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PRESIDENT'S MESSAGE

With this issue of the IAEE Energy Forum we kick off a new year, and we do so with fair hopes that it will turn out better than the old year. The coronavirus played Old Harry with our 2020 schedule of international conferences and regional events, as you all know, not to mention the many personal inconveniences and hazards we have each been forced to endure. Unfortunately, the consequences suffered by some of our colleagues, friends, and family members were far more severe, so before delving into the new year's activities, I would ask in sadness and respect that all IAEE members share a moment to remember those whom we have lost.

The pandemic has made it more difficult for most of us to do our jobs, whether in academia, industry, or government. It has not made our jobs any less important. Indeed, many new questions have arisen regarding the impact of Covid-19 on the energy economy. What will be the final effect on the demand and supply of the myriad energy resources at our disposal? Has public reaction to the pandemic changed society's perception of what is an appropriate degree of government intervention in our daily lives—including how various forms of energy are to be priced or utilized? Going forward, need we recalibrate prior views regarding desirable and sustainable rates of economic growth, and if so, what are the implications for energy markets and the tradeoff between economic growth and environmental quality? How, if at all, has the pandemic changed the probable pace and shape of the highly anticipated and much heralded energy transition? And what will be the likely evolution or transformation of public policies that may be needed (or maybe not) to carry the global economy forward?

Because many of the underlying assumptions that ground these issues have abruptly changed, it may behoove us to revisit even some of those questions and topics that were previously thought to have been fully addressed. The agenda for energy researchers has never been so full and rich, and the role of an organization like IAEE—which strives to promote broad public discussion and understanding of how energy markets and policies affect all our lives—has never been more important. For that reason, the current IAEE leadership team is taking a hard look at how we may best serve our members and society at large while the Association's "normal" operations and the financial resources required to support those operations remain impaired. Here is a brief summary of where we stand and where we are headed.

As you know, the July 2020 International Conference in Paris was initially postponed for a year—as were all subsequent conferences on our schedule. More

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President's Message (continued)

recently, and facing continuing risks and restrictions on international travel, we have been compelled to put off the Paris conference yet again. Because our surveys of members always indicate that IAEE conferences (along with our publications) serve as a major reason for continuing membership, the loss of those conferences for two years running has been a hard pill to swallow.

Although we are unable to assemble in the usual manner during 2021, plans are well underway for the First IAEE International Online Conference, to be held June 7-9, 2021 and organized around the main theme: Energy, COVID, and Climate Change. As the theme indicates, we expect dialogue and debate at the conference to address some of the issues that I mentioned in the paragraph above—and many more. I hope you will remain alert for further announcements coming soon regarding the schedule and agenda of this event. As usual, the virtual conference will provide a venue for panel discussions, roundtables, and the presentation of research papers in concurrent sessions, so if you have something to contribute, please keep working on it. You may already have received the conference Call for Papers via email; if not, consult the IAEE website for more details.

In addition to holding its first-ever virtual conference, IAEE has initiated a new and extensive series of webinars and podcasts that explore a wide range of energy-related topics. Please visit the IAEE website for a complete listing and links to past broadcasts, all of which are free to IAEE members via YouTube. In addition, and even better, watch your email for opportunities to register for and attend our upcoming live webinars as they occur. By so doing, you gain the opportunity to comment, ask questions, and add your voice to the conversation.

With the cancellation and loss of virtually all conference revenues during 2020 and 2021, IAEE budgets have taken a hit. In both years, we expect to suffer losses that are unprecedented in magnitude. We are fortunate, however, that during previous years IAEE managed to accumulate financial reserves that now represent a rainy day fund that is more than sufficient to see us through current difficulties. Of course, we remain on track to resume normal conference operations as soon as conditions allow, which should help to reverse deficits and restore our financial health. In that regard, we are especially grateful and indebted to those financial sponsors of the delayed Paris and Tokyo meetings, all of whom have committed to remain on board with their support. Moreover, the current IAEE leadership team has crafted a strategic plan designed to maintain IAEE's core principles and financial wellbeing during these uncertain times. That plan includes, in particular, an effort to review, refresh, and adapt IAEE's business model and operations in line with the financial and operational challenges we still expect to face even in the post-pandemic world. I thank Peter Hartley, your President-Elect, whose advice and insights were instrumental in this regard.

