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IAEE ENERGY FORUM

CONTENTS

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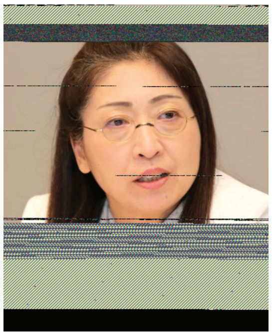
PRESIDENT'S MESSAGE



This is my last message as your President for 2020 and I hope this newsletter finds you well. I feel rather sad that after nearly one year, I have not been able to meet most of you, face-to-face. I had best intentions to get personally engaged at conferences with our PhD students, our young professionals or with governments and industry. Back in February, when we gathered for a very successful Asia-Oceania IAEE Conference in Auckland, it was beyond my imagination that COVID-19 would influence the world in such a profound way. At the time, we were a little naïve to think that the situation would soon be under control. The virus didn't "come and go" but quickly became a pandemic "spreading worldwide". The data tells us that the global economy has been hit very hard and the end of the downturn is not yet in sight.

COVID19 introduced new topics for researchers to analyze and new challenges for companies and policy makers to tackle. National security and self-sufficiency are now carrying heavier meaning then before. Progress towards decarbonization may seem closer than before because the lockdowns and closures of national borders caused sharp decline in oil demand. That may soon change.

Advancing knowledge and understanding remain our goals as an Association. To keep momentum in the absence of conferences, we have conducted more than 50 webinars and podcasts so far this year. Working at home and meeting virtually have been convenient bandages in the current situation. The early success of Webinars can be described as "first dates with a technological chaperon"; they are safe and fun. Digitalization has been in fast forward mode to meet all these needs.

I hope the world will come out of Covid19 healthier, more resilient, and sustainable. Our Paris team has resumed preparations for the scheduled International Conference in July 2021 and so are the other teams on their local/regional/international conferences. I hope that we will see each other in 2021 and re-connect face-to-face, not virtually.

The association is a very big ship to steer and activities of the IAEE during the year 2020 have not been possible without the dedicated efforts of many key people. Special thanks to our Executive director, David Williams, and to Rebecca Lilley for their strenuous and continuous efforts during this challenging year. They kept wath.

I also would like to extend my sincere gratitude to the members of the Executive Committee, David Knapp, Christophe Bonnery, Jim Smith, Inga Konstantinaviciute, and John Jimison. They provided unconditional support and guidance on how to navigate in stormy waters. I am also well aware that the many Vice-Presidents (David Broadstock, Michael Pollitt, Jean-Michel Glachant, Vilayat Valiyev, Troy Thompson, and Ying Fan) worked very hard to perform their duties and responsibilities. I also must not forget to thank our dear Council members and Student representative who

(continued on page 2)

President's Message (continued)

have gracefully remained on board despite the storm (Aaron Praktiknjo, Mohamed Abdulla Alobeidli, Amy Jaffe, Kelly Burns and Pablo Benalcazar).

IAEE is a prestigious Organization essential to the world and I feel privileged to have served. I would like to particularly congratulate Jim Smith, our president for 2021. I will support him, just like Christophe did for me.

Till we see again, I wish you all, safety, happiness and health.

Yukari Niwa Yamashita

Careers, Energy Education and Scholarships Online Databases

IAEE is pleased to highlight our online careers database, with special focus on graduate positions. Please visit http://www.iaee.org/en/students/student_careers.asp for a listing of employment opportunities.

Employers are invited to use this database, at no cost, to advertise their graduate, senior graduate or seasoned professional positions to the IAEE membership and visitors to the IAEE website seeking employment assistance.

The IAEE is also pleased to highlight the Energy Economics Education database available at http://www.iaee.org/en/students/eee.aspx Members from academia are kindly invited to list, at no cost, graduate, postgraduate and research programs as well as their university and research centers in this online database. For students and interested individuals looking to enhance their knowledge within the field of energy and economics, this is a valuable database to reference.

Further, IAEE has also launched a Scholarship Database, open at no cost to different grants and scholarship providers in Energy Economics and related fields. This is available at http://www.iaee.org/en/students/ListScholarships.aspx

We look forward to your participation in these new initiatives.

IAEE MISSION STATEMENT

IAEE's mission is to enhance and disseminate knowledge that furthers understanding of energy economics and informs best policies and practices in the utilization of energy sources.

We facilitate

- **Worldwide information flow and exchange of ideas on energy issues**
- **High quality research**
- **Development and education of students and energy professionals**

We accomplish this through

- **Leading edge publications and electronic media**
- **International and regional conferences**
- **Networking among energy-concerned professionals**

Editor's Notes

The response to our request for articles focusing on electric vehicles has been most gratifying. The result was a super number of articles––so many that we've had to devote two issues of the *Forum* to cover the subject. We have a full complement of artkcles this issue and will repeat in the first quarter of 2021 issue.

Ron Ripple discusses the advent of the position of Chief Economist at the American Petroleum Institute, noting that two of the four individuals who have held the position, Mike Canes and John Felmy held it for a combined 35 out of the 39 years the position has existed. He notes the varying emphasis placed on economics as the Institute went through four leadership changes, seven Presidential administrations and increasing industry volatility.

Peter Brody-Moore, Joseph Cavicchi, Udayan Maithani, Lindsay Mattei, and **Jeffrey Monson** discuss strategies for developing electric vehicle charging infrastructure in the U.S. after reviewing practices outside the U.S. and contrasting them with those in the U.S. The roles of government, regulators and utilities are considered. Best practices from this review are identified, and suggestions are formed for future initiatives.

Philip Walsh writes that Canada's recent policy on investment in electric vehicle (EV) charging infrastructure is a complement to financial incentives in encouraging EV adoption. Increased visibility of charging stations and faster charging technology are instrumental in reducing perceptions of technology risk and improving user satisfaction and retention.

Philipp Andreas Gunkel and **Claire Bergaentzlé** show how flexible EV charging leads to substitution effects of solar PV and costly peak power capacities towards wind power and baseload in the European energy system. Flexible EV charging effectively reduce CO_2 emissions and triggers cross-border effects in terms of energy trade and CO_2 mitigation.

Tilak Doshi and **Nahim Zahur** discuss and evaluate electric vehicles in the context of Singapore. Singapore has recently set a target of phasing out internal combustion engine (ICE) vehicles by the year 2040. Concurrently, the Singapore government has introduced subsidies for EVs as well as a variety of other policies to encourage EV adoption. They provide a critical evaluation of Singapore's existing policies as they relate to EV adoption.

Y. Abdelouadoud, A. Lancelot, A. Le Duigou, M. Petit, D. Quenard, and **H.J.J. Yu** argue that new buildings will be energy production sites thanks to the installation of PV panels for household and Evs recharging. They show the synergy between mobility and housing, for corporate, car-sharing and personal fleets, via the TCO calculations and models of economic organization, and the environmental impacts.

Mamdouh Salameh argues that EVs are going to face an uphill battle against ICEs. And while they are bound to get a share of the global transport system, they will never prevail over ICEs. As a result, ICEs will continue to be the dominant means of transport throughout the 21st century and far beyond.

Marie-Louise Arlt and **Nicolas Astier** note that Public information on electric vehicle charging stations in the U.S. suggests that most stations could be free to use. They may, however, bring indirect revenues to their owners, for example, through bundling. Paid and specialized charging services could play a more important role in the future.

Aasheesh Dixit provides insights into the set of challenges faced by India to promote EV. He discusses the roadblocks, analyses its unique market segmentation and propose business models to accelerate EV penetration. He also examines the opportunity for the country to take a leading role in the world EV market.

API Chief Economists: The Early Days and the Changing Environment in which they Operated

BY RONALD D. RIPPLE

The American Petroleum Institute (API) began in 1919 primarily as a standards-setting organization for the then still relatively young oil and natural gas industry. Not until 1982 did the API designate a Chief Economist. Since then there have been four Chief Economists, and in this Energy Forum we will focus on the first two, Dr. Michael (Mike) E. Canes (1982-2000) and Dr. John C. Felmy (2000-2016), who together account for the first 35 years of the 39 years of this position.[2]

Mike Canes

During their tenure with API (reaching back initially to 1974 for Mike), not only did the energy and political world evolve significantly, but the API also was led by four quite different Presidents. During Mike's tenure, the API Presidency was held by Frank Ikard, Charles DiBona, and Red Cavaney. And, John (whose API tenure began in 1998), who initially worked under Mike, was Chief Economist with Red Cavaney and then Jack Gerard as President.

Each president came from a different background and hence engaged the use of the API economists differently. Mike notes that Ikard, who had been a Congressman from Texas, leaned primarily on lobbying and did not make much use of the economists. DiBona, on the other hand, was trained as an economist and made considerable use of the economics team to carry out research. Indeed, DiBona served as Executive Vice President under Ikard and was the driving force behind building the internal economics capacity of the API. It was during DiBona's tenure that the position of Chief Economist was created, with Mike being the first designee. John observes that Cavaney initially followed Dibona's lead, but as Mike notes his forte was communications. With this emphasis, the economists, and others within API, were put through extensive media training. All were expected to at least support the media efforts of the Institute even if they all did not actually front with the media. The remainder of John's tenure was with Gerard, who also came from a strong lobbying background, being the previous CEO/President of the National Chemical Industry and before that the National Mining Association.

Their tenure at API, both as analysts and Chief Economists also spanned seven U.S. Presidencies, from Ford through Obama, with about one month of the Nixon Administration at the beginning of Mike's stint. The policy evolutions and variations from these Republican and Democratic administrations reflected and affected the evolution observed in both the domestic and international energy sectors.

Mike and John each came to the API with the requisite economics skills and training, and they demonstrated over the years their ability to adapt to changing environments—internal and external—and to serve the mission of the API as the representative body for the oil and natural gas industry at the highest level. Mike completed his PhD in Economics at UCLA, following study at the University of Chicago and the London School of Economics. He then worked as an

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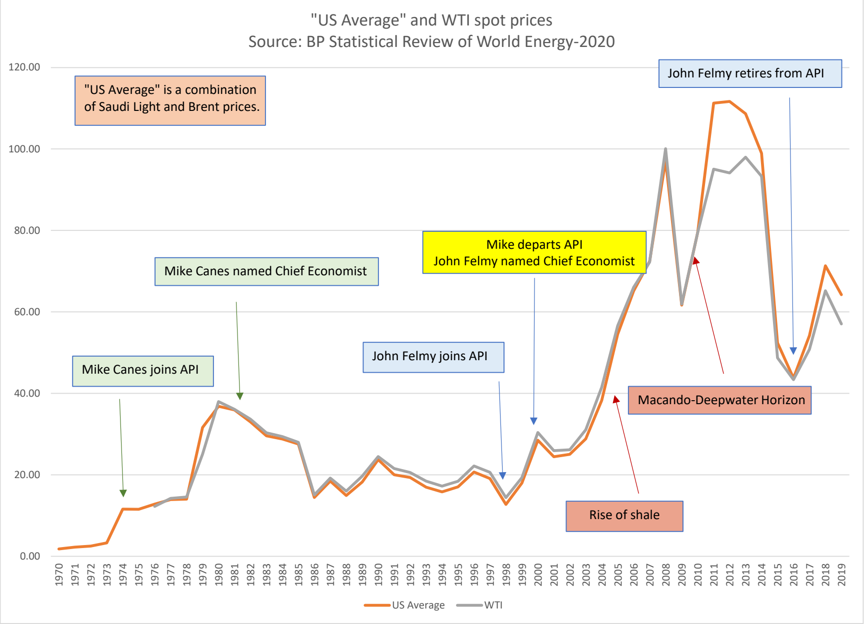


Figure 1

Analyst with The Center for Naval Analyses, where he first met Charlie DiBona. He followed this with a stint as Assistant Professor with the University of Rochester's Graduate School of Management. It was with this education, experience, and an understanding of the economic analyses of price controls and divestitures, quite important to the industry at the time, that he joined the API. He then developed his extensive knowledge of the specific economic workings of the oil and gas markets that provided his foundations to lead and further develop the economics capacity of the API to serve the industry.

John completed his PhD in Economics at the University of Maryland, after earning his Bachelors and Masters at The Pennsylvania State University. He followed this formal economics training with 20 years of consulting, applying his economic analysis skills to a wide range of industries, including significant work in the energy sectors.

John Felmy

The energy world changed and evolved significantly during their combined tenure. Oil prices rose and fell, and U.S. production continued a decline that began in the early 1970s, until shale brought about an amazing and very unexpected resurgence in domestic production.

Figure 1 provides a crude oil price timeline that Mike and John faced during their tenure with API. It is hard to say who dealt with the more difficult public relations communication challenges addressing oil price volatility. Clearly the price rise during John's tenure as Chief Economist was larger in absolute terms, however for the rise in the 2000s the public was more conditioned to volatility than it was for the price increases experienced following the first oil price shock in 1973-74. Prior to the early 1970s, oil prices in the U.S. and the rest of the world had been extremely stable. This stability was severely disrupted by the first oil shock. However, the external price shocks came while domestic price controls were in place[3], so the API economists were first faced with understanding and explaining the implications for the industry and the public of the combination for externally driven price shocks and domestic price controls; they later had to address the implications of the removal of the controls. Throughout this entire period, there was clear need for sound analysis and strong communication skills.

Looking closer to home with the EIA price data for WTI and Brent from the latter part of the 1980s onward, it is clear that volatility ratcheted up. While neither Mike nor John had to deal with explaining a negative price for crude oil, as occurred on April 20, 2020, volatile prices were a part of daily life. Moreover, the volatility, and general persistent price rise during the early 2000s, called upon the API to assist in explaining the causes and dynamics to policy makers and the general public.

Many among the IAEE's *Energy Forum* readership may not be old enough to recall the price controls of the 1970s. This was one of the top issues that the API economists had to address. The oil price controls (ceilings) were part of the overall wage and price controls put in place by President Nixon. The implications of these controls were exacerbated by the first oil price shock. Nevertheless, by today's standards, the prices and their volatility in the 1970s now seem rather modest, as can be observed in Figures 1 and 2. We leapt from $1.80 per barrel (amazing to think of such prices now when the lowest retail price for a gallon of gasoline currently exceeds that price per barrel; in 2019 dollars the $1.80 equates to $11.85, which still equates to just $0.30 per gallon of crude oil).

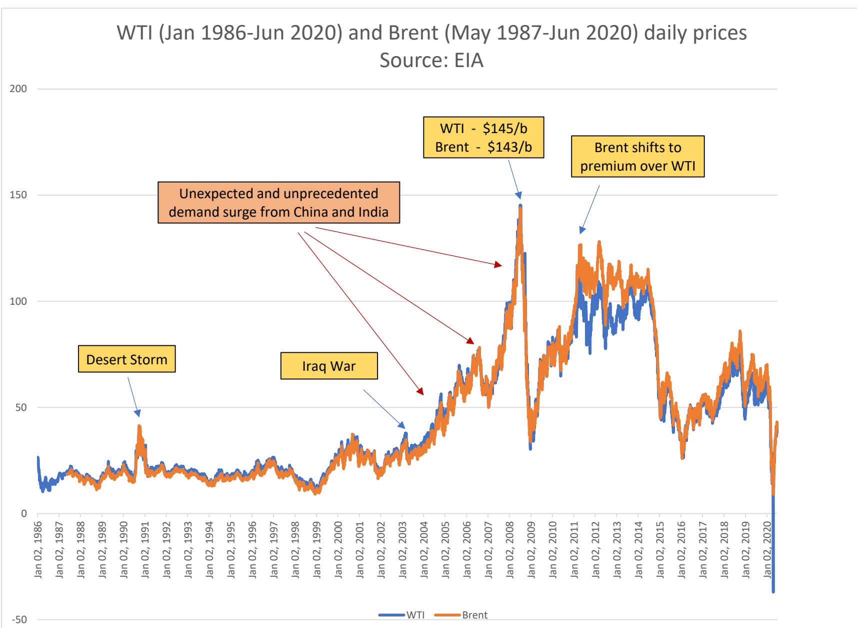


Figure 2

The early 2000s required development of a more complete understanding of a different economic world. Prior to this period virtually all significant crude oil price rises had been primarily driven by supply-side shocks, e.g., the oil embargo (supply reduction) of 1973-74, and the price shocks in 1979-80 related to supply disruptions caused by the Iran-Iraq War. Indeed, the crude oil price decline shock (a significant shock even to U.S.

producers) in the mid-1980s was supply-side driven when Saudi Arabia increased production to discipline OPEC production quota cheaters.

The early 2000s price rise, on the other hand, was driven by the unexpected and unprecedented increase in crude oil demand coming from a rapidly growing China, as well as from India and other developing countries. Such a sustained demand-side-driven price increase was extremely unusual. This led to much debate around what could be driving the increase. Since these are obviously prime economics questions, the API economists, led by the Chief Economist, were called upon to analyze the circumstances and explain it to the policy makers and the public. One significant counter argument to the China demand push on prices was that prices were being manipulated via the futures markets, rather than driven by economic fundamentals of supply and demand balance. The API provided and/or supported much of the economic analyses that went into that debate. The preponderance of the economic analyses came down on the side of prices being driven by economic fundamentals, with the futures markets (including the role of speculators) primarily providing a relatively efficient forum for price discovery (based on fundamentals) and risk mitigation for physical market participants.

