC economies such as Australia;[16] Canada;[17] Chile;[18] China;[19] Indonesia;[20] Japan;[21] Korea;[22] and the US.[23]

Incentives are most effective when provided at point of sale,[24] rather than as a post-purchase tax credit or reimbursement (as they currently are in the US through 2022). Indeed, markets with high EV sales tend to deliver incentives at point of sale.[25] Point-of-sale rebates are estimated to be worth up to three times as much as post-purchase subsidies.[26]

Studies have also shown that exemptions on purchase tax or value-added tax (VAT), which reduce the upfront cost at point of sale, are effective at encouraging EV purchases.[27] These incentives are particularly significant when new-vehicle taxes are high.

In China, purchase incentives are calculated based on range, battery energy density and fuel consumption. EVs with a range of 300 to 400 km get an incentive of around CNY 14,400 plus or minus any adjustments based on battery density or fuel consumption. In some cities, including Shanghai and Beijing, drivers must acquire a licence plate via a lottery or auction, but can bypass the rule by purchasing EVs. Research shows that these policies have encouraged EV sales in China.[28]

Feebates

A compelling policy approach for creating a sustainable funding mechanism is feebates, also known as bonus-malus.[29] Fees are charged to buyers of high-emitting vehicles, and rebates given to buyers of low-emitting vehicles, especially EVs. The fee-and-rebate structure could be designed in many ways, but the goal is usually to adjust the structure periodically so that the total monetary value of fees equals the total monetary value of rebates plus administrative costs. The result is no cost to the government or taxpayers, while creating strong market signals to encourage more purchases of EVs. Feebates can play a critical role in pushing manufacturers toward investing in EVs by reducing EV purchase prices for consumers.

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[15] S. Hardman and G. Tal, "Exploring the Decision to Adopt a High-End Battery Electric Vehicle: Role of Financial and Nonfinancial Motivations," *Transportation Research Record* 2572, no. 1 (2016): 20–7, https://doi.org/10.3141/2572-03

[16] S. Gong, A. Ardeshiri and T.H. Rashidi, "Impact of Government Incentives on the Market Penetration of Electric Vehicles in Australia," *Transportation Research Part D: Transport and Environment* 83 (2020): 102353, https://doi.org/10.1016/j.trd.2020.102353

[17] Z. Thorne and L. Hughes, "Evaluating the Effectiveness of Electric Vehicle Subsidies in Canada," *Procedia Computer Science* 155 (2019): 519–26, https://doi.org/10.1016/j.procs.2019.08.072

[18] J. Urrutia-Mosquera and J. Fábrega, "Impact of Fiscal Incentives in the Consumption of Low Emission Vehicles," *Case Studies on Transport Policy* 9, no. 3 (2021): 1151–9, https://doi.org/10.1016/j.cstp.2021.06.003

[19] N. Wang, H. Pan and W. Zheng, "Assessment of the Incentives on Electric Vehicle Promotion in China," *Transportation Research Part A: Policy and Practice* 101 (2017): 177–89, https://doi.org/10.1016/j.tra.2017.04.037

[20] M.W.D. Utami, Y. Yuniaristanto and W. Sutopo, "Adoption Intention Model of Electric Vehicle in Indonesia," *Journal Optimasi Sistem Industri* 19, no. 1 (2020): 70–81, https://doi.org/10.25077/josi.v19.n1.p70-81.2020

[21] I. Alhulail and K. Takeuchi, "Effects of Tax Incentives on Sales of Eco-Friendly Vehicles: Evidence from Japan," Graduate School of Economics, Kobe University, Japan, March 2014, http://www.econ.kobe-u.ac.jp/activity/publication/dp/pdf/2014/1412.pdf

[22] J.H. Kim et al., "Consumer Intentions to Purchase Battery Electric Vehicles in Korea," *Energy Policy* 132 (2019): 736–43, https://doi.org/10.1016/j.enpol.2019.06.028