Finally, as if the pandemic had not brought enough challenges to business as usual, Dave Williams, Jr. has informed us that his company (Administrative Management Services) will no longer be prepared to work with us after the current contract expires at the end of 2022. That termination will culminate a long and successful collaboration between IAEE and AMS that stretches back to 1991. The transition to new management will undoubtedly bring further changes to our operations and perhaps provide an opportunity to identify and adopt innovations in management processes and technologies that will further enhance our operations.

In any event, please be assured that we have already formed a task force to plan and oversee the transition to a new management team. I thank those members who have joined in this important albeit undesired undertaking, especially Yukari Yamashita (IAEE President 2020) and Christophe Bonnery (IAEE President 2019) who volunteered to spearhead the effort and David Broadstock who will lead the team. Please know that the transition task force is working to ensure that each of you, our individual members, will continue to receive without interruption the benefits, services, and membership privileges to which you are accustomed. As well, I personally want to thank Dave Jr. and Dave Sr. at AMS for all the years of outstanding service they have provided.

I also wish to thank all you IAEE members who continue to work so hard in your personal and professional capacities to promote the Association's mission and goals. We need your ideas, your participation, and your feedback. With your help, and braced for the exciting challenges that lie ahead, may we all enter the new year with enthusiasm and good cheer. And please be safe. Wear the mask. Get the shots.

James L. Smith

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Editor's Notes

We continue our focus on electric vehicles from the fourth quarter 2020 issue. We also begin coverage on weaknesses in the world's electricity systems. We will continue this topic in the second quarter 2021. We all wish for a better 2021, and a very happy New Year to you all.

Timothy C. Coburn, Thomas H. Bradley, Jeffrey Logan, and **Charles F. (Chuck) Kutscher** report that the U.S. currently lags other countries in the world in terms of EV charging infrastructure and must make a significant investment relatively soon in order to accommodate its rapidly expanding EV population. Advances are required in both charging and battery technology, as well as other diverse supporting systems.

William (Blake) Sutton and **Zhen Zhu** write that The costs associated with land management in areas with severed minerals, like the Oklahoma "SCOOP" play, are exponentially high due to the severed minerals leading to complex imaging, title and leasing, expensive title opinions, extensive curative and complex payments. In contrast, the costs of these activities in areas like the Powder River Basin (PRB) in Wyoming can be hundreds of times lower. The importance of getting into a play early cannot be overstated and sometimes taking a leap of faith on the opinion of geologist(s) might prove highly rewarding, especially when E&P companies are making strategic decisions.

Jessica Arias-Gaviria, Veronica Valencia-Hernandez, Santiago Arango-Aramburo, Yris Olaya M, Erik R. Larsen and **Ricardo Smith** discuss the chicken- egg dilemma for charging infrastructure and electric vehicle diffusion in a case from the developing world: Medellin, Colombia. They provide a system's thinking perspective for a balanced growth and discuss a roadmap of policy recommendations considering the potential for reducing air pollution, ghg emissions and noise

Doina Radulesch asks how does the deployment of charging stations affect the uptake of EVs and how do EVs impact electricity demand? Research findings document network externalities between EVs and charging stations. The impact of EVs on overall electricity consumption is still low, however there are considerable effects on the shape of daily electricity load

Anna Ebers Broughel and **Marko Viiding** report that In the early 2010s, Estonia built the world's first nation-wide fast-charging network for electric vehicles (EVs) and subsidized EV purchases. By 2015, the EV market had stalled after some 1,000 EVs were purchased. A decade later, renewed growth of the EV market is expected. They discuss lessons learned from past experiences and takeaways for long-term grid-planning.