At the peak for the Policy Analysis Department (which contained the economics group and was headed by the Chief Economist) in the API there were roughly 20 economists on staff. As industry conditions evolved the numbers ebbed and flowed so that toward the end of John's tenure there were about six. It was apparently contemplated to disband the entire group and to outsource the economic analysis functions toward the end of the 1990s. Interestingly, the anti-dumping legal efforts carried out by the group Save Domestic Oil (SDO) may have saved this function within the API. The charge was that Saudi Arabia and other OPEC members were illegally dumping crude oil into the U.S. market, forcing prices lower, and thus harming domestic producers. In essence, SDO and the counterparties at the time effectively employed all the available oil and gas economics talent in DC and much of the country. This led the API to realize that there are times when external, qualified, economics expertise may be unavailable just when it is most needed to support the industry's interests. This may have cemented the understanding that inhouse economics expertise is indispensable if the Institute is to be able to fully carry out its role of representing the oil and gas industry.

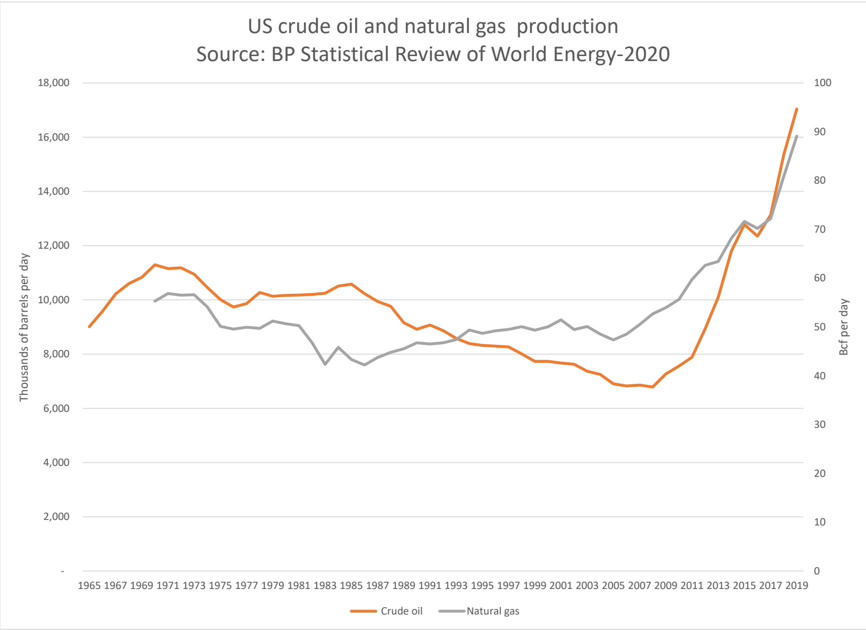


Figure 3

The main method of economic analysis employed was standard price theory, sometimes augmented with econometrics. More sophisticated econometric analyses tended to be conducted by outside consultants and university professors. The bottom line for any of the analysis was that the results must be relatively easily explained to media, politicians, administration policy makers, and be readily encapsulated into TV and radio sound bites for the general public. Communication of the economics ideas and analysis was always the critical point, and it was based on their capacity to deliver on this that the API Chief Economists were chosen.

The API collects and manages significant amounts of industry-related data, which are the primary basis for the statistical analyses conducted inhouse to support oil and gas policy positions, as well as being employed by many external energy economics researchers. The data collection and dissemination functions were at one time independent of the Policy Analysis Department (even though they did report to Mike during his tenure), but during John's tenure this function was brought under his direction. This was likely the acknowledgement of his expertise in this arena (of data collection, management, and marketing) from his years of data management activity in consulting.

While the top-most issues evolved over the tenures of both Mike and John, there were some that continued to be relevant for each of them; indeed some issues like taxes on the industry and questions about pricing certainly predated their tenure and will likely never be off the agenda. During Mike's tenure, the 1970s saw oil industry divestiture and price controls as top issues. During this period Congress was keen to break up oil companies. However, most of us will recall that by the end of the 1990s and very early 2000s major consolidation was what occurred, with the Exxon-Mobil merger in 1999 and Chevron-Texaco in 2000, to name just a couple of the most significant.

Price controls remained in place until 1981 for crude oil and gasoline, when the last vestiges were abolished by President Reagan. During this control period frequent shortages of supply occurred. Natural gas price controls lived on until 1993.

Next on Mike's list of top issues was the proposed BTU tax under President Clinton. The initial proposal was to tax energy use based on heat content, and while some modifications were proposed to shift from heat content to cost, the proposal failed to get through Congress. API and most industry companies opposed the tax; two notable contrarian companies were ARCO and Unocal. Some of the concerns about the tax were that it was biased against oil, and it would have effectively favored coal. There was also concern that it would have led to increased demand for imported gasoline over domestically produced supplies. Also, based on API economic analysis DiBona claimed that the Clinton Administration's cost estimates were far too low and challenged then Energy Secretary Hazel O'Leary to a $1,000 bet that the Administration's numbers were wrong; economics at work. Since the BTU tax legislation failed to be enacted, we will never know for sure whose analysis was right. However, having inhouse economics capacity—both for analysis and communication, and support from external analysts and researchers provided important tools for the API to support public data-based debate and discussion about an important and potentially significant public policy choice.

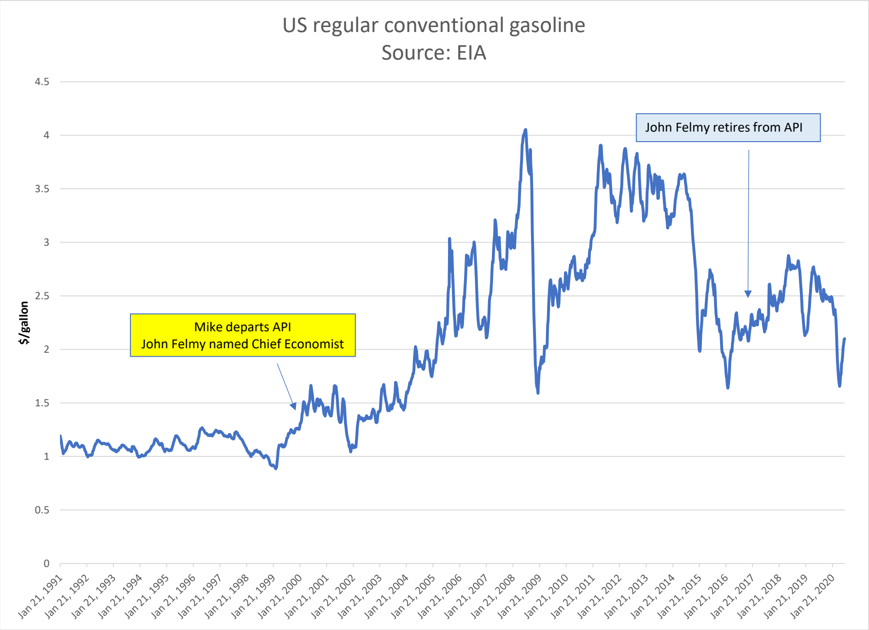


Figure 4

John's tenure as Chief Economist saw the massive increase in natural gas and crude oil production that was facilitated by the joint application of horizontal drilling and hydraulic fracturing within the shale geology, as shown in Figure 3. These technological advances changed the face of the oil and natural gas industry in the U.S. and across the world. The U.S. returned to being the world's largest producer of crude oil and natural gas. The industry, largely through the efforts of the API, had lobbied hard for the removal of the ban on crude oil exports, and these arguments were strongly supported on economics grounds, based on both internal API and external analyses. Due to the combined weight of the economics arguments and the resurgence in domestic production, the Obama Administration removed the tight restrictions on the export of crude oil (December 2015). Further significant debate followed regarding the potential economic consequences of large-scale exports of natural gas in the form of LNG from the lower-48; the U.S. had been exporting LNG from Alaska since 1969. There were weighty arguments and considerable Congressional testimony debating the pluses and minuses of such a development. The API supported the prospect of exporting the natural gas and argued, on economics grounds, that the U.S. would not see significant domestic price increases, as argued by opponents. The U.S. began exporting natural gas in the form of LNG from the lower-48 in February 2016. We have seen no significant increase in domestic prices, and indeed prices have remained relatively low, and low enough to have stimulated the return of natural gas-based petrochemical processing to the U.S. All of this change provoked significant evolutions in the markets and political tension domestically and internationally. This required (and will continue to require) enhanced economic research and analysis to come to a more complete understanding of the new world energy order.

One of the recurring issues that the oil industry faces, and the API Chief Economists have to address, is the level and volatility of gasoline prices[4] (the same is true for heating oil, especially in the winter for the U.S. northeast, but gasoline captures most of the headlines). However, even following the removal of price controls, gasoline prices were modest and relatively stable during Mike's tenure, compared to John's. Figure 4 reports the weekly price of conventional gasoline published by the EIA from 1991 through 2020. The gyrations observed, and lived through, throughout John's tenure kept him very busy explaining the fundamentals of gasoline pricing relative to crude oil prices. This kept him on the road virtually year-round addressing media and state policy makers across the country. His economics skills, as was also the case for Mike, supported by the API economics team and outside analyses, provided the basis for sound discussions, debates, and communication with the public and policy makers.

Additional long-running issues faced by the industry that occupied much of the time for the economists were taxes, access, and regulations. Governments at both the state and federal level have periodically proposed, imposed, and removed taxes on the industry reaching back to the earliest days of the industry. These required engagement and ongoing communication from the API, on behalf of the industry. From the early days of the position, the Chief Economist's responsibilities for this engagement and communication only expanded.

The access issue relates primarily to attempts by the industry to increase access to federal lands for exploration and development and attempts by the government to limit and withdraw access. A seemingly perennial issue, since the 1970s, is the desire to open up (or to counter those attempting to restrict access) the Alaska North Slope for further exploration and production. This desire to expand industry access reached well beyond Alaska to the Gulf of Mexico (including areas of the eastern Gulf), and interest in opening coastal Atlantic areas. Regulatory issues tended to be focused on pipeline developments, and these obviously continue to engage the industry and hence the API even today.

While Mike and John may not be classified as pioneers in energy economics, they and the teams they assembled within the API laid very strong foundations for the role of economics in fact-based, data-based analyses of critical public policy debates for the energy sectors of the U.S. and the world. And, additionally, through their support, the API has been a longstanding supporter of the USAEE/IAEE conferences, which facilitates and supports the presentation of significant economics-based energy policy analyses.

Footnotes

[1] I want to thank Mike and John for generously taking time to engage with me to provide the background that makes this piece possible.

[2] The current API Chief Economist is Dr. Dean Foreman, and between Dean and John Felmy was Dr. Erica Bowman.

[3] President Nixon imposed wage and price controls in 1971 with the aim of countering the effects of inflation.

[4] One recurring issue is the so called "rockets and feathers" question, where it was claimed that gasoline prices increase rapidly with crude oil price increases but fall slowly with crude oil price declines. Both internal API and external economic research tend to find no statistically significant differences.

Regulatory Considerations for Cost Effective Integration of Electric Vehicle Charging Infrastructure

BY: PETER BRODY-MOORE, JOSEPH CAVICCHI, UDAYAN MAITHANI, LINDSAY MATTEI, AND JEFFREY MONSON.

(**Joseph Cavicchi** is a Vice-President, **Udayan Maithani** and **Jeffrey Monson** are Associates, **Lindsay Mattei is** a Senior Analyst, and **Peter Brody-Moore** is an Analyst at Analysis Group. Joseph Cavicchi may be reached at joe.cavicchi@analysisgroup.com.)

See footnotes at end of text

Introduction

Sales of electric vehicles (EVs) in the US were 330,000 in 2019[1] and represented 1.9% of the new light-duty vehicles sold in 2019. Globally, sales of electric cars topped 2.1 million and while the Covid-19 pandemic will affect sales, it is expected that EV adoption will grow as costs decline and automakers shift production toward EVs.[2] Alongside expected growth in EV ownership, US state legislators and regulators are actively formulating policies, and evaluating programs as regulated utilities are expected to play an increasing role in supporting EV infrastructure development.

Depending on state legislative requirements, utility regulatory authorities and the level of involvement of the different stakeholders, the role of the utility can be expected to vary considerably as EV ownership grows. Early experience in a number of countries and some US states shows that EV infrastructure deployment, learning-by-doing and experimentation will be important factors for legislators, regulators and utilities to consider.

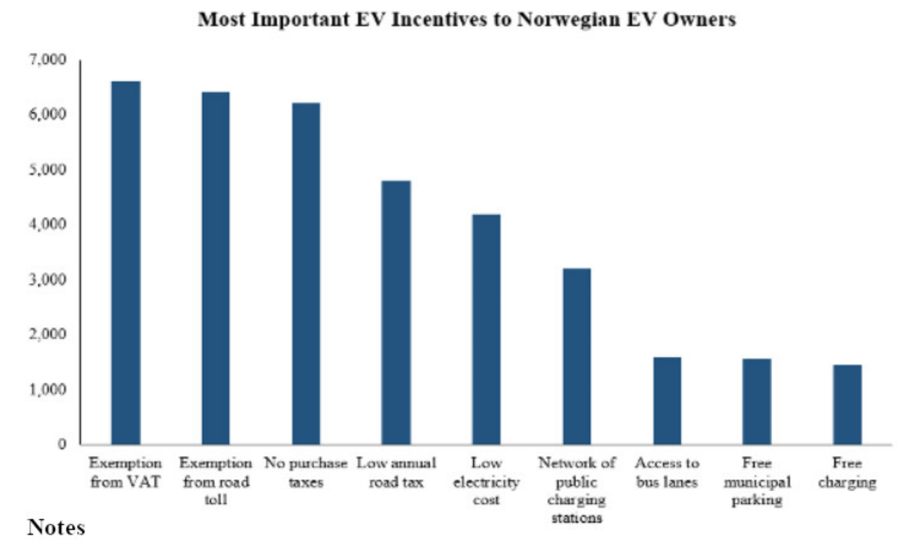
In this article, we examine how Electric Vehicle Supply Equipment (EVSE) and charging stations have developed in some non-US countries and contrast it with the current state of EVSE and charging infrastructure in the US. Based on this experience to date, we identify some key factors that utilities and regulators can consider for effective and efficient EV infrastructure development.

Incentivizing Increased EV Ownership

Experience from other regions and countries reveals that ownership incentives are a key factor for EV adoption, and when EV ownership reaches a high enough level, charging station economics improve considerably. However, while charging station availability is an important consideration for EV owners, early studies show it is not a limiting factor as many early EV adopters are able to use home charging stations.

A study conducted by Energeia reviewed the policy and regulatory framework of leading countries by Plug-In Electric Vehicles (PEV) market share identified several key factors for encouraging the development of PEV models and PEV sales: purchase incentives, government purchase targets, third-party PEV import regulations and fuel efficiency standards.[3] Moreover, in New York, analysis has shown that tax incentives are a key for consumers to replace gasoline-fueled vehicles with EVs.[4]

Similarly in Norway, consumers reported that up-front incentives reducing EV purchase costs are the largest factor when deciding to own an EV (Figure 1). Further, consumers in Norway bought EVs in response to significant vehicle taxes even before much of the charging network was built, where tax exemptions can be worth over half of the retail car price.[5] In particular, Norway's new car purchase taxes, which include the costs of environmental externalities (CO2 and NOx emissions) and Value Added Tax (VAT), increase the cost of gasoline and diesel fuel vehicles such that they exceed EV up-front costs (Table 1). These up-front incentives are an important driver of EV sales. To contrast, in Denmark, even the presence of a much more robust charging network was not sufficient to incentivize EV adoption, as there were fewer up-front



Notes

Put a price on carbon to fund EV incentives - Norwegian EV policy success (2017)

Source

[1] 12,500 Norwegian electric vehicle responded to the 2017 survey

[2] Survey Respondents were asked to select their three most valued electric vehicle incentives

Price Comparison of Electric and Gas Vehicles in Norway

	Audi A7[1]	Tesla Model S[2]	Volkswagen Golf[1]	Volkswagen E-Golf[2]	Volkswagen Up![1]	Volkswagen e-Up![2]
Import Price	319,464	636,000	180,624	259,900	103,621	188,100
CO_2 Tax	125,253	-	31,827	-	19,209	-
NOx Tax	1,525	-	2,263	-	1,276	-
Weight Tax	109,198	-	21,526	-	13,494	-
Scrapping Fee	2,400	2,400	2,400	2,400	2,400	2,400
25% VAT	139,460	-	59,660	-	35,000	-
Retail Price	**697,300 NOK**	**638,400 NOK**	**298,300 NOK**	**262,300 NOK**	**175,000 NOK**	**190,500 NOK**

Notes:
[1] Indicates a gas vehicle
[2] Indicates an electric vehicle
Source:
http://www.ofvas.no/

incentives.6

Further, there is evidence that charging stations can become economically self-sustaining once there is enough EV adoption. In Norway, EV charging stations became self-sufficient when EVs grew to 3% of all vehicles, suggesting "a limited need for public support after a relatively short introduction phase."7 However, data assessing charging station network costs are very sensitive to specific geographic regions and generalized estimates can be misleading.