[23] A. Jenn et al., "An In-depth Examination of Electric Vehicle Incentives: Consumer Heterogeneity and Changing Response over Time," *Transportation Research Part A: Policy and Practice* 132 (2020): 97–109, https://doi.org/10.1016/j.tra.2019.11.004; I. Jenn, K. Springel and A.R. Gopal, "Effectiveness of Electric Vehicle Incentives in the United States," *Energy Policy* 119 (2018): 349–56, https://doi.org/10.1016/j.enpol.2018.04.065

[24] L. Roberson and J.P. Helveston, "Not All Subsidies Are Equal: Measuring Preferences for Electric Vehicle Financial Incentives," *Environmental Research Letters* 17, no. 8 (15 July 2022), https://doi.org/10.1088/1748-9326/ac7df3

[25] E. Kohn et al., "Electric Vehicle Incentives in 15 Leading Electric Vehicle Markets," Plug-In Hybrid & Electric Vehicle Research Center, University of California, Davis, CA, 2022, https://escholarship.org/uc/item/0tn2p4x6

[26] J. Li, J. Jiao and Y. Tang, "An Evolutionary Analysis on the Effect of Government Policies on Electric Vehicle Diffusion in Complex Network," *Energy Policy* 129 (2019): 1–12, https://doi.org/10.1016/j.enpol.2019.01.070

[27] Gong, Ardeshiri and Rashidi, "Impact of Government Incentives"; S. Hardman et al., "The Effectiveness of Financial Purchase Incentives for Battery Electric Vehicles – A Review of the Evidence," *Renewable and Sustainable Energy Reviews* 80 (2017): 1100–11, https://doi.org/10.1016/j.rser.2017.05.255

[28] C. Zhuge et al., "The Role of the License Plate Lottery Policy in the Adoption of Electric Vehicles: A Case Study of Beijing," *Energy Policy* 139 (2020): 111328, https://doi.org/10.1016/j.enpol.2020.111328

[29] A. Ramji et al., "Vehicle Feebate Designs: Lessons Learned for a Zero Emissions Future," 2022.

Several European economies have feebate policies. France was the first to introduce theirs in 2009 and Sweden did so in 2018.[30] Germany and Italy adopted feebate-like policies, pairing point-of-sale incentives with new-vehicle taxes based on emissions; in these two economies, the fees are not specifically used to offset the costs of the rebates.

While it is difficult to untangle the effects of feebates in these economies, one study has found that EV sales rose sharply when feebates were introduced or revised.[31] In one year, sales growth jumped from about 10 percent to 41 percent in Sweden, doubled in Italy (4.3 percent to 8.6 percent), and almost doubled in Germany (13.7 percent to 23.7 percent).

One of the key elements of achieving the EV transition will be a focus on equity. It will be critical to make EVs more affordable to middle- and lower-income consumers. Various economies have made efforts to address some aspects of equity, by way of additional rebates for EV purchases by low-income households, used-EV schemes or vehicle trade-in programmes.[32]

France, for instance, provided a combined rebate of up to EUR 12,000 for the purchase of used or new EVs and for scrapping older ICEVs (older than 2011 for diesel and older than 2006 for gasoline), subject to household taxable income being lower than EUR 13,489 (for year 2021).[33] They also have a bonus of EUR 1,000 if the car buyer lives or works in a low-emission zone, which could be of benefit to low-income families who are either residing in such areas or beneficiaries of affordable housing in low-emission zones or employed in such areas. The conditions for the low-income rebate also distinguish between vehicle buyers who are 'average commuters' and 'heavy drivers' based on their home-to-work commuting distance.