Patrick O. Adoba and **Michael O. Dioha** write that Canada faces unique transportation challenges as the sector contribute around 25% of the country's total GHG emissions. EVs will play a key role in decarbonizing the sector, but this will only be possible with appropriate fiscal policies to bridge the cost gap, robust charging infrastructures, and programs aimed at improving positive consumer perceptions.

Icaro Silvestre Freitas Gomes writes a summary of the round tables that took place on September 10 and 11, 2020 at the Grimaldi Forum located in the Principality of Monaco, under the High Patronage of H.S.H. Prince Albert II of Monaco. The topic was "Positive energy territories and Electromobility." Various stakeholders from different fields of expertise, such as automakers, regulators, original equipment manufacturers (OEM), and grid operators, all contributed to the debate.

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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**

Jamil Khan theorizes that the days are not far away from when in the metropolitan and mega cities we will see more EVs at the expense of the traditional vehicles. This trend will continue to help not only the growth of new technologies and industries but also to reduce the pollution and the pollution-based chronic diseases which are reaching profoundly serious levels in the major cities of the world.

Fereidoon Sioshansi analyzes a report from 6 Oct. titled "Preliminary root cause analysis: Mid Aug 2020 heat storm" jointly released by the California Independent System Operator (CAISO), the California Public Utilities Commission (CPUC), and the California Energy Commission (CEC). Although extreme heat played a role in California's outages, it was the "Duck Curve" that ultimately got CAISO.

Tilaklal K. Doshi writes that the coronavirus pandemic and the collapse in global energy demand in the first quarter of 2020 in conjunction with an oil price war with Russia lead to plummeting oil prices. Despite slashing output, prices have not recovered and the prospects of economic recovery in the Middle East look significantly worse than that of other emerging market regions.

Jeff Combs and **Y. Lydia Hsieh** inform us that most academic articles that deal with nuclear fuel focus on the uranium resource aspect of the fuel. This is especially the case when examining the long-term prospects for the fuel, as the adequacy and price of the fuel becomes more of an issue. However, the enrichment technology dimension of nuclear fuel is critically important since most reactors are of the light water variety and require enriched uranium to operate. Enrichment technology may become even more important in the future, not just because of its ability to extend uranium resources, but because of how reactor technology and related fuel needs are likely to change over time.

Matteo Muratori, Catherine Ledna, Chris Gearhart, John Farrell, and **David Greene** respond to Mamdouh Salameh's article from the 4th Quarter 2020 Energy Forum entitled "An Uphill Battle for EVs vs ICEs" and assert that his conclusions are not based on the most recent data and are possibly misleading. They offer up-to-date data and statistics on the state of the global EV market and EV technologies.

DLW

Perspectives on Expanding EV Charging Infrastructure in the United States

BY TIMOTHY C. COBURN, THOMAS H. BRADLEY, JEFFREY LOGAN, AND CHARLES F. KUTSCHER

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See footnotes at end of text.

The path to decarbonization and sustainability in the transportation sector requires vehicle electrification to become dominant in every sector and every application.[1] This demands more extensive adoption of electric vehicles (EVs), along with development and deployment of supporting transportation systems and networks, market-promoting and system-supporting policies/regulations, and cooperative and innovative financing mechanisms.

In 2018, the U.S. reached the milestone of having more than one million EVs on the road.[2] Sales of light-duty EVs (plug-in hybrid electric vehicles, or PHEVs, and battery electric vehicles, or BEVs) have risen rapidly since 2016, increasing from 159,616 that year to 361,315 in 2018. While projections about future growth in the light-duty EV sector vary, most place the market share at 7%-10% by 2025-2026. U.S. sales of all vehicles, including those of EVs, have wavered since late 2019 as the COVID-19 pandemic has progressed, but the overall market is expected to recover in due time, with new EV models (including SUVs, trucks, and mid-sized sedans) continuing to drive growth in total EV sales.[3]