These factors suggest that EV charging infrastructure should be planned in conjunction with EV purchase incentives; if there are up-front incentives, more consumers are likely to buy EVs, the EV share of all vehicles will increase, and the need to subsidize EV charging stations will be reduced. Thus, a principled economic analysis for the development of EVSE and charging stations can be expected to be an important tool to guide future investment as utilities seek regulatory approval for EV infrastructure investment.

Considerations for EVSE and Charging Station Development

In order to support EV adoption, it is important for EV owners to be able to cost-effectively charge their EVs. Evidence compiled to date, learnings from non-US countries, and pilot projects across US states shows that there are a number of key factors to consider that can help ensure EV owners can access cost-effective charging stations. Some of the factors that utilities/regulators should consider are:

- Sequencing the investment in, and construction of, different types of EV charging sites to ensure complementary growth of EV charging stations. It has been observed that most EV owners use EV for daily commuting and short trips.[8] Ensuring that EV owners can charge at home/workplace can meet charging demand and encourage EV adoption. By prioritizing charging at home (overnight), then at work during the day (if necessary, albeit less so as EV travel ranges are now reaching 300 miles), and then public fast charging (including corridors for longer trips) EV charging infrastructure can develop organically; the development of charging stations meets the expected demand for each type of charging site.[9] Legislators and regulators can evaluate bottlenecks and determine where publicly supported financing may be necessary. For example, not all multi-unit dwellings allow for cost-effective EV charging. Further, potential EV owners that lack off-street parking face a barrier to home charging.[10]
- Planned and thoughtful siting of EV charging stations: by analyzing demographic data and the experience gained from various pilot projects regulators can evaluate policies and programs that allow utilities to identify potential sites for EV charging stations. Demographic data at zip-code level can be used to estimate charging demand and merging it with insights from utility data on customer willingness to host a DCFC or Level 2 charger can help identify potential sites for home/workplace charging. For example, a pilot study conducted for the city of San Diego developed a mathematical model to calculate the demand of public Level 2 chargers using data on zip code, charging behavior, EV range and factors like duration/power consumed in charging an EV. The study concluded that although San Diego had enough chargers to meet the existing demand, the public charging distribution network was neither well designed nor effective in its usage therefore it was recommended to implement charging location priority.[11] Such initiatives can help lead the way in meeting the demand for EV charging adequately and effectively.
- Evaluate utilizing existing gas station networks to increase EV charging connectivity: the adoption of EVs will lead to greater demand for public chargers specifically for non-city travel. The existing gas station infrastructure may be utilized by installing EV chargers at these existing sites. Countries like Germany have taken this initiative, and as part of a broader Covid-19 stimulus plan, Germany now requires all gas stations to offer electric car charging.[12] The move comes as "range anxiety" was identified as one of the main reason for consumers not buying EVs.[13] Within the US, the state of California has budgeted more than $3 billion to electrify transportation with the funding coming from a mix of sources: utilities (San Diego Gas & Electric, Southern California Edison and Pacific Gas & Electric), California Energy Commission, California Air Resources board, and more than $800 million from the Volkswagen settlement.[14] Private players are also getting involved; for example, Chevron is collaborating with EVgo

to provide EV charging stations at Chevron's gas stations.[15]

Also, in the U.S., companies like ChargePoint, which focus on charging station development, also offer "turnkey" solutions for site hosts, removing an additional hurdle from the charging infrastructure deployment process.[16] In Europe, New Motion provides back office services such as billing and payments in addition to building charging stations; EV owners pay a subscription fee for access to the charging network.[17]

While the most common pricing is time-of-use, demand response pricing can manage impact on the grid. In the US, states such as CA and VT have more mature demand response charging tariffs. Lastly, a central database can provide up-to-date information on the whole charging network. China has advanced data collection,[18] and Norway's NOBIL gathers information and distributes it to third parties.[19]

Thus, evaluation of expansions to EV charging infrastructure can include sequencing the types of chargers to accommodate EV owners, relying on data analysis to inform charging site locations, and building on the existing gas station network if economically viable. Moreover, charging station business models that generate additional revenue can be used to improve the economics for charging station investments, and demand response tariffs can provide attractive prices to customers while simultaneously reducing EV charging stations' impact on the power system.

Role of Government/Utilities in EV Charging Station Development

The role of public financial support for EVSE and EV charging stations is evolving and there are a number of considerations that arise when policymakers and regulators evaluate the various approaches that may be adopted to support EV charger accessibility. Three key concerns that emerge are: 1) Ensuring that investment is in the public interest; 2) Minimizing potential public policy interference with market-driven, private investment that is not borne by the public; and, 3) Guarding against electricity consumer cross-subsidization that can result if a subset of customers benefits at the expense of other customers that do not realize the same benefits (i.e., EV owners being subsidized by non-EV owners). Moreover, establishing policies and programs that do not fundamentally change is critical to provide the certainty necessary for investors to be able to access capital at attractive interest rates.

Adherence to a consistent and long-term policy framework supported by government can facilitate charging network development. Predictability of plans and policies over time encourage consumers and industry to invest. For example, consistent support from the parliament helped drive EV adoption and charging station development in Norway.[20] Moreover, governments are using public funds to support the creation of pilot cities/regions and EV corridors.

Although not expected to turn a profit, the goal of early stage investment is to encourage competition among charging providers leading to the growth of early infrastructure and help in identifying the leading business models over time.[21] For example, Germany has eight pilot regions for testing new charging programs.[22] To address the issue of range anxiety, the concern of not finding chargers over long-distance trips, EV charging corridors used in Europe include fast charging, and often target a set distance between chargers.[23] Europe has FastNed in the Netherlands, as well as a network of fast-charging stations between Munich and Leipzig.[24]

However, some experts believe that the US is more episodic and short-term, which creates a more difficult environment to invest in and can impede EVSE and charging station investment.[25] In the US, strong and consistent support at the state and local level is key. For example, in the state of Massachusetts, the Governor signed Senate Bill 2505, An Act Promoting Zero Emission Vehicle Adoption to encourage the purchase and use of Zero emission vehicles. The legislation works to increase access to ZEV charging stations for the general public by prohibiting owners of public charging stations from charging users a subscription or membership fee and requiring the use of payment options available to the general public. Further, the legislation allows municipalities and private businesses to restrict parking spaces specifically for ZEV use. These measures serve to provide convenient and predictable access to EV charging.[26]

In addition, in the US, state regulators often collaborate with different stakeholders to set policy and define standards for EV infrastructure implementation. For example, New York's "Reforming the Energy Vision" includes an economic framework for evaluating the costs and benefits of publicly financed investments that ultimately informed detailed economic analyses of EVSE and EV charging stations in New York.[27]

For example, in New York the state designed a program to incentivize development of EVSE for Level 2 chargers and DCFC.[28] The state of NY commissioned a study to understand and assess the cost-effectiveness of potential utility transportation electrification programs to guide its potential recommendation, in order to publicly back investment of $750 million in EVSE and charging station infrastructure.[29] Importantly, the economic cost-benefit analysis revealed that societal, program participant, and ratepayer benefits will vary widely and depending on the monetization of benefits (for example, environmental externalities) and the inclusion of tax incentives, benefits may or may not exceed costs.[30] Similarly, in Massachusetts the Department of Public Utilities (DPU) put in place a regulatory policy that identified principles it would consider when evaluating utility proposals to develop, and in some instances own, EVSE and charging stations. The DPU noted that: "For Department approval and allowance of cost recovery, any proposal must: be in the public interest; meet a need regarding the advancement of EVs in the Commonwealth that is not likely to be met by the competitive EV charging market; and not hinder the development of the competitive EV charging market."[31] The DPU has applied its principles and in doing so turned down a proposal by National Grid to spend $140 million on a large proposed program.[32] In addition, in California, the California Public Utilities Commission (CPUC) has instituted a "balancing test" that weighs the benefits of utilities owning and operating EVSE against the potential anticompetitive nature of utility ownership on a case by case basis.[33] Such intervention by policymakers can ensure that private market participants are not crowded out by public investment.

Policymakers and regulators should carefully evaluate the various approaches available to support EV charging system development. Guiding investment based on careful analysis is a viable public policy solution, as the large number of charging options and significant variation in costs across these options allows for a mix of public and private investment. This requires flexible regulatory frameworks that can be used to assess private and utility proposals to build and own EVSE and charging station hardware. While government support and policies that may support utility investments appears required for the development of EV charging infrastructure in the near-term, it is important to ensure that government intervention does not adversely affect the development of a competitive market for EV charging infrastructure.

Footnotes

[1] https://insideevs.com/news/393629/us-plugin-sales-charted-2019.

[2] https://www.iea.org/reports/global-ev-outlook-2020.

[3] Australian Electric Vehicle Market Study, May 2018, Energeia, at 20.

[4] Benefit-Cost Analysis of Electric Vehicle Deployment in New York State, Feb 2019 at 29.

[5] Example: Audi A7 has 375,436NOK in taxes for 697,300NOK retail price, while Tesla Model S has no taxes for 638,400NOK retail price (2,400NOK scrapping fee is included in retail price for both). See Put a price on carbon to fund EV incentives -- Norwegian EV policy success, October 2017, EVS30 Symposium, at 4.

[6] Charging infrastructure experiences in Norway -- the worlds most advanced EV market, October 2017, EVS30 Symposium, at 9.

[7] Charging infrastructure experiences in Norway -- the worlds most advanced EV market, October 2017, EVS30 Symposium, at 10.

[8] Australian Electric Vehicle Market Study, May 2018, Energeia, at 35.

[9] Australian Electric Vehicle Market Study, May 2018, Energeia, at 5.

[10] In response to this issue, the UK took steps to promote curbside residential charging. See Emerging Best Practices for Electric Vehicle Charging Infrastructure, October 2017, ICCT, at 11.

[11] Development of an assessment model for predicting public electric vehicle charging stations, 2018, European Transport Review, at 8.

[12] Germany will require all petrol stations to provide electric car charging, Reuters, June 2020 at https://www.reuters.com/article/us-health-coronavirus-germany-autos/germany-forces-all-petrol-stations-to-provide-electric-car-charging-idUSKBN23B1WU.

[13] Germany to Require EV Chargers at Gas Stations, June 2020, at https://www.convenience.org/Media/Daily/2020/Jun/8/6-Germany-Require-EV-Charger-Station_International.

[14] Here's how much California is spending to put electric cars on the road, The North Bay Business Journal, at https://legacy.northbaybusinessjournal.com/industrynews/technology/9254147-181/california-electric-vehicle-transportation.

[15] Chevron starts deploying EV charging stations at its gas stations, Electrek, May 2019, at https://electrek.co/2019/05/20/chevron-ev-charging-gas-stations.

[16] ChargePoint also provides additional services to customers as well as advertising to generate revenue beyond electricity provided for charging. See https://www.chargepoint.com/about.

[17] See https://newmotion.com/en.

[18] Electric Vehicle Charging in China and the United States, February 2019, Columbia Center on Global Energy Policy, at 57.

[19] https://info.nobil.no/eng.

[20] Policies include removing purchase taxes on EVs in 1990, exemptions from road tolls in 1997, 50% reduced company car tax in 2000, and exemptions from VAT in 2003. See Put a price on carbon to fund EV incentives -- Norwegian EV policy success, October 2017, EVS30 Symposium, at 2.

[21] Emerging Best Practices for Electric Vehicle Charging Infrastructure, October 2017, ICCT, at 28.

[22] Emerging Best Practices for Electric Vehicle Charging Infrastructure, October 2017, ICCT, at 11.

[23] Evolution Electric vehicles in Europe: gearing up for a new phase, Amsterdam Roundtable Foundation, 2014, at 33.

[24] See Evolution Electric vehicles in Europe: gearing up for a new phase, Amsterdam Roundtable Foundation, 2014 at 33.

[25] Electric Vehicle Charging in China and the United States, February 2019, Columbia Center on Global Energy Policy, at 56.

[26] See https://www.mass.gov/news/governor-baker-signs-electric-vehicle-promotion-legislation.

[27] See http://www3.dps.ny.gov/W/PSCWeb.nsf/All/8C1741CD17739013852582F30056EEE8?OpenDocument#ElectricVehicles and Benefit-Cost Analysis of Electric Vehicle Deployment in New York State, Feb 2019.

[28] Proceeding on Motion of the Commission Regarding Electric Vehicle Supply Equipment and Infrastructure, New York State Department of Public Service, 2020.

[29] Proceeding on Motion of the Commission Regarding Electric Vehicle Supply Equipment and Infrastructure, New York State Department of Public Service, 2020.

[30] Benefit-Cost Analysis of Electric Vehicle Deployment in New York State, February 2019 at 79.

[31] Order on Department jurisdiction over electric vehicles, the role of distribution companies in electric vehicle charging and other matters, DPU 13-182-A, Department of Public Utilities, August 2014 at 14.

[32] See Petition of Massachusetts Electric Company and Nantucket Electric Company, each doing business as National Grid, pursuant to G.L. c. 164, § 94 and 220 CMR 5.00, for Approval of General Increases in Base Distribution Rates for Electric Service, Department of Public Utilities.

[33] See Phase 2 Decision Establishing Policies to Overcome Barriers to Electric Vehicle Deployment and Complying with Public Utilities Code Section 740.2, Rulemaking 09-08-009. Note that more recently, the CPUC released a proposal for a new transportation electrification framework (TEF), but it appears to still be cautious about publicly supported utility investment crowding out private competitors. See also, Phase 1 Decision Establishing Policy to Expand the Utilities Role in Development of Electric Vehicle Infrastructure, Application 14-04-014.

Driver Experiences with Electric Vehicle Infrastructure in Ontario, Canada and the Implications for Future Policy Support

BY PHILIP R. WALSH AND RANJITA SINGH

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See footnotes at end of text.

On the 14th of February this year, Canada's Minister of Innovation, Science and Industry announced that the Canadian government was investing $8 million to construct 160 fast chargers for electric vehicles at 73 locations in the Province of Ontario. The federal policy on energy and the environment has included the goal of encouraging the purchase of electric vehicles (EV) by Canadians as part of a strategy to reduce greenhouse gas (GHG) emissions.[1] From 1990 to 2017, emissions from the transportation sector in Canada grew by over 40% accounting for approximately 24% of total national GHG emissions (174 megatonnes of CO_2eq) and second only to emissions from the oil and gas industry.[2] The Greater Toronto and Hamilton area (GTHA) is both Ontario's and Canada's densest urban corridor and as such is faced with significant transportation-related challenges such as traffic congestion and local pollution. With increasing national environmental consciousness, federal government policies have re-focused their attention on urban reform and GHG emission reduction goals. Electrification of transportation is considered important to meeting those goals and as part of that strategy, government policy has specifically targeted the expansion of EV-charging infrastructure. Provincial policies in British Columbia and Quebec have provided purchase rebates for EVs since 2011-2012 and when the Ontario government cancelled its rebate program in 2018, the federal government introduced its sales rebate program in early 2019. These policies have combined to encourage the adoption of both battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEVs) in Canada (Figure 1).

The government's technology push strategy can contribute to assisting in the diffusion of EVs in the marketplace but a certain level of technology pull is also required. Consumer acceptance of EVs is essential and recent studies in North America have shown that in addition to the common dissatisfaction with the higher initial pricing of EVs, consumers remain concerned about EV performance and access to charging facilities.[3] These concerns are driven to some extent by widespread misinformation and misunderstandings about the technology and, regardless of government policy to provide financial incentives to purchase, there remains anxiety on the consumer's part about the distance that EVs can cover per charge and the availability of charging infrastructure. Accordingly, this "range anxiety" persists as a major barrier to EV adoption in Ontario and the user-grid interaction has clearly become a priority for government, as reflected by their policy at improving and optimizing access to EV charging infrastructure.