Germany does not have a specific low-income grant for purchase of EVs, but provides incentives for purchase of used EVs. In Italy, the feebate scheme includes a provision for low-income households, that is, those households with an equivalent economic situation indicator (ISEE) of less than EUR 30,000. Households that purchase new EVs with batteries less than 150 kW and a list price less than EUR 30,000 (excluding VAT), will be provided 40 percent of the expenses incurred, though this scheme cannot be combined with any other eligible benefits.[34]

Consumer subsidies

The use of consumer subsidies is an important approach to promote EV adoption, and policymakers should consider implementing these financial incentives. This is because consumer subsidies do well at increasing demand for EVs. For instance, in the top 13 EV markets, including four APEC economies (Canada; China; Japan; and the US), financial incentives amounted to USD 43 billion from 2013 to 2020 and this amount induced around 40 percent of total EV sales.[35] Moreover, an estimated 17 percent of the cross-economy variation in EV sales is driven by observed differences in the levels of subsidy, highlighting the importance of offering consumer subsidies as a policy to promote EV adoption.[36]

Financial incentives to consumers were found to have been integral to the rapid growth of EVs in China,[37] and more recently, to have been effective at inducing demand in Korea.[38] Higher government subsidies are considered one of the most influential factors in purchasing EVs.

In sum, policymakers should consider introducing consumer subsidies because these financial incentives are proven to work. They lower the purchase price of EVs, boosting demand for EVs. In designing the subsidies, policymakers must consider their longevity as their premature removal could negatively affect the subsequent adoption of EVs.[39] To facilitate the transition to EVs, it would be

[30] Kohn et al., "Electric Vehicle Incentives."
[31] Ramji et al., "Vehicle Feebate Designs."
[32] S. Wappelhorst, "The Role of the Used Car Market in Accelerating Equal Access to Electric Vehicles", The International Council on Clean Transportation (ICCT), 27 April 2021, https://theicct.org/the-role-of-the-used-car-market-in-accelerating-equal-access-to-electric-vehicles/
[33] A. Dechezleprêtre, A. Fabre and S. Stantcheva, "The French and Climate Policies," French Council of Economic Analysis, Paris, July 2022, https://www.cae-eco.fr/staticfiles/pdf/cae-note073-en.pdf
[34] European Automobile Manufacturers Association (ACEA), *ACEA Tax Guide 2021* (ACEA, 2021), https://www.acea.auto/publication/acea-tax-guide-2021/
[35] V. Foster et al., "If You Build It, They Will Come: Lessons from the First Decade of Electric Vehicles", World Bank Blogs, 20 December 2021, https://blogs.worldbank.org/transport/if-you-build-it-they-will-come-lessons-first-decade-electric-vehicles
[36] S. Li et al., "The Global Diffusion of Electric Vehicles: Lessons from the First Decade," Policy Research Working Paper 9882, World Bank, December 2021, https://documents1.worldbank.org/curated/en/225111639490843204/pdf/The-Global-Diffusion-of-Electric-Vehicles-Lessons-from-the-First-Decade.pdf
[37] S. Li et al., "The Role of Government in the Market for Electric Vehicles: Evidence from China," *Journal of Policy Analysis and Management* 41, no. 2 (2022): 450–85, https://doi.org/10.1002/pam.22362
[38] S. Kim et al. "Analysis of Influencing Factors in Purchasing Electric Vehicles Using a Structural Equation Model: Focused on Suwon City," *Sustainability* 14, no. 8 (2022): 4744, https://doi.org/10.3390/su14084744; S.Y. Kim and M.J. Kang, "A Study on the Factors Influencing the Purchase of Electric Vehicles," *International Journal of Internet, Broadcasting and Communication* 14, no. 1 (2022): 194–200, https://doi.org/10.7236/IJIBC.2022.14.1.194
[39] Hardman et al., "The Effectiveness of Financial Purchase Incentives."

imperative that policies are designed to help shift middle- and higher-income households to EVs. As the benefits provided to EVs are realised in the market, there will be an overall reduction in vehicle prices, especially given the trends in battery costs and efficiency (Box 1), and a better realisation of resale values for EVs, improving accessibility and affordability for consumers at the lower end of the income spectrum.[40]

Provide vehicle usage incentives

Policymakers can also provide indirect or recurring incentives tied to vehicle use.[41] These incentives reduce the cost of using EVs and can provide more convenience. The incentives may include free, discounted or preferential location parking; special lane access (e.g., bus lane access, carpool lane access); road toll discounts or exemptions; free charging; and freedom to operate in low-emission or congestion charge zones. Examples of these policies include:

- In California, EVs can drive in carpool lanes even if they have only one vehicle occupant.[42]
- EVs in China; California; the Netherlands; and Norway pay reduced tolls on bridges, roads and ferries.[43]
- China; California; London; Sweden; and Norway have offered free parking for EVs.[44]
- In Beijing, EVs are exempt from the rule that vehicles could not be driven one day per week.[45]
- In Norway, EVs can drive in bus lanes, though this is being phased out as EV sales increase.[46]
- In London, EVs are exempt from paying the GBP 15 per day congestion charge.[47]

Studies have shown that these usage incentives are effective at encouraging consumers to purchase and use EVs.[48] Note that some of these usage incentives may only be appropriate during the early stages of the market. They can greatly reduce government revenues and may even be counterproductive as the market expands, for instance, where EVs are allowed in bus-only lanes and slow the speed of buses.

A study investigating special lane access, emissions zone access and preferential parking incentives for EVs in China; the US; and Europe[49] found that these incentives are effective in promoting EV sales and use. Norway's early EV market benefited from allowing EVs to drive in bus lanes, pay lower tolls and park for free or at a discounted price in urban areas.[50] Since the EV share of new-vehicle sales in Norway has reached over 80 percent as of 2022, policymakers have begun to phase out these incentives as the EV market expands, though they had been effective at promoting early market growth. Research on China shows how reduced local restrictions on EV use and purchase compared to conventional vehicles was influential in EV market growth.[51]

Develop charging infrastructure

In places where many people own detached houses and can easily install home chargers, early ZEV market growth is possible without much public charging investment. Some chargers are needed in this case to support occasional charging and along intercity corridors. But as the market expands, and in areas where most people live in multi-unit buildings, large investments in public charging infrastructure will be needed.[52]

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[40] Environmental Defense Fund (EDF), "Making Electric Vehicles More Accessible in the UK Can Save Low-Income Households Millions," 11 November 2019, https://www.edf.org/media/making-electric-vehicles-more-accessible-uk-can-save-low-income-households-millions#:~:text=(LONDON%20%E2%80%93%2011%20November%2C%202019,EV%20and%20fossil%2Dfuel%20vehicles

[41] S. Hardman, "Understanding the Impact of Reoccurring and Non-financial Incentives on Plug-in Electric Vehicle Adoption – A Review," *Transportation Research Part A: Policy and Practice* 119 (2019): 1–14, https://doi.org/10.1016/j.tra.2018.11.002

[42] California Air Resources Board, "Carpool Stickers", accessed 31 August 2022, https://ww2.arb.ca.gov/our-work/programs/carpool-stickers

[43] Hardman, "Understanding the Impact of Reoccurring and Non-financial Incentives."

[44] Hardman, "Understanding the Impact of Reoccurring and Non-financial Incentives."

[45] D. Hall, M. Moultak and N. Lutsey, "Electric Vehicle Capitals of the World: Demonstrating the Path to Electric Drive" (ICCT, 2017), https://theicct.org/wp-content/uploads/2021/06/Global-EV-Capitals_White-Paper_06032017_vF.pdf

[46] "Norway Considers Cutting EV Advantages," electrive.com, 20 June 2022, https://www.electrive.com/2022/06/20/norway-considers-cutting-ev-advantages/

[47] "Do Electric Cars Pay the Congestion Charge?" 29 March 2022, https://www.rac.co.uk/drive/electric-cars/running/do-electric-cars-pay-the-congestion-charge/#:~:text=Electric%20cars%20and%20hydrogen%20fuel,drivers%20now%20have%20to%20pay

[48] E. Figenbaum, "Perspectives on Norway's Supercharged Electric Vehicle Policy," *Environmental Innovation and Societal Transitions* 25 (2017): 14–34, http://dx.doi.org/10.1016/j.eist.2016.11.002; Hardman, "Understanding the Impact of Reoccurring and Non-financial Incentives"; T.L. Sheldon, J.R. DeShazo, "How Does the Presence of HOV Lanes Affect Plug-in Electric Vehicle Adoption in California? A Generalized Propensity Score Approach," *Journal of Environmental Economics and Management* 85, (2017): 146–70, https://doi.org/10.1016/j.jeem.2017.05.002

[49] A. Ajanovic and R. Haas, "Dissemination of Electric Vehicles in Urban Areas: Major Factors for Success," *Energy* 115, part 2, (2016): 1451–58, https://doi.org/10.1016/j.energy.2016.05.040

[50] Figenbaum, "Perspectives on Norway's Supercharged Electric Vehicle Policy."