Ready access to battery recharging facilities is among the most critical elements in an electrified transportation system. So, although electricity as a transportation energy source has great advantages in terms of its consumer preference, ubiquity, and safety, individual consumers and fleet managers must be convinced that EVs can be "refueled" essentially on demand similar to refueling gasoline or diesel vehicles, thereby eliminating "range anxiety."[4]

While rapid strides have been made in the development of charging infrastructure throughout the U.S., in recent years, the pace of deployment still lags the pace of EV sales. As of mid-2020, there were over 25,000 public and non-residential private (e.g., businesses) EV charging stations across the U.S. with more than 80,000 connectors (outlets or charging units)[5], an increase in stations of more than 50%, and an increase in connectors of more than 85%, from 2016.[6] In contrast, as noted above, there are more than one million plus EVs of all types on U.S. roads. Further, the number of charging stations is somewhat overshadowed by the 100,000 or more gasoline/diesel fueling stations around the country, although this is somewhat of an apples-to-oranges comparison since official counts of EV charging units do not include the untold number of residential charging outlets.

Counting the numbers of stations and connectors can be somewhat confusing because there are different levels. Level 1 charging (similar to a residential 120V outlet plug) adds two to five miles of range per hour of charging, or up to 40 miles of range in eight hours of charging for a mid-sized vehicle. Level 2 charging (similar to a residential 240V plug) adds 10-20 miles of range per hour of charging, or up to 160 miles of range in eight hours of charging. Typical DC fast charging (DCFC) adds 60-80 miles of range for every 20 minutes of charging.[7] These estimates may differ depending on the vehicle-battery combination in question.[8] All told, roughly 82% of the connectors available in mid-2020 were Level 2 units and the remainder were DCFC units.[9,10]

In the U.S., ownership and operation of charging networks are dominated by a few major players who provide access to charging largely on a subscription or pay-as-you-go fee basis. ChargePoint has the most extensive network in the country. Tesla, with the second largest U.S. network, primarily provides proprietary services for its own vehicle owners, but does maintain some multi-user business partnerships. Significant expansion of other existing networks (e.g., EVgo, EV Connect, Electrify America, Blink) is also being planned, in some cases involving joint ventures or collaborative efforts with travel-related entities such as major truck stop companies and convenience store chains. ChargePoint and Electrify America have announced plans to allow joint roaming access to their mutual networks in much the same way that wireless communications companies share cell towers.[11] Facilitating interoperability of this type among network providers is one of the keys to optimizing the charging experience. All these initiatives suggest that non-residential EV charging has the potential to become a significant industry, with even the major auto makers, oil companies, and power providers getting onboard.[12]

Despite the many positive developments, edge issues pertaining to scarcity of charging resources often dominate a prospective EV buyer's thinking, such as (1) how far it is to the next/closest charging station and (2) how long it takes to get to the next charging point. For individuals traveling cross-country, access to charging (especially, fast charging) is an important concern, particularly when not traveling on major thoroughfares or interstate highways. In addition, individuals who live beyond urban/suburban areas are relatively unlikely to have access to charging outside their own homes. Hence, development of a comprehensive, national charging network, or absent this, regulated or greater voluntary cooperation among network providers, is an absolute necessity if full electrification is the goal.[13]

While the foregoing points are largely centered on cross-country transportation, the need for an intra-urban, optimally situated charging network is not diminished. The U.S. Department of Energy's Vehicle Technologies Office (DOE/VTO) has recommended that city drivers should not be farther than three miles to the closest charging station,[14] but others have suggested that improved battery technology may mitigate the need for such density.[15] It may be unrealistic to think that every existing gasoline/diesel station in the country will be retrofitted with an EV charging station, but it is certainly within reason to expect that a large segment of those within urban/suburban/near-urban areas will be. In fact, they must—or there must be new stations constructed—in order for the vehicle population to approach full electrification. While public charging stations are necessary for long distance travel and transportation of goods, they are also a prerequisite for individuals who want to purchase an EV, but for one reason or another, cannot charge at home (e.g., street parking only). The jump to a more widespread charging network—even a national charging network—seems well within reach, at least for light-duty vehicles, since Tesla, which today has a majority of the U.S. EV market, has largely solved the infrastructure problem for its drivers.[16]