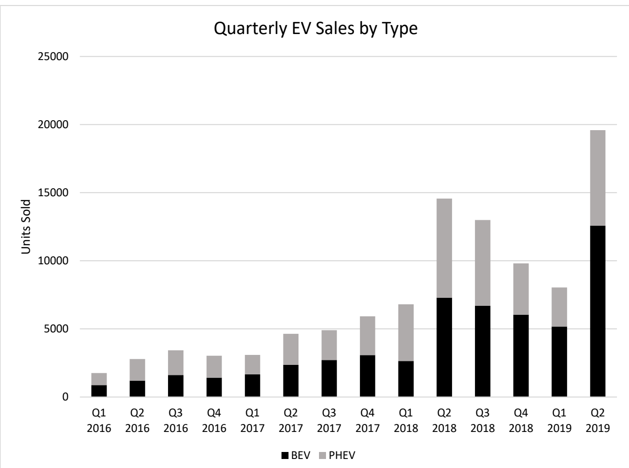

Figure 1 – EV Sales by Type (Source: Electric Mobility Canada)

In examining if the Canadian government's policy of investing in expanding EV charging infrastructure would be beneficial to the future adoption of EVs it helps to understand what current EV owners are experiencing in regards to range and availability of charging infrastructure. The justification of focusing on current EV owners instead of the broader car owner population is two-fold: first, technology adoption models consider ease of use and relative cost advantages as significant predictors of successful market diffusion and second, actual experience is preferred over perceptions. In 2017, a survey conducted by Plug'n'Drive, a Toronto-based non-profit organization that promotes EV use, asked 192 EV owners who live in the GTHA a series of questions pertaining to their experiences post-EV purchase. Access to that data was provided to us for further study and review. The outcomes of that study provided some interesting observations. Range anxiety turned out to be a relatively minor issue in contrast to non-EV owner perceptions with only 14% of EV drivers expressing dissatisfaction with the distance that can be travelled on a fully-charged battery. When it came to driving distances greater than 100 kilometers, approximately three-quarters of respondents used their EVs to do so entirely (~54%) or sometimes (~20%). In terms of charging infrastructure, more than two thirds felt that electric charging systems were not complicated. This latter observation is likely due to the fact that over eighty percent of the EV owners surveyed had purchased vehicles that were plugged into regular 110V-120V electric wall outlets and most relied on overnight charging all of the time or some of the time (~83%). It also appears that their home or office charging experiences have eased their concerns about the complexity of faster AC Level II charging systems and DC Fast Charging systems. In regards to the time it took to charge their EVs at home or work, a significant level of satisfaction (Figure 2) was found with only a smaller number of owners having been dissatisfied with the time it took to charge their EV while at home (~5%) or at work (~15%). However, EV owner satisfaction with charging away from the home or work tells a different story, with nearly half of those who were on the road being dissatisfied with the time it took to charge their EV. This was especially true when travelling longer distances along highways and in need of charging quickly (Figure 3) with only a minority of surveyed EV owners being satisfied with the availability of AC Level 2 charging stations (~27%) and a slightly better satisfaction result for highway DC Fast charging stations (~41%). From the ease of use perspective, this dissatisfaction with charging time and availability of charging infrastructure when away from the home or work can present itself as a potential barrier to adoption. An examination of the data in terms of the relative cost advantages of the EV when compared to a conventional internal combustion engine (ICE) vehicle found that a significant percentage of EV drivers were saving money on fuel (~85%) and maintenance (~79%) and most were satisfied with the associated cost of installing their charging system (~59%). The data gathered was subjected to correlation analysis to identify any statistically significant relationships between the EV drivers' current experiences and their willingness to consider purchasing an EV again. Generally, the EV drivers who were surveyed would likely do so (~88%) again supporting the importance of user experience with the technology as a significant driver for adoption. Of all the experience variables

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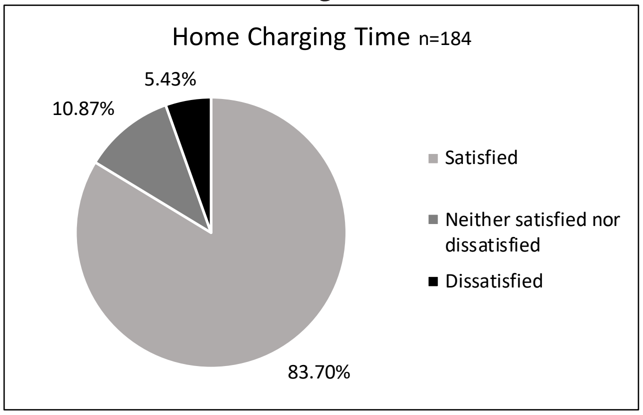
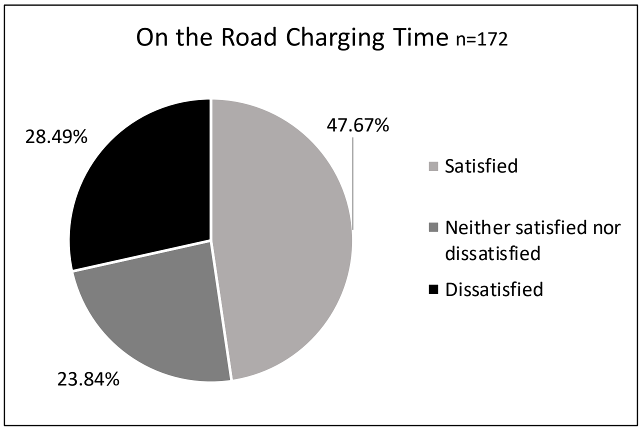




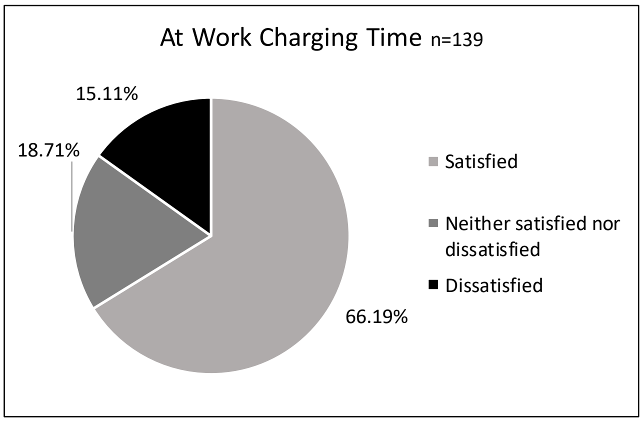
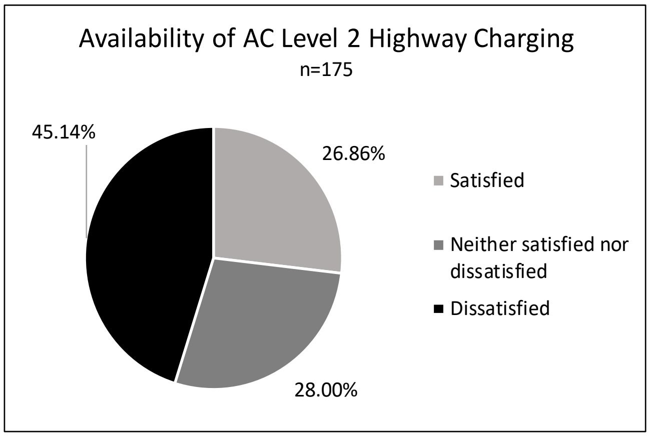


Figure 2. EV User Satisfaction - Charging Time at Various Locations



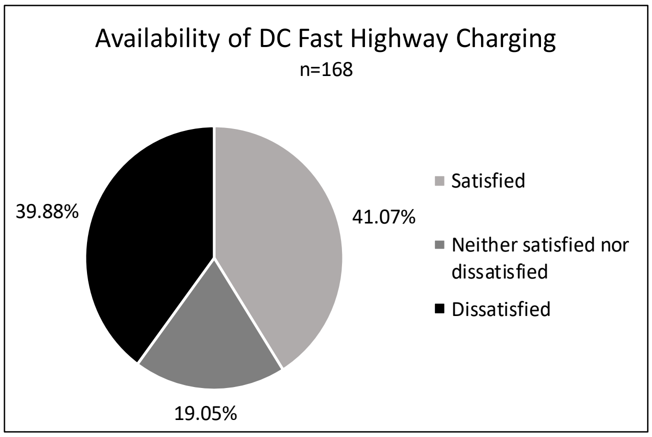


Figure 3. EV User Satisfaction - Highway Charging Availability

Electric Vehicle Charging: Impacts on European Energy Systems and CO_2 Reduction

BY PHILIPP ANDREAS GUNKEL AND CLAIRE BERGAENTZLÉ

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Context and Method

Electricity systems are undergoing deep transformations to reach full decarbonisation. Not only are changes in the means of production necessary to the integration of Variable Renewable Energies (VRE), but new challenges are also arising on the consumption side, due to the continuous growth of electricity demand. Especially, the market uptake of Electric Vehicles (EV) can result in important threats for the electricity system. In the meantime, EV also consists of a source of flexibility to balance VRE production, thereby accelerating the decarbonisation of electricity mix. With the upcoming growth of EV, existing electricity systems will face important risks due to the increasing load effects, which are difficult to predict in detail. A charging process that flexibly reacts to electricity price and network signals can, however, offset these risks. EV charging can then in turn support the integration of low-cost, competitive VRE technologies while acting for a more reliable system.

This paper investigates the effects of flexible charging schemes such as smart charging and vehicle-to-grid on energy system development in Northwest Europe from 2020-2050. It shows how EV affects the energy landscape in the electricity and heat sector and highlights how flexible charging can give rise to cross-border decarbonisation strategies.

Three main concepts for EV charging are available. Passive charging (PC) is the current state of the art. The EV battery charges at full charger capacity as soon as it is connected to a charger. It is expected that large numbers of vehicles will start charging during late afternoon when people return from work. Consequently, substantial loads are added to the already existing peak in electricity consumption, which can lead to congestion and cause severe issues for electricity supply. The alternative to PC is smart charging (SC). In the enrolment process of dynamic prices on household level, SC gets more and more applied. SC allows shifting the charging process to hours of low prices while ensuring to offer enough energy in the battery at all times. This charging scheme therefore supports cost savings at the household level, limits the need for backup capacities, while it simultaneously prevents network congestion. The third charging process is called Vehicle-to-Grid (V2G). While SC charges the vehicle in only one direction, V2G gives the option to discharge the battery and to provide services to the grid. This is done by a simple upgrade of the previously installed unidirectional charger to a bidirectional charger. V2G offers the opportunity to actively participate in several electricity markets and balancing of energy by buying, storing and selling electricity at appropriate times.

This paper investigates the impact of the three EV charging schemes on future European electricity and heat systems and greenhouse gas emissions. The fundamental areas and questions this paper aims to shed light on are:

- How increasing flexibility in EV charging affects electricity and heat mix and generation?
- What effects on CO_2 emission mitigation does each EV charging scheme have?

The energy system model Balmorel is applied to determine optimal investments into production and the operation of units in Northwest Europe in the annualized decades from 2020-2050 [1]. The model includes a progressive CO_2 tax and a net-zero emission goal in 2050 for the entire modelling region for a steady integration of VRE. Assumptions on policies and data are taken from the Flex4RES project[2]. The transmission system is expanded according to the ENTSO-E ten year network development plan until 2030 and capacities are fixed for the following decades. It is assumed that approximately half of the national vehicle fleets are electrified with battery electric vehicle (BEV) and plug-in hybrids (PHEV) in 2050 with a gradual increase [3]. It is focused on charging at home to simplify the problem of space. Three different scenarios are investigated. PC acts as a base case, which is used as a comparative scenario for SC and V2G. Finally, this study develops a methodology for EV availability and consumption patterned from the Danish National Transport Survey [4]. The model considers limited availability and state-of-charge targets of EV. Furthermore, the methodology includes a battery degradation model, which converts calendrical and cyclical aging of the battery into cost. The battery degradation model helps to not only prevent uneconomical charging but also allows for lifetime extension of the battery itself.

Results and discussion

The Northwest European electricity production is shown for PC in Figure 1. This provides the baseline against which the scenario with SC and V2G are compared in Figures 2 and 3.

In this baseline scenario, the main changes in the electricity mix are driven by the progressive CO_2 tax. The tax takes out of the mix the thermal power plants using fossil fuels, starting with coal that is entirely

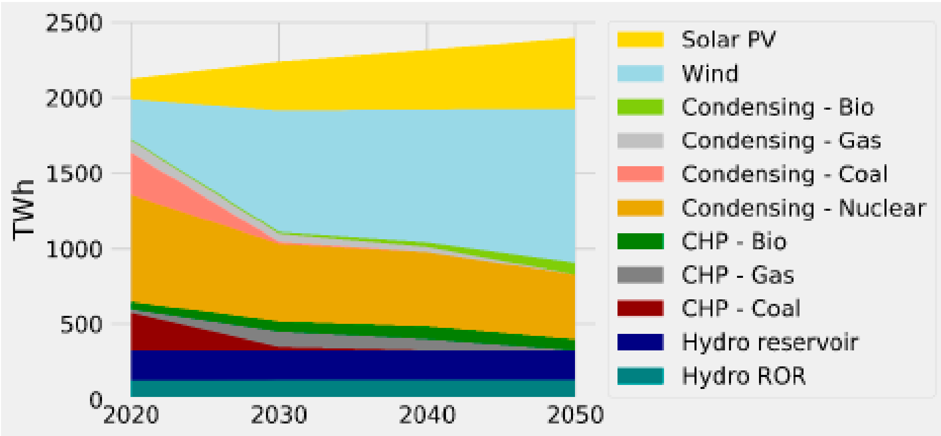

Figure 1 Electricity production in Northwest Europe by technology while integrating EV using PC charging scheme from 2020 until 2050 [3].

phased out in the 40's. CHP plants using natural gas increase their output until 2030 and produce approximately 75 TWh more than in 2020. In 2050, all the fossil fuels-based units are phased out in response to the applied zero emission cap. From the 30's, the largest share of electricity is produced by VRE technologies. Solar PV produces around 473 TWh of electricity, whereas wind power contributes most with 1019 TWh in 2050. In this set-up, the major flexibility provider is hydropower, especially coming from Norway and Sweden, and new capacities utilizing biomass in condensing power plants and CHP. Finally, baseload technologies (nuclear and run-of-river hydro) keep a relatively stable share of electricity production throughout the period, the oldest decommissioned piles being to some extent replaced by the new EPR reactors. Overall the results show, that passive charging vehicle are not a threat towards a carbon neutral electricity production and VRE produce the largest share.

Figure 2 presents the variations in electricity production induced by SC and V2G compared to the base scenario with PC

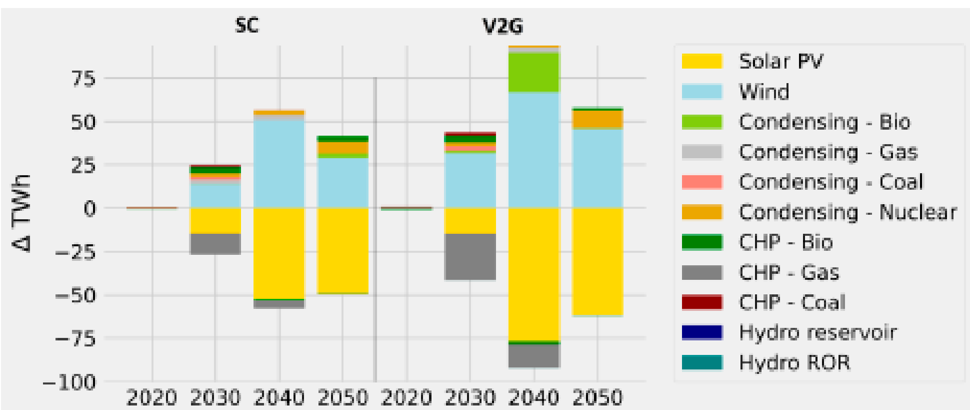

Figure 2 Difference in electricity production of SC and V2G compared to the base case PC from 2020 until 2050 [3].

Increasing the flexibility of EV charging results in three main impacts on the power mix. First, more flexibility generates a substitution of solar PV by wind. With PC, EV charge immediately when car users arrive at home with full charger capacity. Therefore, the major part of the load is situated in the late afternoon hours. In this time, solar PV produces more reliable electricity, compared to wind, which does not follow a comparable daily pattern. With more flexible charging schemes, charging hours are more spread in time. Solar PV is less invested in and contributes less to total production, especially in 2040 and 2050 with -50 TWh to -76 TWh (-10.5% and -13.1% compared to PC). The main part of this loss of production is substituted with wind power. Besides, flexible charging concentrates charging times to low residual load hours when electricity is cheap, further increasing the final use of wind energy output.

Second, SC and V2G, by definition, avoid charging during peak hours. This load shifting from peak to baseload hours directly reduces the participation of gas-based CHP power plants. In the 30's, when natural gas still participates substantially to the mix, passing from PC to V2G lowers by 26.6% gas plants production.

Third, the more flexibly EV are charging, the better can baseload technologies cover demand. EV charging shifts to baseload hours. This increases full load hours for large power plants such as nuclear, which increase their production by between 8-12 TWh, or up to 2.5% in 2050.

Our results also point out the impact of EV charging across sectors. We show that more flexibility in EV charging limits the electrification of the heat sector. The reduction of peak prices on the wholesale electricity market limits the business case for highly flexible gas-based CHPs as described earlier. Besides, due to this increased flexibility on the demand-side, average electricity prices increase and price fluctuations simultaneously decrease. As a consequence, the deployment and operation of power-to-heat equipment such as heat pumps and electric boilers are negatively affected. The overall electricity production is therefore lower in SC and in particular in V2G compared to PC, because the heating sector uses more biomass. Cross-sectoral competition effects can subsequently be expected in the future. This competition affects investment decisions not only from households, but also from utilities reacting on available flexibility sources on the consumer side.

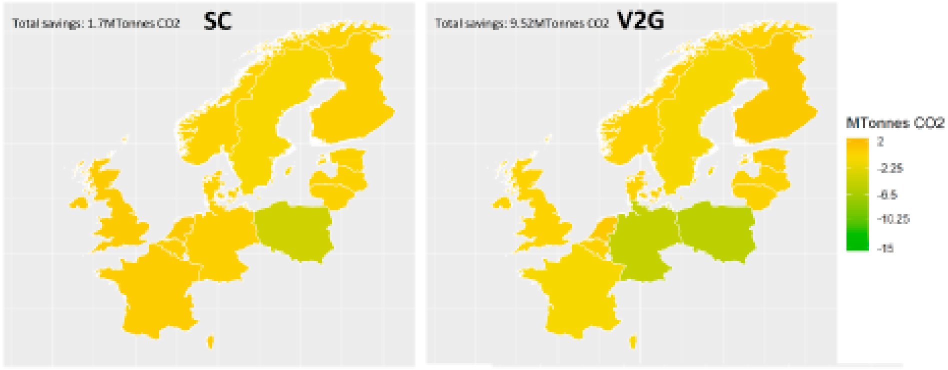

Figure 3 Cumulative reduction of CO_2 emissions in Northwest Europe compared to the base case PC from 2020 to 2050 [3].