[51] Y. Wang et al., "China's Electric Car Surge," *Energy Policy* 102 (2017): 486–90, https://doi.org/10.1016/j.enpol.2016.12.034

[52] S.A. Funke et al. "How Much Charging Infrastructure Do Electric Vehicles Need? A Review of the Evidence and International Comparison," *Transportation Research Part D: Transport and Environment* 77 (2019): 224–42,

Charging needs will differ across regions and would depend on household travel patterns, number of vehicles per household, whether households have off-street parking and whether drivers can charge their vehicles at work. Policymakers should consider these local conditions in urban and infrastructure planning. For example, high levels of work charging, shorter travel distances, more household vehicles and more home charging access reduce the need for public charging infrastructure.[53] In most regions, the majority of EV charging occurs at home, followed by the workplace, and finally in public locations.[54,] Home charging is the most frequently used as it is the most convenient location for drivers, and thus has the largest impact on consideration to purchase an EV. Policymakers can support the introduction of charging at all appropriate locations with public funds, and by streamlining permit processing, providing locations for infrastructure installation and supporting infrastructure providers.

In locations with long dwell times (home, work) lower-speed charging is suitable, and can be more cost-effective than fast-charging. In locations with short dwell times (e.g., longer trips), faster charging will be needed, though it will be more expensive to install and operate. Research on the impact of public charging infrastructure availability on EV sales is mixed. Some studies find a positive relationship,[55] though not always a causal one. Other studies show that initial interest, intent to purchase or purchase decision is not caused by infrastructure, but by prior interest and engagement with an EV.[56] Policymakers, therefore, should not consider charging infrastructure as simply a necessity to operate EVs but as part of an engagement strategy to raise demand and awareness.

Subsidies are almost always needed, especially in the early years of direct current fast charging (DCFC), when utilisation rates are low.[57] These subsidies can come from employers as employee benefits, large retail establishments that want to attract customers, and electric utilities that anticipate load management benefits. But governments at all levels also need to subsidise charging because it is difficult to make a profit in most situations selling electricity to vehicles. The revenue stream is too low to offset the cost of the chargers, especially where the soft costs of installation are high.

For most light duty vehicle application, the rule of thumb is one AC level 1 (110/120V) or AC level 2 (220/240V) charger per vehicle, including home charging. This ratio can be lower in more mature markets when households with older EVs or multiple EVs are not using each vehicle intensively. In California, for example, it is estimated that less than 10 million public chargers will be needed to support about 25 million vehicles.[58]

Charging infrastructure is vital and policymakers should consider strengthening investments in charging infrastructure to promote EV adoption. There is global evidence that expanding charging networks, especially on freeways, is essential to promote electric mobility.[59]

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https://doi.org/10.1016/j.trd.2019.10.024; T. Gnann, P. Plötz and M. Wietschel, "Can Public Slow Charging Accelerate Plug-in Electric Vehicle Sales? A Simulation of Charging Infrastructure Usage and Its Impact on Plug-in Electric Vehicle Sales for Germany," *International Journal of Sustainable Transportation* 13, no. 7 (2019): 528–42, https://doi.org/10.1080/15568318.2018.1489016

[53] Funke et al. "How Much Charging Infrastructure Do Electric Vehicles Need?"