The ability to recharge an EV at home is the ideal situation for most everyday activities. In fact, the need for a public charging network notwithstanding, the ability to conveniently recharge a vehicle has always been, and will continue to be, mostly about charging at home—in the garage, using a wall plug or overhead charging connector, or at a free-standing driveway charging port.[17,18,19] For multi-occupancy dwellings, such as apartment buildings, university dormitories, and living facilities for independent senior adults, the situation is not so clear-cut. Some of these housing arrangements may come with access to garages (attached or detached units, or multi-level parking facilities) that can accommodate charging units, but many do not. For such environments there are unresolved questions about who pays for the infrastructure (procurement, installation, operation, and maintenance) plus issues concerning how vehicle electricity usage is billed (assuming it is not automatically linked to an individual housing unit's consumption). Cooperative charging for occupants of self-contained communities (e.g., homeowner associations, over-55 adult neighborhoods, or resort commons such as RV parks) and their guests/visitors, in which the costs of infrastructure and electricity may be shared through covenant requirements, is a feasible model for some, but not all, situations.

To achieve full electrification, private businesses, public corporations, and non-profit entities (e.g., churches and schools) should be incentivized to provide charging facilities at work, recreation, entertainment, shopping, and related venues. Urban and city center parking garages will need to be reimagined and reconfigured in order to incorporate sufficient charging capabilities. A number of companies (e.g., Walmart, Whole Foods) are already moving in this direction, but more capacity will need to be added as EVs become more ubiquitous. Again, the issue of who pays for infrastructure deployment, which in the public sphere can involve individuals, local/regional/national businesses, utility companies, and governmental jurisdictions, remains unresolved in many situations and may have to be addressed statutorily.[20] Utility ownership may raise questions concerning the appropriate use of customer money on public charging facilities and whether investment in such facilities by regulated monopolies gives them an unfair competitive advantage.[21] Further, participation of private entities will depend on creation of innovative business models likely involving partnerships that leverage risk to guarantee a return on investment.[22]

Within the vision for an expanded charging network it will not be sufficient for most public stations to be Level 2. While Level 2 charging will certainly be adequate for many situations and applications, the majority of prospective vehicle buyers will not want to spend any more time charging their EVs than when refueling a typical gasoline or diesel vehicle. The goal of DOE/VTO is to decrease charging time to 15 minutes or less,[23] but even 10 minutes is more than most people spend refueling a gasoline vehicle. Currently, most DCFC units can fully charge an EV battery to at least 80% of full range within 30 minutes (Tesla's superchargers can be even faster), whereas Level 2 charging takes about three and a half hours to fully charge an 80-mile battery and about eight hours for a 200-mile battery.[24] On the other hand, most drivers do not need to fully charge their vehicle's battery every day given daily travel demands, in the same way that most gasoline or diesel vehicle owners do not need to refuel every day. Some compromise acceptable to the vast majority of prospective EV buyers will need to be reached, perhaps through culture-building, educational, and outreach programs. Over time, as EV ownership increases, the capabilities of recharging systems will undoubtedly improve and evolve as business models adapt to driver preferences and requirements.