Figure 3 summarizes the cumulative saving effects from EV charging schemes on CO_2 emissions compared to PC.

Distributional effects take place when improving the flexibility of EV. The overall emissions savings go up to 1.4%. The largest mitigation takes place in Central Europe. Mainly Poland and Germany achieve better results when EVs charge with V2G. The reduction of CO_2 emission are 5.23 mTonnes of CO_2 in Poland and 4.65 mTonnes CO_2 in Germany compared to the base case. At the same time, other countries pollute more than before, such as Netherlands and Denmark. They emit together approximately 1 mTonnes CO_2 more than in the PC scenario. The main reason for that are the overall positive effects when adjacent countries support the high emission energy systems of Poland and Germany. As both electricity sectors are strongly dependent on coal, the optimization suggests that surrounding countries such as Denmark produce more electricity using their high efficient CHP plants. Low efficient gas and coal condensing power plants in Germany and Poland are therefore substituted.

In addition, EVs with V2G contribute with their storage capacity to absorb the volatile wind production and discharge electricity when needed. This also allows utilization of existing transmission capacities more efficiently, because electricity from VRE is stored for several hours and injected as well as exported again when wind and solar production is low. Consequently, it is expected that flexible EV can not only support the integration of VRE locally, but also strengthen the utilization of interconnection and therefore serve European efforts for greenhouse gas mitigation. In particular in the case of a less progressive CO_2 pricing, it is expected that the overall emission reduction as well as distributional effects are stronger with flexible EV.

Conclusion

In a future where EV are passively charged and create substantial peak effects on electricity supply, decarbonised energy system get more balanced by the supply-side and more specifically by hydropower and biomass power condensing plants as well as CHPs. However, solar PV and wind power are still the largest contributors to electricity generation with EV using PC, whereas polluting power plants are phased out.

The energy system adapts with the introduction of SC and V2G. Wind energy is the main benefiter of the growing flexibility provided by SC and V2G charging schemes in Europe. This is both visible in terms of additional installed capacities and production and is attributable to a double dynamics. On the one hand flexible charging facilitates load shifting to the hours where large quantities of wind (and solar) energy is produced. It thereby releases the constraint on increasing the production of (carbon free) electricity during restricted periods of charging as it is the case with PC. On the other hand, in the case of V2G, extra flexibility services are provided to the system, not only to absorb production surpluses, but also to provide balancing services when VRE output drops.

Flexible EV charging also creates losers in either accelerating the downfall of some technologies or slowing down the uptake of others. Flexible plants with high marginal cost like gas power plants are among the first technologies who suffer from demand-side flexibility, as already well described in the literature. Flexible EV charging is no exception to the rule due to its direct impact on price variation. The other less scrutinized impact of flexible charging is on the heat sector and its substitution to power-to-heat technologies and subsequent thermal storage. This competing effect between flexible EV charging and heat electrification calls for a better appreciation of the links between both sectors in the design and implementation of suited integrated regulatory frameworks for flexibility and storage.

The mitigation of CO_2 emissions is greatly supported by flexible EV charging schemes. Distributional effects get furthermore visible. While countries such as Poland and Germany can significantly reduce their emissions, surrounding countries increase slightly their CO_2 emissions. The slight rise in some countries are however more than offset by countries with historically large shares of coal in their mix. This suggests that flexible EV not only supports local integration of VRE, but also strengthens cross-country trade, and subsequently the mitigation of European emissions. In order to strengthen the role of EVs in energy systems, policy barriers need to be addressed to facilitate flexibility and to pick low-hanging fruit. At the same time, distributional effects along several countries and regions may create conflicts. We therefore suggest further research on cross-border and cross-sectoral impacts of EV integration to support stakeholder and policy makers with data-driven and robust policy recommendations for optimal decision-making.

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Walsh (continued from page 16)

measured, there was only one that had a significant and moderate negative effect on the likelihood of not purchasing another EV and that was the EV user experience with the time it takes for them to charge their EVs when on the road. The levels of dissatisfaction with availability of charging stations does not appear to be a significant barrier to their continued purchasing of an EV.

While investment in infrastructure is important to future EV adoption, the principal challenge that remains is the initial conversion of ICE drivers to EV owners. The evidence from our study seems to imply that once they have experienced driving an EV they are likely to realize that their range anxiety is unfounded and that the technology works. Continued financial incentives to assist in purchasing an EV would help lower the initial price of the vehicle but the cost of such incentive programs, and the political resistance to them, can be avoided if instead, government policy was designed to influence industry financing of EVs so that the monthly cost to the consumer, net of the fuel and maintenance costs, would be lower than if they drove an equivalent ICE vehicle. Once converted, our study suggests that federal government investment in EV charging infrastructure in urban areas will then be beneficial for a number of reasons. Firstly, the investment will assist in attracting the ICE driver, as it would provide a positive optic to help alleviate concerns about being able to charge their EV when and where needed. Second, increasing the availability of EV charging stations outside of the home or work would reduce user dissatisfaction and improve ease of use. Finally, the added investment in charging infrastructure would mitigate what appears to be a barrier to the continued use of EVs by improving charging times when the driver is away from home or the office. These findings confirm the need for continued policy support on the part of the Canadian government to encourage technology advances in EV charging in order to stimulate increased demand for EVs. They also suggest that additional study is required to better understand the electricity system demands associated with encouraging EV drivers to fast charge during peak hours instead of doing so off peak at home and overnight.

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Assessing Singapore's Electric Vehicle Policies

BY TILAK K. DOSHI AND NAHIM B. ZAHUR

Introduction

Singapore begun exploring the option of adopting electric vehicles (EVs) in the late 2000s. In 2009, the Land Transport Authority (LTA) and the Energy Market Authority (EMA) launched the EV Phase I test-bed in order to assess the feasibility of a larger-scale roll-out of EVs in Singapore[1]. After the conclusion of the Phase I test-bed in 2013, the LTA and Economic Development Board (EDB) announced Phase II of the EV test-bed in 2014. Phase II is focused on fleet electrification and electric car-sharing, in contrast to Phase I which focused on individual corporate users[2]. Under Phase II of the test bed, Singapore is expected to involve the launch of over a 1,000 EVs and 2,000 charging stations by 2020[3].

More recently, Singapore has made a much bigger push towards the adoption of EVs. In February 2020, Singapore announced the ambitious target of phasing out internal combustion engine (ICE) vehicles entirely by 2040[4]. The Singapore government concurrently announced the introduction of a number of policies in order to achieve this target[5]. First, the existing Vehicular Emissions Scheme, which involves the use of tax rebates and surcharges as a function of a vehicle's emission levels, was extended to light commercial vehicles. (It previously covered cars and taxis). Second, the government introduced an EV Early Adoption Incentive, providing a rebate of up to 45% on the Additional Registration Fee for purchases of EV cars and taxis from 2021 to 2023 (capped at S$20,000). Third, the road tax for EVs and some hybrid vehicles was reduced. Finally, the government announced that it will substantially expand the EV charging infrastructure, from 1600 charging points to 28,000 charging points. To compensate for the shortfall in excise duties from fuel sales, the government will instead charge a lump sum tax for EVs starting at S$100 in 2021 and increasing to S$350 from 2023 onwards[6].

Singapore's electric car population equalled 1,125 in early 2020, or just 0.18 per cent of the total population of vehicles.[7] Thus the target of phasing out ICE vehicles by 2040 is highly ambitious and marks a significant departure from Singapore's earlier transportation policies. It is not yet clear whether "cleaner" categories of ICEVs, such as hybrids, will be phased out.[8] It is also unclear whether the target of phasing out ICE vehicles by 2040 constitutes a hard target that will be achieved if necessary through regulations, though the policies announced so far (such as the tax rebate or the reduction in road tax) suggest that the government is taking a largely market-based approach towards incentivizing EV adoption.

Environmental Externalities in the Transport Sector

From the perspective of economic efficiency, policy interventions that affect individuals' choices of whether to drive an EV or an ICEV are only justified if they correct an existing market failure. There are two key environmental externalities to consider. Firstly, pollutant emissions from ICEVs (e.g., emissions of particulate matter (PM), oxides of nitrogen and sulfur, carbon monoxide) are damaging to human health.[9] Secondly, CO_2 emissions from ICEVs contribute to global warming and thereby generate a negative externality: the "social cost of carbon" (SCC) is the marginal damage generated by an additional unit of CO_2 emissions. The size of these negative externalities is what determines the extent to which government intervention is justified.

Formulating an appropriate policy response to the negative externality caused by carbon emissions, in particular, poses considerable conceptual and practical challenges. Firstly, estimating the SCC is fraught with difficulties. The usual approach towards estimating the SCC is to rely on Integrated Assessment Models (IAMs) that "integrate a description of GHG emissions and their impact on temperature (a climate science model) with projections of abatement costs and a description of how changes in climate affect output, consumption, and other economic variables (an economic model)".[10] The results from these models are, however, sensitive to crucial assumptions regarding the value of equilibrium climate sensitivity (or the expected global warming due to a doubling of accumulated greenhouse gases in the atmosphere), the discount rate, and the damage function. A recent review concluded that these issues are severe enough to warrant IAMs "close to useless as tools for policy analysis," which in turn naturally implies a considerable degree of uncertainty of the SCC estimated through these models.[11]

A brief survey of recently published SCC estimates is indicative of this uncertainty. Nordhaus (2017) estimates an SCC of $37/ton in 2020 under baseline assumptions (measured in 2010 US dollars), with a range of $22/ton to $140/ton depending on the discount rate adopted.[12] Even holding the discount rate fixed, a recent analysis based on several of the leading IAMs suggests that the SCC in the year 2020 (measured

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See footnotes at end of text.

at constant 2005 US dollars) ranges from $2/ton to $55/ton, due to uncertainty over population growth, total factor productivity and equilibrium climate sensitivity.[13] The equilibrium climate sensitivity plays a key role in determining the SCC. A recent study suggests that using empirically grounded estimates of this parameter would reduce the SCC in 2020 from $12/ton to $7/ton in the DICE model (using a 5% discount factor) and from $2.5/ton to -$0.5/ton in the FUND model.[14] The uncertainty over SCC also reflects uncertainty over the extent to which accelerating plant growth caused by CO2 emissions can help modulate global warming.[15]

Secondly, the optimal Pigouvian tax to place on carbon emissions equals the SCC only when all parties adopt a uniform carbon tax. In a world where different national jurisdictions adopt different policies on regulating carbon emissions, a Pigouvian externality tax imposed unilaterally in one jurisdiction (such as Singapore) inevitably leads to carbon "leakage": the reduction in carbon emissions in the country imposing the tax is accompanied by an increase in carbon emissions elsewhere. This reduces the net social benefits from the Pigouvian tax and implies that a carbon tax calibrated to the global SCC will be too high.[16]. When carbon leakage occurs, the optimal tax levied by governments should be equal to the best estimate of SCC in the case where carbon leakages occur.

A third issue that arises is whether the global SCC is the most appropriate measure of the external cost of carbon for policies instituted by an individual country. The global SCC differs from the country-level SCC, or the portion of the global SCC that is borne by an individual country. The country-level SCC is naturally significantly lower than the global SCC, given that the benefits from CO2 mitigation are global. A recent study that calculated country-level SCCs under different emissions scenarios found, for example, that the country-level SCC for US was on average 11% of the global SCC.[17] From the perspective of maximizing global welfare, the global SCC is evidently the appropriate measure to use (after suitably adjusting for the issue of carbon leakage), but an individual country may well find it in its own interests to refer to the country-level SCC when formulating policies, especially in a situation where its own carbon mitigation efforts are not being reciprocated elsewhere.

Policymakers face a choice between whether to price in the SCC using a Pigouvian tax or use an alternative market-based instrument such as cap-and-trade. The key difference between the two instruments is that a tax fixes the price of carbon but allows emission levels to vary, while the cap imposes a limit on emissions and lets the price of tradable carbon allowances vary. To the extent that the ultimate objective is to set an optimal path of emission reduction to reach a target end-state of stabilized and reduced emission rate, the cap-and-trade solution is the correct one. It achieves an environmental goal, but the cost of reaching that goal is determined by market forces. In contrast, a tax provides certainty about costs of compliance, but the resulting reduction in carbon emissions cannot be predetermined.

Cost-effectiveness of EVs in Singapore

A study released in 2018 analyzed the cost-effectiveness of EVs in Singapore relative to ICEVs.[18] The key conclusion was that, under reasonable base case conditions, EVs are a highly costly transportation option relative to ICEVs, even after accounting for the health damages of fuel emissions from ICEVs. In particular, the upfront cost of EVs is more than 50% higher than the upfront cost of a comparable ICEV vehicle, and this more than compensates for the additional health damage costs from the particulate matter (PM) and SO_2 pollution emitted by ICEVs. Crucially, the operating or variable costs of operating EVs on a lifetime basis are comparable to those of ICEVs: because over 90% of Singapore's population live in high-rise apartments, widespread EV adoption will necessitate a heavy reliance on costly communal charging stations, which offsets some of the savings from not needing to run on gasoline. As a consequence, EVs are a highly costly means of achieving CO2 emissions reductions: the social cost of carbon (SCC) would need to be as high as S$9,700 per tonne of CO2 before EVs break even with ICEVs on the basis of social costs.

The analysis of the Phase I EV test-bed published by LTA and EMA in 2014 also came to similar conclusions.[19] EVs were found to be technically feasible in Singapore: the daily average driving distance for corporate EV users was equal to 46 km, considerably lower than the EV manufacturers' reported range of 120-160km per charge, and this meant that the bulk of charging took place at the participants' primary charging sites. However, the study noted that "EVs are currently not economically feasible for adoption, even after factoring in the health and environmental benefits to society", primarily due to the high upfront cost of EVs.

Subsidies vs. Taxes

Even if EVs are costlier than ICEVs, there is an economic case for market-based instruments that correct the negative externalities imposed by ICE vehicles. The aforementioned study calculated that the lifetime external cost (from the health damages caused by PM and SO2) of driving a typical ICEV equals about S$6,300.[20] However, it is important to note that subsidies are generally considered by economists as only a second-best policy tool for addressing negative environmental externalities in comparison to first-best policies such as carbon taxes and cap-and-trade. This is because the latter address the issue of environmental damages directly by putting a price on the externality and letting the market determine the cheapest and most efficient way of achieving the desired reduction in emissions: which, in the case of the transport sector, may involve greater EV penetration, increased fuel efficiency in ICE vehicles, or other technologies under development (such as hydrogen fuel cells). Targeted subsidies (such as subsidies for EVs), by contrast, provide incentives for just one means of emission reduction, so that there is no guarantee that the emissions reduction will be achieved at least cost, and in general the costs will be higher. For instance, a 2008 study found that carbon prices provide the most cost-effective means of achieving climate mitigation targets for the United States, and that the overall cost of achieving the same target using subsidies for renewables is almost 2.5 times greater.[21]

Despite the theoretical benefits from targeting negative externalities from ICEVs directly by raising the cost of driving ICEVs, Singapore has largely adopted the alternative approach of subsidizing EVs. It could be speculated that this is because the political costs of taxes are higher than the "hidden costs" of subsidies and command-and-control mandates.[22] While Singapore has recently introduced a carbon tax, this is targeted at large industrial emitters and is not currently applicable to emissions from the transportation sector. Singapore also charges a fuel excise tax that in 2015 was between S$0.56-0.64 per liter for octane (varying depending on the grade).[23] It is unclear whether Singapore's current fuel excise duties have appropriately priced in the negative externality from ICEV fuel emissions.

Any government subsidy support of specific technologies, such as EVs, runs counter to the principles of microeconomics. We have already expostulated the economic efficiency requirements in resolving externalities. Aside from the case for a Pigouvian tax to mitigate externalities and allowing markets to incentivize appropriate technologies, there is nothing in economic theory that suggests governments are adept at "picking winners". The question remains as to why governments should have technology-specific policies in the first place. Governments which set aside technology-agnosticism in their discretionary policy actions do so at the peril of wasting tax-payer funds.