[54] T. Franke and J.F. Krems, "Understanding Charging Behaviour of Electric Vehicle Users," *Transportation Research Part F: Traffic Psychology and Behaviour* 21 (2013): 75–89, https://doi.org/10.1016/j.trf.2013.09.002; S. Hardman et al., "A Review of Consumer Preferences of and Interactions with Electric Vehicle Charging Infrastructure," *Transportation Research Part D: Transport and Environment* 62 (2018): 508–23, https://doi.org/10.1016/j.trd.2018.04.002

[55] A.C. Mersky et al., "Effectiveness of Incentives on Electric Vehicle Adoption in Norway," *Transportation Research Part D: Transport and Environment* 46 (2016): 56–68, https://doi.org/10.1016/j.trd.2016.03.011; W. Sierzchula, "Factors Influencing Fleet Manager Adoption of Electric Vehicles," *Transportation Research Part D: Transport and Environment* 31 (2014): 126–34, https://doi.org/10.1016/j.trd.2014.05.022

[56] K. Hoogland et al., "Understanding the Impact of Charging Infrastructure on the Consideration to Purchase an Electric Vehicle in California," Institute of Transportation Studies, University of California, Davis, CA, 2022, http://dx.doi.org/10.7922/G21G0JKP; A. Miele et al., "The Role of Charging and Refuelling Infrastructure in Supporting Zero-emission Vehicle Sales," *Transportation Research Part D: Transport and Environment* 81 (2020): 102275, https://doi.org/10.1016/j.trd.2020.102275; F. Nazari et al., "Modeling Electric Vehicle Adoption Considering a Latent Travel Pattern Construct and Charging Infrastructure," *Transportation Research Part D: Transport and Environment* 72 (2019): 65–82, https://doi.org/10.1016/j.trd.2019.04.010

[57] Gnann, Plötz and M. Wietschel, "Can Public Slow Charging Accelerate Plug-in Electric Vehicle Sales?"

[58] D. Chakraborty et al., "Demand Drivers for Charging Infrastructure-Charging Behavior of Plug-in Electric Vehicle Commuters," *Transportation Research Part D: Transport and Environment* 76 (2019): 255–72, https://doi.org/10.1016/j.trd.2019.09.015; A.W. Davis, D. Chakraborty and G. Tal, "How Many Chargers Must California Install to Complete the Transition to Electric Vehicles? An Analysis of Electric Vehicle Adoption and Potential Charging Infrastructure Needs 2022–2045," Institute of Transportation Studies, University of California, Davis, CA, 2022, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4113824; G. Tal, A. Davis and D. Garas, "California's Advanced Clean Cars II: Issues and Implications," Institute of Transportation Studies, University of California, Davis, CA, 31 May 2022, https://escholarship.org/uc/item/1g05z2x3

[59] T. Lieven, "Policy Measures to Promote Electric Mobility – A Global Perspective," *Transportation Research Part A: Policy and Practice* 82 (2015): 78–93, https://doi.org/10.1016/j.tra.2015.09.008

Lastly, charging infrastructure must be constructed in locations with high demand from the beginning and an accessible thoroughfare for emergency and road charging.[60] Fast-charging public stations are desirable in public parking lots, public institutions, retail fuel stations, and in areas that attract the most crowds, whereas slow-charging public stations would be viable near apartment and industrial complexes and in areas that attract fewer drivers for longer dwell times.

Educate, inform and reach out

Even in mature EV markets such as California, most car buyers remain disengaged and largely ignorant of the various incentives, availability of charging infrastructure, and EV models.[61] In Norway, the economy with the most rapid EV transition, lack of awareness remains a barrier to EV market growth.[62] The most common way buyers learn about EV has

Box 1. Trends in EV battery costs and efficiency

The performance, production and supply of EV batteries are among the most important drivers of the shift toward vehicle electrification.[1] Battery efficiency and cost factors play a decisive role in EV adoption. Batteries are crucial because they are the most expensive component of an EV, accounting for about a third of its total cost.[2] Improvements in battery technology are key to reductions in the cost of EV.[3]

The price of lithium-ion battery packs, on average, fell from USD 1,200 per kilowatt-hour (kWh) in 2010 to USD 132 per kWh in 2021 in real terms.[4] This translated to an 89 percent decrease in battery pack prices in just 11 years. Further, a 6 percent decline in the price of lithium-ion battery packs was observed from 2020 to 2021. Continuing cost reductions are expected, due to advancements in lithium-ion technology. By 2024, the price of lithium-ion battery packs is expected to fall below USD 100 per kWh. At this price point, EVs could be sold at the same price as ICEVs.