Reducing charge time is not solely a facility or infrastructure issue. In addition to the power of the charging station, it has to do with the ability of the battery itself to accept the charge and the type of charging port available on the vehicle. Lithium-ion batteries, which power most EVs today, do not perform optimally in extreme temperatures, and are more difficult to fully charge in these conditions. Unfortunately, these are some of the situations under which drivers do not want to be waiting for their battery to charge. Further, continuous and repeated fast charging is not recommended because it can stress the battery thermally and chemically and lead to more rapid degradation.[25] Research into alternative stationary and non-stationary charging strategies (wireless inductive charging, dynamic charging,[26] charging-while-driving,[27,28] and catenary charging),[29] as well as battery structures and chemistries that are both practical in size and more amenable to fast charging, is proceeding, but technology development, standards development, and financial support must work together to achieve more progress.[30] Charging will inevitably still take longer than filling a gasoline tank, but fast charging is both a fundamental and systems problem that must be addressed because it constrains progress towards full electrification.

To one degree or another, expansion of charging infrastructure in the U.S. is also confounded with (1) vehicle-to-building integration and (2) the cost of electricity to the vehicle owner/consumer. To accommodate appropriate and sufficient charging infrastructure, buildings must be EV-ready; meaning that garages, parking areas, etc. must be wired appropriately and provide sufficient space for placement of charging facilities. Ensuring EV-readiness will likely require changes in code restrictions, at least for new construction, along with funding and/or financial incentives for retrofitting existing structures. With regard to electricity cost, consumers are more likely to consider an EV purchase if EV-friendly electricity pricing scenarios are available. While time-of-use (TOU) or dynamic pricing provides an important incentive to EV purchasers who primarily intend to charge their EVs at home, those same advantages are not necessarily enjoyed while charging elsewhere and should be expanded. Other incentives such as the elimination of demand fees, whether charging at home or away, also create a more EV-friendly market scenario that will, in turn, support a more prolific charging infrastructure network.

Developing and deploying an expansive charging network to support electrification of the transportation sector will not come cheaply. This is true whether stationary or non-stationary solutions become the norm, but it would be particularly costly to build out an entirely new infrastructure system such as inductive charging on a widespread basis. The estimated need for capital investment in the U.S. through 2030 is at least $11 billion,[31] assuming current projections hold true, with more than $2.5 billion needed in major U.S. metropolitan areas through 2025.[32] These costs must be balanced against the many benefits of electrifying mobility, including improved energy security, air quality, environmental justice, and greenhouse gas mitigation, among others.

Relative to other countries in the world, the U.S. is behind in terms of charging capacity infrastructure[33] and it will need to make a major investment relatively soon in order to satisfy demand and meet transportation-related GHG emissions reduction goals. The challenge is substantial, but so are the opportunities, both in terms of economic development and climate impacts.[34]

Footnotes

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[29] Other non-stationary options such as battery swapping and mobile charging continue to receive periodic consideration in the contexts of heavy duty fleet vehicles such as buses, garbage haulers, snow plows, and long-haul tractor-trailer rigs used in supply chain and logistics applications, but are largely considered to be impractical today for light-duty vehicles because of the way the battery packs are being integrated into a vehicle's chassis.

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Cost Savings in Areas with Unproven Reserves: Risk = Reward in Big Oil

BY WILLIAM (BLAKE) SUTTON AND ZHEN ZHU

Introduction

Exploration and Production (E&P) companies face a tremendous amount of financial risks nowadays with oil prices experiencing historical lows and large volatilities. Just like any businesses in the competitive market, maximizing expected future cash flows is the way for E&P companies to meet investors' return expectations and sometimes it may be the way to survive the harsh business environment. Oil and gas firms will not only consider the expected revenues to be successful, but also expected costs when make strategic investment decisions. With the advent of deep horizontal wells, the costs associated with exploration and production have gone through the roof. Simply drilling and completing the average one-mile lateral well has an average cost of approximately 4.5 million dollars in Grady or McClain county Oklahoma (SCOOP), two-mile lateral wells will double that cost. However, this exorbitant figure is not the only thing exploration and production (E&P) companies need to take into consideration. In these areas where high production levels are typical, but not guaranteed, oil and gas companies can have millions of dollars tied up before the bit even hits the ground. This article discusses the often overlooked but ever important costs associated with the land management process. Each play not only has its own geological characteristics but also the wells within it typically have similar associated costs and ownership (USGS, 2017). To illustrate the idea, the land management costs in two main plays will be compared and contrasted in the present work: the heavily explored and proven "SCOOP" in Oklahoma and the comparatively new and "unproven" Powder River Basin (PRB) in solitary Wyoming.