Two other important considerations arise when evaluating subsidies for electric vehicles. Firstly, EV subsidies are likely to be quite regressive: given their high upfront cost, EVs are likely to be affordable only for high-income households, and thus on the margin the benefits from EV subsidies are likely to be enjoyed by these households. It would be egregious from an equity perspective if EV subsides are funded from general tax revenue, paid for by the average tax-payer, so that the rich could buy their "EV toys" at subsidized prices.[24] Secondly, from the perspective of energy security, it is not clear whether EVs provide a tangible benefit over ICEVs. While reducing the use of ICEVs will indeed reduce Singapore's dependence on oil imports, this in turn is replaced by a corresponding increase in imports of natural gas (needed to generate electricity). Moreover, the mass adoption of EVs potentially increases Singapore's dependence on rare earth minerals (such as cobalt and lithium) that are necessary for EV batteries. Globally, production of these minerals is highly concentrated; for example, 60% of cobalt production takes place in the Democratic Republic of Congo (DRC),[25] and China controls over 90% of global rare earths production.[26] This makes Singapore susceptible to supply disruptions in these countries: for instance, China has threatened in the past to reduce its exports of rare earth minerals during its trade war with the US.[27]

Concluding Remarks

As a high per capita income signatory to the Paris Agreement, the Singapore government is under pressure in international forums to signal the country's commitments to reducing greenhouse gas emissions. EVs offer a means of reducing emissions from the transport sector. And doubtless, along with many other governments, EVs will be seen by Singapore's policy makers as a "high technology" sector that offers potential spinoffs that may benefit national industrial development. Nevertheless, in a world where government are seldom capable of picking winners, the first-best policy is to tax externalities across all sectors on a level playing field and allow markets to incentivize innovation. Furthermore, when there are great uncertainties as to the measurement of theorized social costs such as global warming and the level of credible international participation in global agreements, policy circumspection is called for. Primum non nocere or "first, do no harm", commonly attributed to the Hippocratic Oath, may well be the best policy advice for those who advocate EVs.

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An Uphill Battle for EVs vs ICEs: Can They Prevail?

BY MAMDOUH G. SALAMEH

The race between electric vehicles (EVs) and internal combustion engines (ICEs) for market share and dominance will continue unabated throughout the 21st century and far beyond with huge implications for the environment, the global oil industry and the future of oil.

Three major trends support a rising demand for EVs. The first is that the future is electric. The second trend is the continued pressure to reduce carbon emissions and the third is that investors are beginning to think seriously about reducing their carbon footprint.

Still, I will argue that EVs are going to face an uphill battle against ICEs. And while they are bound to get a share of the global transport system, they will never prevail over ICEs. EVs' share of the market could only decelerate slightly the demand for oil. As a result, ICEs will continue to be the dominant means of transport throughout the 21st century and far beyond.

The thrust of my arguments will be based on some pivotal factors including the global energy transition, EV logistics and the practicability and convenience of EVs.

The Global Energy Transition

Increased use of renewable energy, combined with intensified electrification, could prove decisive for the world to meet key climate goals by 2050. Ramping up electricity to over half of the global energy mix (up from one-fifth currently) in combination with renewables would reduce the use of fossil fuels, responsible for most greenhouse-gas emissions according to a study from the International Renewable Energy Agency (IRENA).[1]

Based on IRENA's analysis, energy-related CO_2 emissions would have to decline 70% by 2050 compared to current levels to meet climate goals. A large-scale shift to renewable-generated electricity could deliver 60% of those reductions; 75% if renewables for heating and transport are factored in; and 90% with ramped-up energy efficiency.[2]

With electricity becoming the dominant energy carrier, global power supply could more than double, the report finds. Renewable sources including solar and wind, could meet 86% of power demand.

However, global energy transition will be governed by the following realities in the market and not by wishful thinking and realms of fantasy. The first reality is that there will be no post-oil era throughout the 21st century and probably far beyond.[3] It is very doubtful that an alternative as versatile and practicable as oil, particularly in transport, could totally replace oil in the next 100 years and beyond. What will change is some aspects of the multi-uses of oil in electricity generation and water desalination which will eventually be mostly powered by solar energy.

The second reality is that there will be no peak oil demand either. Peak oil demand has become one of the most contentious and fascinating debates in the oil industry over the past few years with forecasts for the pending peak seemingly creeping closer to the present with every new publication. The precise dates vary. Royal Dutch Shell, for instance, has said that the peak could come within 5-15 years. BP, for its part, says demand could plateau in the 2030s or 2040's.[4] While an increasing number of EVs on the roads coupled with government environmental legislations could slightly decelerate the demand for oil, EVs could never replace oil in global transport throughout the 21st century and far beyond.

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See footnotes at end of text.

The third reality is that the notion of imminent global energy transition is a mirage. In fact, the percentage of fossil fuels in the world's energy mix—coal, oil and natural gas—is still lingering well above 80%, a figure that has changed little in 30 years. That remains the case despite being challenged by serious environmental policies and despite a global expenditure of $ 3.0 trillion on renewable energy during the last decade.[5]

The fourth reality is that oil and gas will continue to be the core business of the global oil industry well into the future. While the oil industry is investing huge amounts in renewables, such investment pales in size when compared with that in oil and gas. The slower pace of oil majors toward alternative energies is due to two key reasons. The first is that they all believe that oil and gas will continue to be needed well into the foreseeable future. And the second reason is that financial returns from renewables are nothing compared to those for oil and gas.[6]

For now, we're in an era of energy diversification where alternative sources to fossil fuels, notably renewables, are growing alongside—not at the expense of—the incumbents. Still, any mandatory transition to renewable energy and EVs will not achieve the desired outcome without individuals, businesses and governments getting on board about the benefits of transition.

However, for energy transition to accelerate, it should have three realistic objectives: benefit to users, practicability and lucrative financial returns from renewables to match those from oil and gas.

EV Logistics

Hardly a day goes by without another media report about the impending demise of the ICEs as they are replaced by super-clean EVs.

Some experts are now saying that widespread EV use could spell the end of oil. The tipping point, they reckon, is 50 million EVs on the roads. This they believe could be reached by 2024.[7] However, 50 million EVs could hardly make a dent on the global demand for oil let alone replace it.

Currently, EVs and hybrid cars combined number around 4 million out of 1.5 bn ICEs on the roads worldwide, or a negligible 0.27%. The total number of ICEs is projected to reach 2.0 bn by 2025 rising to 2.79 bn by 2040 according to U.S. Research.[8]

In 2019 the world consumed 36.9 bn barrels of oil (bb) of which 73% or 27.0 bb were used to power 1.5 billion ICEs. Bringing 50 million EVs on the roads will reduce the global oil demand by only 0.68 bb (equivalent to 1.87 mbd), or 2.5%. This will neither be the end of oil as some experts are suggesting nor a tipping point.

A tipping point for oil could only be reached once 750 million EVs (50% of the current global ICEs) are on the roads worldwide. This is impossible to achieve within that time frame. One then can only guess how many decades will have to pass before the entire global fleet of ICEs is replaced by EVs.

Moreover, growth in EV sales thus far has been supported by significant government subsidies. Sales would slump once the subsidies are withdrawn according to a report in April 2017 by U.S. Auto research firm Edmunds.

Furthermore, there will be a need for trillions of dollars of investment to expand the global electricity generation capacity in order to accommodate the extra electricity needed to recharge 50 million EVs. How could such expansion be sourced: nuclear, hydrocarbons or solar?

Practicability and Convenience

Despite the hype, EVs enjoy niche rather than mass-market appeal. Take-up of EVs among consumers remains relatively small. Three hurdles stand in the way of mass adoption of EVs: price, range and ease of charging.

The greatest contributor to the price is the battery, which could account for a significant portion of the cost of an EV. The dominant force in battery-powered cars is the costly lithium ion technology, the same used in laptops and mobile phones.

Other options are being pursued, from magnesium-based batteries to those that use silicon rather than carbon anodes. Solid state batteries, which promise much greater power and more flexible sizes, are also being investigated. Battery costs are a fraction of what they were ten years ago, but still have some way to go to be competitive.

Tesla for instance is said to be preparing to launch a million-mile battery as soon as this year or early in 2021 for its Model 3 in China as part of a wider plan to introduce longer-lasting, low-cost batteries that would bring EV prices to parity with ICEs.[9]

The second and most significant public concern about EVs is range. EVs with a range of 250-300 miles remain positively expensive for many, costing between $70,000 and $100,000. Car manufacturers are pushing to hit a compromise on technology and price – a $35,000 car that can travel up to 300 miles.

The third and final hurdle is the ease and speed of charging at home and en route. Current technology allows batteries to deliver around 30 miles of range for every hour of charging. It would take the power output of 1,000 electric kettles to charge a car fully in two minutes – and rapid charging is damaging to most batteries. The nature of electricity doesn't support the power transfers needed for two-minute charging, a long way into the future. It currently takes up to two hours to charge a car for a full range of 250 miles.[10]

According to a recent AAA survey, 63% of Americans cited "not enough places to charge" as a reason not to purchase an EV. While many EV owners can charge their cars at home, they can't yet recharge their vehicles with the ease and speed of gas stations. They need new fast-charging points.[11]

There are more than 63,000 public charging stations in the US, a third of which are in California, but there is a need for hundreds of thousands more to enhance EV sales. Government support at all levels – federal, state, and local – is critical to spur investment in the charging and fuelling infrastructures needed for EVs.

Still, there is an accelerating momentum behind the shift towards EVs. The UK Government's announcement to stop all sales of petrol and diesel cars by 2040 is the latest in a string of high-profile policy decisions in recent months. France has already announced its own ban on petrol and diesel vehicles by 2040.

These are seismic decisions, when one considers that at present there are only around 100,000 EVs in the UK out of a total car fleet of 31 million.[12]

A major study by the National grid in the UK outlined many scenarios about the future progress of EVs. One scenario sees a dramatic rise in EVs with sales being more than 90% of all cars by 2050. Another features 25 million EVs on the UK roads by 2050. At the other end of the spectrum, other scenarios see low growth with EVs accounting for only 11% of car sales by 2050. The government's announcement, if it becomes law, will clearly accelerate the move away from ICEs.[13]

The study concludes that as the numbers of EVs increase, their peak time electricity demand is one of the challenges that will need to be met. For example, EVs will create an extra 18GW of demand by 2050 – that's equivalent to an extra 30% on top of today's peak demand.

There is a lot of debate about different models for charging EVs in future. Several companies are investing in 'flash battery' technology that could allow a vehicle to run for a long distance from a five-minute charge. If successful, this super rapid EV charging could support the introduction of more forecourt charging sites.

Still, range, charging time and price are only temporary teething problems for EVs. Technology will sooner or later resolve them. However, the real challenge facing a deeper penetration of EVs into the global transport system is the realization that oil is irreplaceable now or ever.

And whilst EVs are benefiting from evolving technologies, ICEs are equally benefiting from the evolving motor technology. As a result, ICEs are not only getting more environmentally-friendly but they are also able to outperform EVs in range, price, reliability and efficiency.

Fad or Fixture: Are EVs the Future of Motoring?

EVs have been celebrated as the greener, cost-efficient future of travel. Still, at the back of many motorists' minds, there's a nagging question: Are EVs cheaper to maintain and run?[14]

The initial cost of an EV tends to be higher than that of an ICE but the government in the UK for instance currently offers a grant of up to £3,500 towards brand new EVs. Moreover, EVs with a list price of under £40,000 are exempt from vehicle excise duty (road tax) as well as London's congestion charge and its ultra-low emission zone (ULEZ) charge. EVs don't need oil changes and have fewer moving parts, so one can save a bit on servicing and maintenance costs compared with a petrol or diesel car.[15]

However, it is not the cost of oil changes and maintenance that matters most, it is ease of charging and also the availability of charging points particularly when one is embarking on a long journey of hundreds of miles. Furthermore, the running costs of EVs are not cheaper than ICEs given the continuous rise in electricity charges. It is claimed that charging an EV using a public charging point costs on average 8-10 pence a mile compared to 12-13 pence for a petrol or diesel car. But this doesn't take into account the fact rises in electricity are far bigger than that of petrol or diesel.

A Robust Future for EVs Remain in Doubt

Projections about the spread of EVs have never been straightforward. A new study based on 17 forecasts submitted by governments, thinktanks, consultants, investment banks and oil industry representatives, helps to shed light on possible EV futures.

The *Electric Vehicle Penetration and Its Impact on Global Oil Demand Survey,* the second in its kind, aims to become a benchmark on the topic in years to come. It was carried out by Marianne Kah, a researcher at Columbia University's Centre for Global Energy Policy.[16]

Despite positive trends in renewables and energy storage, projections for the spread of EVs have got less ambitious in 2019.This has to do mainly with expected increases in battery prices without subsidies, which could decrease the competitiveness of EVs with ICEs.[17]

EV batteries are expected to become competitive with ICEs only in 2025, which is when a $100/kWh milestone is reached. Uncertainty about growth rates has left its mark on overall EV sales with over 60% of surveyed entities having reduced their sales compared to last year's survey.[18]

The study puts a special focus on the link between EV spread and oil demand but this comes with a warning that policymakers and shareholders overestimate how quickly the global oil demand trajectory can flatten and decline.

It is claimed that policy actions to support decarbonization and lower-emission transportation in the post-pandemic world could accelerate global energy transition and displace larger volumes of oil demand for road transport to the point of bringing peak oil demand closer than previously anticipated.[19]

However, the CEOs of ExxonMobil and Shell the world's two biggest supermajors poured cold water on such claims made their positions on peak oil demand very clear. Darren Woods the chief executive of ExxonMobil demolished the environmental activists' arguments when he declared that "the long-term fundamentals that drive our business have not changed." This was echoed by Shell's CEO Ben Van Beurden who said that it is entirely legitimate to invest in oil and gas because the world demands it". "We have no choice."[20] There you have it.

Conclusions

The global economy and oil and inseparable. There could neither be a global economy nor a modern civilization as we know and enjoy without oil. The global economy operates on oil and gas and will continue to do exactly that throughout the 21st century and probably far beyond.

EVs are going to face an uphill battle against ICEs. And while they are bound to get a share of the global transport system, they will never prevail over ICEs. EVs' share of the market could only decelerate slightly the demand for oil by the global transport system. As a result, ICEs will continue to be the dominant means of transport throughout the 21st century and far beyond.

My conclusions are based on the arguments I presented and also on market realities and I am yet to find another convincing argument to persuade me otherwise.

Footnotes

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Le Duigou (continued from page 26)

emissions due to kilometers traveled in France is very low compared to the total from well to wheel (8g vs. 40gCO_2 / km), it increases by 2.25gCO_2 / km in Hauts de France and drop of 2.7gCO_2 / km in the PACA region.

Conclusions and Perspectives

There is a real synergy between mobility and housing in the context of solar photovoltaic (PV) equipment. This is valid both from real consumption data and on the construction of scenarios from behavioral statistics. The margins of progress that exist today on PV systems, allow us to envisage the massive deployment of competitive PV systems without public incentives, and this in the short term.

Mobility will benefit from organizing EV recharging periods in line with the electrical consumption already in place. Massively produced, battery and hydrogen EVs are today, or at least in the short term, competitive with TVs. The EV and EV-Re H2 can also contribute to the network primary frequency adjustment, in the short term. The environmental benefits in terms of CO_2 emissions are hardly visible.

Acknowledgments

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Photovoltaics, Buildings and Electric Mobility: What Synergies?

BY Y.ABDELOUADOUD, A. LANCELOT, A. LE DUIGOU, M. PETIT, D. QUENARD, AND H.J.J. YU

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Introduction

Based both upon real and statistical behaviors' data [1], evaluations were carried out on the technical, economic and environmental feasibility and advantages of the innovation which consists in creating a synergy between the building and the transport of people. For the first two case studies, the photovoltaic installation covers all of the annual electricity requirements, for the third case, we take into account the available roof areas. A first case modeled the interactions between consumption of a corporate building, photovoltaic production and recharging of 20 Twizy electric vehicles made available to employees of the CEA Grenoble site. A second case modeled a fleet of car-sharing vehicles deployed by the company Clem', without interaction with a building. These first two cases also analyzed the technical and economic valuation associated with primary frequency adjustment (vehicule-to-grid services). Finally, a third case modeled the French residential park: characteristics of buildings, equipment, socioeconomics of occupants, cars. Three EVs recharging strategies have been identified: average behavior (upon returning home), smart behavior, and based on market prices. The environmental benefit was assessed too.

Results

SmartCharging for a corporate fleet and a carsharing fleet

In Europe, France is responsible for 700 MW network management as soon as frequency deviates from 50Hz due to excess production or consumption. This primary frequency reserve must be available in a few seconds. An aggregator will be responsible for optimizing local and global systems. The exchanges were from the network to the battery, and vice versa.

In the case of the corporate fleet, each Twizy is connected to its charging point from 8 p.m. to 5 a.m. and on weekends, and constantly exchanges with the aggregator thanks to its specific characteristics and constraints.

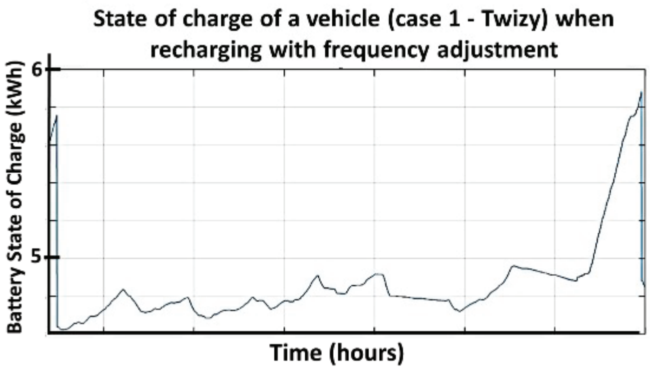

Fig.1: Actual realization of the states of charge for a given EV

For the entire fleet of 20 Twizys, the model gives an annual remuneration ranging from € 15 to € 150 per vehicle. For the car-sharing fleet, the monthly revenues for the average of the most representative stations in eastern Paris are higher, around € 60 / month per station and vehicle. The difference is mainly related to the lower power of the terminal for the Twizy, and the lower capacity of its battery (6.1 kWh against 24 kWh).