At the same time, research and development on battery chemistry and manufacturing continues. Continuing reductions in battery costs through at least 2030 are expected to come from incremental refinements in lithium-ion batteries, including improvements in manufacturing, battery chemistry and physical design. Billions of dollars are being invested not only in cost reduction, but also increased energy density, power, charging speeds, lifetime and safety. The diversity of battery chemistries being commercialised and used in today's batteries has increased[5] and is expected to continue as new technologies and chemistries are commercialised. The diversification is partly motivated by the desire to reduce supply chain barriers and respond to geopolitical mineral supply concerns.

One factor that could slow reductions in battery costs is the rising costs of metals.[6] Metal prices are likely to increase through the 2020s as the opening of new mines and the supply of metals lag the volume of battery EVs being manufactured and sold. But metal costs are a relatively small share of total battery costs, and the downward trend in battery costs is likely to continue. In this manner, the provision of consumer subsidies in purchasing EVs is an important policy space to consider in order to effectively lower the purchase price of EVs, especially, in light of supply shocks in the future.

[1] "EV Revolution: Are Electric Vehicle Batteries Ready?" May 2022, https://www.dhl.com/global-en/delivered/sustainability/electric-vehicle-battery-technology.html
[2] Nikkei Asia, "Global EV Group Sets Standards for Pricing Used Batteries," *Nikkei Asia*, 26 October 2021, https://asia.nikkei.com/Business/Automobiles/Global-EV-group-sets-standards-for-pricing-used-batteries
[3] M. Scott, "Ever-Cheaper Batteries Bring Cost of Electric Cars Closer to Gas Guzzlers," *Forbes*, 18 December 2020, https://www.forbes.com/sites/mikescott/2020/12/18/ever-cheaper-batteries-bring-cost-of-electric-cars-closer-to-gas-guzzlers/?sh=2785d60873c1
[4] BloombergNEF, "Battery Pack Prices Fall to an Average of $132/kWh, But Rising Commodity Prices Start to Bite," 30 November 2021, https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/h
[5] EV Volumes, "EV Data Center," accessed 15 February 2022, http://www.ev-volumes.com/datacenter/
[6] IEA, "Technology Cost Trends for Liithium-ion Batteries, 2015-2021," updated 20 May 2022, https://www.iea.org/data-and-statistics/charts/technology-cost-trends-for-lithium-ion-batteries-2015-2021

[60] Kim et al., "Analysis of Influencing Factors in Purchasing Electric Vehicles."
[61] S. Hardman, K.S. Kurani and D. Chakraborty, "The Usual Policy Levers Are Not Engaging Consumers in the Transition to Electric Vehicles: A Case of Sacramento, California," *Environmental Research Communications* 2, no. 8 (2020), https://doi.org/10.1088/2515-7620/aba943; K.S. Kurani, "2021 Multi-state Zero Emission Vehicle Market Study Volume 1: Zero Emission Vehicle States," Institute of Transportation Studies, University of California, Davis, CA, 2022.
[62] L. Noel et al., "Understanding the Socio-technical Nexus of Nordic Electric Vehicle (EV) Barriers: A Qualitative Discussion

been word of mouth, from friends, family and fellow workers. In the absence of social network effects, policymakers may need to proactively engage consumers through marketing (social and conventional media), engagement events and auto dealers.[63]

After addressing vehicle cost, vehicle range and access to infrastructure, educating consumers may be the most important barrier for policymakers to address. Examples of publicly funded and public–private partnerships include Veloz in the US and, previously, the Go Ultra Low campaign in the United Kingdom. Automakers have generally not substantially invested in marketing of EV models, perhaps because the market is currently supply-constrained, rather than demand-constrained. Whether this will change as EV sales goals are promulgated in law is not clear.