Refilling Stations	Average Monthly Income (Euro)	Number of Yearly Bookings
Bienvenu	57.87	336
Bussy RER	63.92	238
Montevrain	66.14	174
Einstein	65.80	142
CSTB	66.23	95
Galilee	64.42	138

Tab. 1: Average annual monthly income per station and vehicle for the car-sharing fleet

Assessment of the TCO associated with each of the cases studied

The TCOs of photovoltaic installations connected or not to the network have been calculated with an hourly basis dedicated tool, as well as those of the modes of mobility: EVs (electric vehicles), TVs (thermal vehicles), as well as fuel cell electric vehicles (EV H2) and hydrogen + battery range-extender vehicles (EV-Re H2) [2]. We took into account subsidies for the purchase of EVs and the installation of systems, as well as the electricity buy-back tariffs, and we characterized self-consumption.

For the corporate fleet case 1, according to 2015 – 2017 ADEME's PV cost assumptions [3], the average cost of electricity from the PV + grid system is significantly higher than using the grid alone. But there are margins: R&D (recent significant progress), organization of the system (curtailment) and discount rate (the financial cost of capital represents 50% of the total cost). We reach a self-consumption rate of 48%. The cost of grid connecting when using PV for the sole purpose of recharging EVs represents the major part of the cost of electricity (little energy in total, a lot of power demand). Thus, the synergy [Building + VE] is

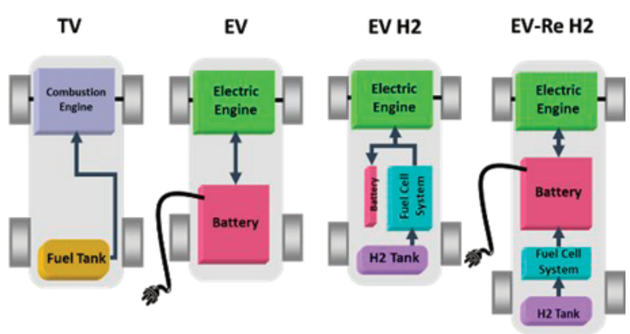

Fig.2: Vehicles studied

valuable, more precisely as long as the use of EV leads to less or equal power than the building one.

The full cost per km of battery EVs is the lowest, slightly lower than hydrogen Evs: 0.643€/km vs. 0.654€/km. It is however much better than that of the TV. The impact of the price of electricity, PV or network, is negligible in the TCO.

In case 2 of the car-sharing fleet, we observe low rates of self-consumption: from 13 to 21%, because there is a real gap between PV production and the need for EV recharging, and the network satisfies the electricity consumption peaks. As the installation is small and considering the assumptions done, the cost with PV system remains higher (*196€/MWh)* than that of the grid alone *(121€/MWh)*, including with governmental incentives which are useful but do not promote self-consumption. For such an installation, the total cost of the installed PV should reach 1.57 €/Wp to reach the network parity, a value that can be achieved in the short term by the sole effect of the R&D and financial margin (discount rate 0%).

In a similar way to case 1, the cost of electric power supply for EVs, with or without PV, suffers from a very low rate of use of the grid electricity to which the installation subscribes: disproportionate connection compared to the energy consumed. Such an EV power supply system should be connected to a quite different demand, for example, a building for professional or domestic use (see case 3). The very high underuse of vehicles leads to a very high cost per km for each solution, and places the TV in the lead. EVs, with battery and range extender, again become the least expensive when the annual mileage regains the values of conventional rentals, the purely hydrogen electric vehicle being the least attractive today (purchase costs still too high).

Case 3 differs from the other two in one major point: we are in the prospective, at the level of individuals, both of the deployment of PV solar energy, but also, in coupled mode, of individual electric mobility.

The overall French housing energy coverage reaches 93.5% with the PV, and the self-consumption rate stands at 42.2% in the event of a recharging strategy upon returning home (average behavior). The EV recharging situation based on market prices drops the self-consumption rate to 34%, while this value reaches 52% in the case of smart behavior («Local optimum»).

The cost of electricity is always in favor of PV (145€/MWh vs. 160€/MWh), and the public support does not value self-consumption resale. The latter can be reduced by a factor of 2 if the cost of the installed PV goes from 2.86 to 2.25 €/Wp, a completely reasonable development, with a system with PV cost equal to that of the network alone. The combined use of PV for the building and EV systematically leads to an increase in profitability. The accumulation of Building + EV recharging slightly increases the maximum power of connection to the network and we can see once again the advantage of recharging EVs in «local optimum» mode, as well than to associate buildings and EVs. In addition, in the event of a PV surplus sale to the network, a reasonable PV cost progress makes the State aid no longer necessary: 2.12 €/Wp (installed) instead of 2.86 €/Wp, which is achievable in the short term.

Regarding actual mobility and for the next decades, the EV is already competitive compared to the TV, despite a much higher CAPEX, with a bonus of € 6,000 and thanks to the very low cost of its «fuel» (electricity): ca.3€/100 km. The EVs using hydrogen are not out of the running, if production becomes massive, and the EV-Re H2 is already a real alternative, thanks to the bonus too. All EVs TCOs converge over time, and are identical in 2040 and lower than that of TV; all costs

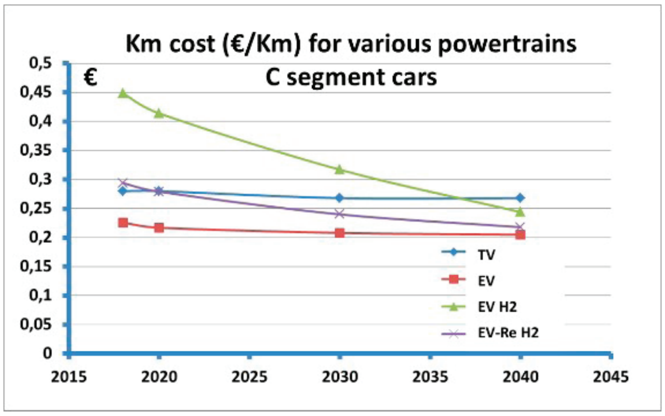

Fig.3: Km costs of the various powertrains for the next decades, 6,000€ bonus included

would be equivalent if the bonus disappears.

Environmental balance sheet estimates: CO_2 avoided due to the use of PV

Concerning the PV systems, the CO_2 emissions avoided [4] are, overall in France, of the order of magnitude of the PV manufacturing emissions: the solar systems are thus practically neutral in terms of CO_2 balance, even in situation of Asia countries manufacturing (mainly China)[5]. The difference is however visible depending on the regions, it would be interesting to be able to "pump up PV energy" from the south (surplus) to the north in order to compensate for

(continued on page 30)

Where can Drivers Charge Their Electric Vehicle for Free in the U.S.?

BY MARIE-LOUISE ARLT AND NICOLAS ASTIER

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See footnotes at end of text.

Introduction

The ability to charge conveniently and reliably is one of the prerequisites for the widespread adoption of electric vehicles (EVs). However, with over half a million stations deployed worldwide (IEA, 2020), EV charging is still a nascent industry.[1] Charging services are currently offered by very diverse market players such as utilities, original equipment manufacturers (OEMs), specialized charging companies, but also outsiders like shops and malls with customer parking. These companies have very different incentives for installing charging stations. It is thus unclear how the EV charging landscape will evolve as EV adoption increases.

The U.S. is the second largest car market in the world and therefore a primary area of both academic and industry research (e.g., Idaho National Lab (2017), Li (2016), Muehlegger and Rapson (2018)). Substantial efforts have, for example, been directed to the study of the optimal placement of charging stations (e.g., Zhang et al., 2015) or drivers' charging behavior (e.g., Nicholas et al., 2017). By contrast, the analysis of current business practices has drawn less attention in the academic literature. Understanding economic incentives and business opportunities is, however, crucial to design public policies in an environment where private investment is substantial.

This work focuses on how the service of EV charging is currently priced in the U.S. This is important for at least two reasons. First, fuel costs represent a large fraction of the operating costs of a vehicle, and thus play an important role in car purchasing decisions. Second, the expected revenue from the provision of charging services is one of the main determinants of investment decisions by charging station providers. Based on the analysis of a widely used public dataset (made available by the Alternative Fuel Data Center (AFDC)), we surprisingly find that drivers may be able to charge their EVs for free at more than half of the stations listed in the dataset. We explore and discuss several possible explanations for this unexpected stylized fact. First, we note that many "free" charging stations are implicitly or explicitly bundled with some other service, and may thus require to consume a distinct service and/or pay for parking. Second, we present evidence that the share of free charging stations is likely to decrease as the market becomes more mature, although a significant amount of free slow-charging stations may very well remain an important feature of the EV charging landscape.

Data

We use the publicly available dataset on charging stations provided by the Alternative Fuel Data Center (AFDC). This data source was launched by the U.S. Department of Energy and is administered by the National Renewable Energy Laboratory. It has been used in many empirical studies on EVs (e.g., Li et al. (2017)) and contains information on more than 20,000 EV charging stations in the US.[2]

Besides information on the location and design of charging stations, the dataset also describes the price schedule faced by EV drivers. This information is, however, provided in a descriptive text format. For the purpose of this work, we thus manually converted the text into a standardized format, making it possible to run quantitative analyses on the observed pricing strategies of EV charging station providers. In this article, we focus on "free" charging stations, i.e., stations where drivers do not need to pay for charging. By contrast, at "paid" stations, a charging fee applies. Ambiguous or absent textual descriptions of price schedules are labeled as "unknown". Because manually-filled text information can be error-prone and prices may change over time, we compared the AFDC database to Plugshare.com, a private platform listing public charging stations.[3] For a sample of a few hundred charging stations, we find that, for about 8% of the charging stations labeled as "free" in the AFDC dataset, Plugshare.com lists instead a non-zero price. These discrepancies may however stem from differences in how ambiguous price schedules are reported (e.g., parking fees) or mistakes by either of the two information providers. Overall, this sanity check suggests that, while not perfectly accurate, price information listed in the AFDC dataset seems to be of sufficient quality for the purpose of our study.

Main result

A high-level analysis of our three pricing categories (free / paid / unknown) yields a very surprising and striking result: *more than half of the charging stations listed in the dataset seem to offer at least one free charging option.* In what follows, we explore in more detail possible explanations for this unexpected stylized fact.

Possible explanations

Characteristics of free charging stations. In this paragraph, we analyze the relationship between the characteristics of charging stations and their pricing category. First, EV charging is not a homogenous commodity, but is differentiated by speed of charge.

Three different categories are generally used to capture this feature which are, by increasing speed of charge: Level 1 (L1), Level 2 (L2), and direct current fast charging (DCFC). A faster charging speed is typically associated with a higher quality of service as it reduces customers' waiting time. We thus start by computing the share of free charging stations conditional on a given charging speed. A minority of charging stations host chargers of two or more distinct speeds (most often L2 and DCFC). Such stations may use a different price schedule for each technology, in which case we retrieve pricing information for both charging speeds. Table 1 reports the obtained results. We observe that 76.3% of L1, 60.7% of L2, and 17.5% of DCFC stations are free. This fraction is smaller for DCFC stations, which is consistent with basic economic intuition. First, drivers are likely to have a higher willingness to pay for faster charging due to shorter waiting times. Second, investment costs for DCFC stations are at least ten times higher than the 2,000 to 3,000 USD required to install a "slow" charging station (L1 or L2; Idaho National Lab, 2017).

	L1	L2	DCFC
Free charging	371	11,536	615
Paid charging	74	5,497	2,546
Unknown	41	1,966	356
Total	486	18,999	3,517
Percentage known to be free	76.3%	60.7%	17.5%

Table 1: Number of stations per pricing category and charging speed

We then identify the owners and/or operators of free charging stations which are responsible for designing price schedules. We find that virtually all DCFC stations labeled as "free" are part of ChargePoint or Greenlots charging networks, or not part of any charging station network at all. Both ChargePoint and Greenlots have adopted a business model under which they are responsible for the installation and maintenance of charging stations, but leave most operational decisions, including pricing, at the discretion of the hosting facility. Similarly, the majority of free L2 stations are operated by Tesla Destination and ChargePoint or are non-networked stations. By contrast to ChargePoint and Greenlots, however, Tesla Destination is centrally operated by Tesla, an OEM that offers free charging to their customers exclusively.

We thus analyze the nature of the hosting facilities where free charging stations are located. This information is available from the original AFDC dataset for about two thirds of the sample of free charging stations. Whenever feasible, we further use the names and locations of stations to manually label the type of hosting facilities for the remaining stations. We then group facilities into broad categories, such as hotels, college campuses, gas stations, etc. The obtained results are shown in Figure 1. First, hosting facilities usually have a distinct core business, and may offer free charging as a way to differentiate their service (e.g., hotels, public facilities for entertainment, parking spaces for shopping) or to be more attractive for employees (e.g., office buildings, public facilities, college campuses). Second, the vast majority of DCFC stations labeled as free are located in car dealerships or other car-related businesses, possibly as an additional benefit to customers or employees and/or as a tool to familiarize prospective EV buyers with charging stations.

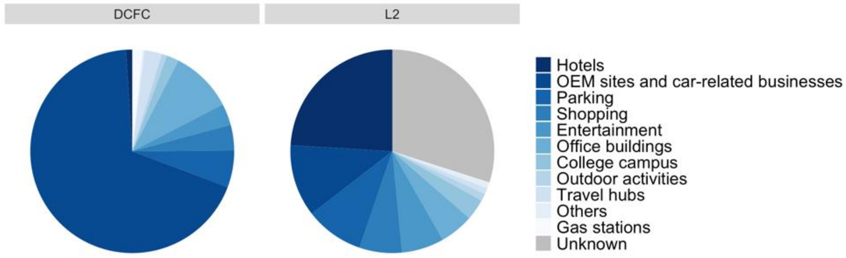

Figure 1: Type of facilities hosting free DCFC (left) and L2 charging (right)

Our results suggest that the charging networks and hosting facilities providing charging for free do not deploy charging stations to generate revenue from charging services, but rather because they derive other benefits from it. More specifically, charging stations can have a positive impact on the network's or hosting facility's business, for instance by increasing EV sales (e.g., Tesla Destination) or attracting customers (e.g., stations installed in shopping centers).

Furthermore, we analyze the typical size of charging stations, as measured by the number of available chargers. While both paid and free L2 stations host an average of 2.7 chargers, we find that free DCFC stations have on average 1.5 chargers and paid stations 4.8.[4] This difference in means has strong statistical significance,[5] indicating that DCFC stations labeled as "free" tend to be smaller installations. This observation suggests that facilities hosting paid DCFC stations may pay more attention to whether they have sufficient charging capacity for drivers to be able to reliably charge there on a regular basis.

Overall, we find that the majority of free charging stations are hosted or operated by companies whose primary business objective is not the sales of charging services to drivers. Instead, these hosting facilities get distinct benefits from installing a charging station, which seem to exceed the investment and operating costs. A corollary is that, in practice, many stations labeled as "free" may not be readily accessible to drivers and cannot be used on a regular basis, as their usage is likely to be restricted, for example to customers or employees.

Market maturity and free L2 charging. EV charging is still a rather immature market. It is therefore an open question whether our main result will persist as the EV industry grows. To start exploring this question, we first analyze how the share of free charging stations among newly commissioned stations has evolved over time.

For each year between 2011 and 2019, Figure 2 shows the fraction of non-networked L2 charging stations commissioned in that year that are free. We choose to focus on non-networked stations because (i) many charging network providers have a centralized pricing policy, and (ii) opening dates are available for the vast majority of these stations. We find that the share of free stations among this sample exhibits a downward trend, from nearly 90% down to about 65%, suggesting that the provision of free charging might become less attractive over time.

We then look in more detail at the subset of paid DCFC stations which are operated by companies

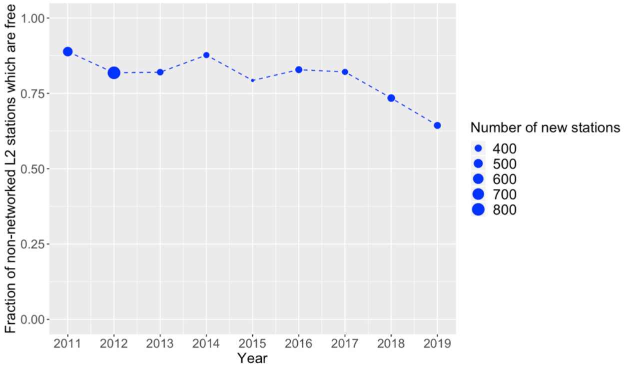

Figure 2: Fraction of non-networked L2 stations commissioned that are labeled as free

that derive their main revenue from the payment for charging services by drivers (similarly to existing gas stations).[6] As no opening dates are available for these stations, we leverage the fact that the maturity of the EV ecosystem differs significantly across U.S. states and use the state-level market share of EVs in the car market[7] as a proxy for market maturity. Figure 3 plots the fraction of these DCFC stations (out of the total number of DCFC stations in the state) as a function of our metric of market maturity. We find that the share of such stations is positively correlated with state-level EV market shares. This suggests that, in more mature markets, companies for which EV charging is the core business may serve a higher share of charging demand.

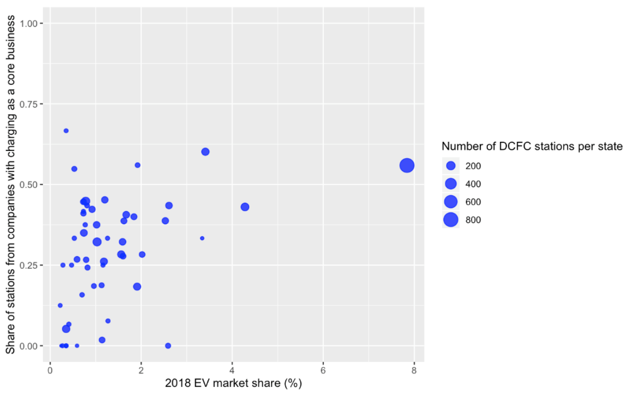

Figure 3: Share of DCFC stations owned by charging companies that derive their main revenue from the payment for charging services by drivers (each dot is a U.S. state)

Overall, our results suggest that EV charging stations may be more likely to be free in the early stages of deployment of the charging infrastructure. With the increasing adoption of EVs, however, potential profits from the charging market might attract companies that derive their main revenue from the payment for charging services by drivers. It is however an open question how, in the future, the market will be split between such specialized companies and charging providers which offer charging as a service to their customers or employees.

Conclusion

Although the academic literature on EVs is growing, surprisingly little attention has been dedicated to studying the business practices currently observed in the charging industry. This work makes a first step in shedding light on the price structures used by charging stations in the U.S. Quite unexpectedly, we find that more than half of the EV charging stations seem to provide charging services for free. However, further investigation suggests that such “free” stations are most often installed by companies or facilities that may derive indirect revenues from the provision of charging services (e.g., by selling more cars or attracting more customers). Although these stations may not be readily accessible to any driver willing to charge an EV, it came as a surprise that the perceived benefits from installing a charging station may be high enough to provide free electricity supply in so many instances. We further show suggestive evidence that, as market maturity increases, a larger fraction of the EV fast charging market is likely to be covered by paid and higher quality services provided by companies for which charging is their core business.

Footnotes

[1] For example, McKinsey (2018) estimated that around $50 billions of cumulative investment may be directed to the EV charging infrastructure over the next decade.

[2] Alternative Fuels Data Center (2020), Alternative Fueling Station Locator, https://afdc.energy.gov/stations/#/find/nearest?fuel=ELEC, last accessed on 07/07/2020. In this article, we use the database as downloaded on June 08, 2020. The database contains 21,645 public EV charging stations within the 50 US states and the District of Columbia.

[3] We are grateful to Michael Hohmann at the University of Freiburg for outstanding research assistance.

[4] The 356 DCFC stations for which the pricing schedule is unknown are excluded from this analysis.

[5] A t-test rejects with high confidence ($p < 0.001$) the null hypothesis that both populations have identical means for the number of chargers per charging station.

[6] As stated by their website. In our dataset, these companies are Blink, Electrify America, Webasto, and EVgo.

[7] Retrieved from https://evadoption.com/ev-market-share/ev-market-share-state/

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India's EV Policy

BY AASHEESH DIXIT

Governments across the globe are promoting electric vehicles (EVs) primarily due to the inherent benefits such as improvement of local air quality, reduction in fuel requirement, and enhanced energy security. China has emerged as the largest EV market accounting for 99% of the global e-bus market. Norway is the worldwide leader in terms of penetration of electric cars with 70% market penetration by March 2019. Aware of the benefits, the Government of India (GOI) is proactively working towards large scale deployment of cleaner mobility solutions in the country and aims to achieve 30% penetration in private EV ownership. The country is home to some of the most polluted cities in the world (14 in top 20) and is the third-largest contributor of carbon emissions. Hence, it stands to gain a lot by developing its EV market and fast-tracking its adoption. On the economic front, EVs adoption will help the country to save U.S.$330 billion in its oil bill and reduce 1 Gigaton of carbon-dioxide emissions in the periiod 2020 to 2030.

Considering the advantages and benefits of EV, GOI has announced a series of policy measures to promote its adoption. In 2013 it launched its first policy "National Electric Mobility Mission Plan" with an ambitious target to achieve 6-7 million sales of electric and hybrid vehicles by 2020. It also helped in reducing oil dependency and achieve national fuel security. In 2015, GOI rolled out "Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles" (FAME) framework with a budget outlay of $120 million. The policy aimed to fast track the development of EVs infrastructure and promote private sector participation. Phase II of the FAME scheme was launched in 2019 with a budget outlay of $1.3 billion for three years. Besides, the government has laid out various incentive schemes and subsidies to promote EVs growth. These measures include steps like:

1. Relaxation of customs duties on EVs and related components,
2. Income tax rebate of up to INR 1.5 lakh on interest paid on loans to buy EVs.
3. Reduction of Goods and Services Tax (GST) on EVs to 5% from 12%.
4. Declaring setting up charging station as a de-licensed activity.

However, India's EV dream faces multiple roadblocks like lack of infrastructure and ambiguous policy framework leading to unwanted burning of taxpayer money. Learning from its past mistakes, the government is focusing on accurate demand prediction and development of efficient new-generation power infrastructure as the EV mission is rolled out. We discuss a few roadblocks and challenges faced by the country.

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Roadblocks and challenges:

India's automotive sector is the 6th largest and the fastest growing industry in the world. Hence the transition from internal combustion (IC) engines to EVs is a mammoth task for the country. The EV demand is estimated to be 80 million leading to 28 GW of energy consumption. It's inefficient energy sector, dominated by public companies (75% market share) and a massive debt on DISCOMS ($20 billion) is a major setback for India's EV dream. Rapidly Increasing and inconsistent demand is bound to bring with itself problems of higher waiting time for charging and fluctuating power load. These problems are expected to be more aggravated than the European market due to the bigger market size. Hence, an EV policy for the country must be tailor-made to meet its particular needs and overcome unique challenges.

To understand how the country's market is different from European and the U.S. context, we will have to analyse its auto-segments. The estimated ratio of segments are:

79% Two-wheelers
4% Three-wheelers (passenger and goods)
3% Buses and large goods vehicles
12% Economy four-wheelers (< 1 million rupee)
2% Premium four-wheelers (> 1 million rupee)

India's love for the two-wheeler and economic four-wheeler is evident and is explained by the income structure of the country. To bring any substantial change in EVs use, the focus should be to overcome the challenges of these two segment. Recognising the high penetration of two-wheelers, the GOI shifted its attention to develop its EV market centred around these segments. Under its "FAME II" policy, it announced a series of incentives for manufacturing and reduced import duties on its equipment. Its policy think-tank, NITI Aayog, proposed production of only electric three-wheelers after March 31, 2023, and two-wheelers after March 31, 2025. Hence, the market division of Indian offers a lucrative opportunity for the two-wheelers segment manufacturer.

The economic four-wheeler segment also presents the opportunity to promote EVs. Comparing car ownership figures, India is far behind, with only 22 cars (per thousand) as compared to New Zealand's 774, Australia's 740 and Japan's 591. Moreover, the market of shared mobility has seen an explosion with players such as Uber and Ola. Hence, the low car ownership and an increasing fleet size of riding companies are bound to propel the demand of four-wheelers. Sensing the favourable circumstances, GOI has also come up with incentive schemes, including a reduced GST rate, tax-free registration and support for research and development (R&D) of new technologies. The low operating cost of EVs and subsidies from the government is pushing ride-sharing companies to partner with OEMs to replace their fleet. In 2017, Ola, partnered with Mahindra & Mahindra to develop an electric mass mobility ecosystem in Nagpur, Maharashtra. The company also agreed to pool in over 100 Mahindra's e20 plus vehicles. Uber India, one of the largest ride sharing company also joined hands with Mahindra & Mahindra to set out 100 electric cars, in Hyderabad and Delhi. The growing usage of electric vehicles in shared mobility services and potential growth in car ownership creates an opportunity for four-wheeler manufactures.

Turning challenges into opportunities

India recorded over 18.5 million two and three-wheeler sales, making it the largest market in the world. Battery-powered scooters and motorcycles are spearheading the e-revolution in India. These small vehicles require a particular set of technological and industrial capabilities. It calls for the development of infrastructure exclusive to these demands and requires automakers to adopted themselves to meet the challenges. We discuss some of these difficulties and steps that manufactures have taken to meet the requirements.

a. Erratic power supply: The electricity distribution system in India is still outdated with irregular power supply in smaller towns and cities. The high cost of electrification and inefficiency of DISCOMs limit the regular supply of electricity. However, the government is focused on providing electricity to the remotest cities in India, driving on renewable energy sources. These cities are the market with high two wheeler demand. To overcome the challenge of erratic power supply automakers have come up with the idea of removable batteries. They provide an option to remove the discharged battery, place it for charging in-home and replace it with a charged spare battery. The demand for e-scooters has seen an uptick in tier 2 and 3 cities since the introduction of the concept. It also provides a local business opportunity to provide charging services. These models are expected to be a game-changer for the Indian EV market

2. Lack of engine power: The second challenge stems from comparison of engine power of IC and EV scooters. Customers find that available electric scooters on the market are useful for daily use but are not as powerful as petrol engines, which can go faster and climb slopes easily. To overcome the limitation, automakers propose the use of the lithium-ion battery. However, this increases the cost of vehicles, making it more costly by nearly two times as compared to lead acid batteries. The manufacturers therefore continue to produce lead based electric two wheelers, catering to the demand of price sensitive customers and driving the segment growth. With the availability of subsidies and increasing capabilities of lithium-ion battery automakers are focused on reducing its cost with significant R&D expenditure and making them in-house.

3. Supply chain problem: The supply chain for e-vehicle components is still in the nascent stage and is not robust. Manufacturers need to rely on importing components, which increases their manufacturing cost. Moreover, the lack of service centres and a skilled workforce hurts customer experience. Hence, manufacturers demand support of government and subsidies to develop a robust and efficient supply chain. Government's help in such cases will not only increase the demand for two-wheelers but also increase customer awareness of EVs.

The private automakers have played their part by improving vehicle efficiency, power and developing its supply chain. This has led to invaluable learning for the manufactures and development of their technology. They find a high place in the learning curve as compared to other European or U.S. market competitors. The experience gained creates an opportunity for these companies to take a leadership role in the world for the two and three-wheeler segment. The statement by NITI chief Amitabh Kant echoes the same "We were late in making India a hub for mobiles, ICE four-wheelers, but we have to make sure the country becomes the manufacturing hub for the two-wheeler and three-wheeler".

Business model for increasing EV penetration:

We now discuss a few possible business models that can be used based on market maturity. In India, the initiative to push and promote a shift towards EVs has mainly been taken by the government. The infrastructure and charging station (CS) facilities are majority government-owned with few private partnership. The single ownership, lack of expertise and diverse need of the market pose a significant challenge to the government. Sharing risk and responsibilities with private enterprise and state governments will help GOI build a sustainable business model. We discuss a Public-Private Partnership (PPP) model with a division of responsibilities for setting up the charging infrastructure. The primary objective of the business model is to promote both small and large scale charging stations across the country.

a Central - State – Private partnership-driven model: In its unique strategy to penetrate and build its EV infrastructure, the government has come with a plan to collaborate with other state governments and private companies. The focus is to provide funding to replace public owned vehicles to make an early impact. The steps include the replacement of public buses with EVs models. Under its AMRUT scheme and funding of $8.3 billion, the government is planning to replace the old public bus fleet with e-buses. It also extends subsidies to states for the use of the electric bus. The move has inspired individual states to come up with their own policy to develop EV infrastructure. Examples include procurement of five hybrid city buses from Volvo and 25 hybrid buses from Tata Motors by Navi Mumbai Municipal Transport (NMMT). Going further, the government plans to replace the IC car fleet of government employees. The move is expected to drive the development of EV infrastructure in public places and other parts of the city. The Department of Economic Affairs and the Ministry of Finance have already added 15 electric vehicles to their fleet. To ensure a seamless shift, the department has also announced installation of 28 charging stations with 24 standard AC chargers and 4 fast DC chargers. The PPP model proposed is as follows:

1. The centre government (GoI) provides funds to states to replace public transport and government vehicles with EVs.
2. The state government is responsible for the development of charging infrastructure for public vehicles. Responsibilities include identification of the location of charging stations, provision of adequate land, invitation of tender and selecting equipment supplier.
3. Private involvement includes leasing out land in return for rent, setting up CS and generating revenue from the service.
4. The equipment manufacturer provides the charging equipment. State government are expected to provide aid in establishing CS.
5. Power distribution companies provide the required electrical connectivity.

The PPP model involves various stakeholders, establishing synergies and creating a win-win proposition for all. It is best suited for the initial stage of the market where promotion and creating awareness of EV is essential. The significant role is played by central and state governments in providing required capital and financial support. However, it is possible that the government might not get private partnerships. In such a case, the government may consider going solo to drive the market towards EV. We call this a government-driven model.

b Government driven business model: In the government-driven business model, the complete responsibility of developing infrastructure and driving demand growth lies on the government. The model is centred on the proposition that because of the significant capital requirement, uncertain rate of return and high risk, attracting sufficient private players would be a task. Hence government will assume complete accountability, right from procurement, establishing and maintenance of infrastructure facilities and revenue collection. In India, with numerous government-controlled offices and a large fleet of government buses and cars, it is capable of creating demand even by considering replacement of the existing fleet. The supporting infrastructure can be built with help of the public sector power companies in public office space. The government can even consider inviting the state-owned petrol marketing companies to build CS on their owned land and gradually shift their base from oil and gas to electric. Along with this, it is necessary to bring in a policy for the phasing out of petrol and diesel vehicles by bringing in a sunset policy.

Under this business model, the charging infrastructure is owned, operated and maintained by the public equipment supplier. Example of such supplier is ELSS, which is a 100% government-owned and a joint venture of state-owned Power Finance Corporation, NTPC Limited and Rural Electrification Corporation. The business model is suitable when the government is unable to find sufficient private partnership or seeks control of the market. It requires adequate funds, expertise in technical areas, and the ability to take on high risk.

As the demand grows, the market will attract private players to cash in on the opportunity by developing infrastructure. In such case, automakers will roll out models and collaborate with existing CS owners to add capacity. Over time, the business will take the shape of a manufacturer driven business model as discussed below.

c Manufacturer driven business model: In the manufacturer driven business model, the manufacturer senses the opportunity to set its own charging infrastructure. The incentive is to leverage its accumulated knowledge of EV, regarding vehicles compatibility, battery type and its ability to provide maintenance. The private manufacturers own the full responsibility of acquiring land, setting up the infrastructure and running operations. It also provides them with the opportunity to do marketing of their product, gain customer confidence and spread awareness of EV models. The model will not only improve electric mobility but will also provide manufacturers with a new revenue stream generated by collecting service charges at market rates. However, the model has a shortcoming that, to eliminate competition and promote its EV model, the manufacturer may install proprietary charging infrastructure, thereby limiting the interoperating capability of CS. Tata Motors is an example of such a business model with its own charging stations compatible with its cars.

However, the model will also attract foreign investment in manufacture and establishing R&D capabilities. The private sector is expected to operate its own CS only in high density and profitable cities with substantial EV penetration. We cannot expect investment in tier 2 or tier 3 cities, where demand is limited. Hence this business model is applicable for the matured market.

Conclusion

With investment-backed policy changes, the Government of India has made its stand clear on the future of EVs in India. These changes have led to increased penetration of EVs in the Indian market. There is a need to establish adequate infrastructure and sufficient charging stations across the country. Government's aim is to provide one CS in every 4x4 area in the city and on both sides of the highway for every 25 km. This requires considerable capital and financial resource. To ensure a sustainable ecosystem, we need to look for PPP in initial stages of market maturity. The focus should be to develop business models so that the industry can grow and become self-sustainable.

Besides, the demographic diversity and unique market structure can help the country develop its technology around these demands. Developing technologies to meet the high demand for two and three wheelers will provide it with a first-mover advantage and place it higher on the learning curve. It can aim to become a global leader and cement its place and market share in economic class segment vehicles. The EVs also provide an opportunity for India's power sector to deleverage and improve its balance sheet. Power sector plays an essential role in developing and building infrastructure for EVs. Private and public power companies can look to develop technology to provide better service. Investment in improving technology is likely to pay off in the future as the opportunity is vast.

In this article, we have discussed the government policies and proposed business models that can be tailor-made for India. The use of different business models depends on the evolving market scenario. The decision of choosing a particular business model relies on the importance of ownership and the level of control that the government wants. Studies suggest that more responsibility and ownership should be handled by the private sector, given the efficiency and competitive nature of the work. With its share of setback and challenges, India's EV market looks promising and poised to grow. It is also expected to create social value for society by generating employment and business opportunity. The vast market size will accommodate many competitors and the success will be shared among different players. The growth will be bolstered by the citizen's changing mindset and realisation of the need for clean air.

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