To accelerate the shift toward vehicle electrification, policymakers should consider investments in information programmes, given that consumer awareness of EVs and their characteristics is a necessary precondition for potential buyers.[64] In addition, the accuracy of perceptions on the attributes of EVs also influences decisions to purchase.[65] Research has shown that this is a source of concern as the majority of respondents have incorrect perceptions about the basic attributes of EVs. This lack of awareness highlights the necessity for policymakers in the APEC region to address the information gap related to EVs and their characteristics.

Conclusion and Recommendations

The transition to EVs is well underway in many APEC economies. The speed of the transition will differ across regions because of different regulatory processes and different priorities for air pollution and climate, as well as different consumer preferences and affluence. For example, the larger EVs produced in the US will not be suitable for most APEC markets; electric two-wheelers will be more popular in less affluent economies; and economies with strong domestic oil industries will usually resist electrification and EV policies. Policies need to be sensitive to these many different circumstances. A suite of policies is needed, including:

1. *Long-term binding rules requiring or motivating* automakers *to sell EVs that match local market needs.* Automakers are well positioned to scale up EV production; many have already announced plans to end production of gasoline vehicles and all are making massive investments in EVs. With battery costs having dropped dramatically and continuing to drop, automakers can scale up in the markets as soon as policy forces them to, and/or as soon as consumers indicate a willingness to buy.

2. *Purchase and use incentives for EV in the near and mid-term.* Evidence suggests that incentives will be needed even as sales expand, going well beyond the early adopter market – even after EVs reach parity on TCO. Indeed, the importance of incentives may increase even as sales increase.[66] Norway is maintaining incentives for buyers even with EVs at 80 percent market share. For this reason, among others, revenue-neutral incentives may be the most appropriate policy for sustainable EV market growth.

3. *Public investment in charging infrastructure, especially in the early years, for all types of vehicles, especially cars, trucks and buses.* Charging infrastructure is vital and policymakers should consider strengthening investments in charging infrastructure to promote EV adoption. Evidence shows that expanding charging networks, especially on freeways, is essential to promote electric mobility.

4. *Increased outreach, education and engagement.* Even in mature EV markets, most car buyers remain disengaged and largely ignorant of the various incentives, availability of charging infrastructure, and cost-effectiveness of EV models available in the market. Policymakers need to consider investing in education and information campaigns to improve consumer awareness of EVs and improve the perception of EVs in the market.

5. *Local leadership by cities and regions in support of EV policies and initiatives.* All the policies related to EV promotion and infrastructure cannot be implemented by one agency. It is important that central or federal agencies as well as local governments coordinate on vehicle regulations, charging investments and oversight, permitting of charging stations, and incentives for vehicle buyers.

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of Range, Price, Charging and Knowledge," *Energy Policy* 138 (2020): 111292, https://doi.org/10.1016/j.enpol.2020.111292

[63] Hardman et al., "The Effectiveness of Financial Purchase Incentives for Battery Electric Vehicles"; Hardman, Kurani and Chakraborty, "The Usual Policy Levers Are Not Engaging Consumers."

[64] G.H. Broadbent, D. Drozdzewski and G. Metternicht, "Electric Vehicle Adoption: An Analysis of Best Practice and Pitfalls for Policy Making from Experiences of Europe and the US," *Geography Compass* 12, no. 2 (2018): e12358, https://doi.org/10.1111/gec3.12358

[65] R.M. Krause et al., "Perception and Reality: Public Knowledge of Plug-in Electric Vehicles in 21 U.S. Cities," *Energy Policy* 63 (2013): 433–40, https://doi.org/10.1016/j.enpol.2013.09.018

[66] A. Jenn et al., "An In-depth Examination of Electric Vehicle Incentives: Consumer Heterogeneity and Changing Response over Time," *Transportation Research Part A: Policy and Practice* 132 (2020): 97–109, https://doi.org/10.1016/j.tra.2019.11.004

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