Land Management Process

There are six main land management processes necessary when drilling any oil and gas well in the United States: imaging, title, leasing/acquisition, obtaining title opinions, curative and payment; the landman is involved in all of these processes.

Before a company can drill a well, they must obtain the rights to do so; to do this they need to know who owns mineral, surface, and leasehold rights in the area where they plan to explore. For Title Landmen to be able to generate ownership reports they have to examine all relevant documents such as deeds, leases and assignments. These documents are kept of record in the offices of the County Clerk at the courthouse for the county where the land is located. In some Counties these documents are available online, in some Counties they are not. For the latter, the E&P has two options: to have Title Landmen run "Stand Up Title" at the County Clerk's office or have the relevant documents "imaged."

Running "Stand Up Title" is an industry term which refers to a Title Landman going to the courthouse and running title there. The Title Landman physically pulls each book from the shelves, and researches ownership from the origins of title (Patent) to present. From this method, the E&P does not have the ability to examine these documents themselves to "check" the work of the Title Landman.

Having the relevant documents "imaged" involves sending an imager (or imagers) to the County Clerk's office and taking pictures of those documents. Imagers need to have a rudimentary knowledge of Title in order to know what constitutes a relevant document, but they are generally not considered "Landmen." The E&P will have copies of all of these documents to "check" the work of the Title Landman, as well for reference for later steps.

Whichever method the E&P chooses, the Title Landman examines all relevant documents and prepares an ownership report for the client. This includes surface owners, mineral owners and leasehold owners in a particular area. The SCOOP and PRB horizontal wells are typically one- or two-mile lateral wells, and occasionally three- and even four-mile lateral wells. The area "drained" by these wells is determined by geologists for the oil and gas companies and is confirmed/approved by state regulatory agencies. The area "drained" by these wells is referred to as a "Unit."

Once it is known who the owners are in a target area (Unit) the E&P company needs to obtain the rights to drill from the owners of record. This step is called leasing and acquisition and is typically performed by a Leasing Agent (Landman). Leasing Agents can obtain the rights through a mix of the following 3 ways:

Obtaining oil and gas leases from mineral owners

Each mineral owner is typically paid a bonus at the time of leasing

ie: $5500 per mineral acre

And is given a royalty interest which will be paid based on future production

ie: 1/8th Royalty

Purchasing mineral rights from mineral owners

The E&P purchases the mineral rights outright

ie: $15000 per mineral acre

Obtaining Assignments of existing (valid) oil and gas leases from other E&Ps

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The E&P purchases the lease outright
The E&P purchases rights to certain depths

After an E&P company begins to obtain the necessary rights, they will typically order a Title Opinion. Title opinions are generated by bonded attorneys (Title Attorney) who reexamines all relevant documents and verifies (or contradicts) the work of the Title Landman. In effect, verifying that the company has obtained all necessary rights to proceed with their plans to drill. If there are title issues of record, the attorney then comments on them and makes requirements for landmen to "cure".

Curative involves contacting owners and obtaining necessary documents to resolve title defects. Frequently, these requirements involve determining and contacting the heirs/devisees of mineral owners who are deceased. In these cases, the heirs have not filed the proper documents of record to pass title from the decedent to his or her heirs. Passing title to these heirs and obtaining leases from them is part of the Curative process.

It is always in the best interest of the E&P to obtain as much interest as possible in agreement with the mineral/leasehold owners; however it is not always possible to obtain 100% working interest in a Unit through leasing (for example an owner cannot be found or refuses to deal). If these rights cannot be obtained, the E&P can obtain the rights through a legal action known as forced pooling. Ideally, this occurs prior to the E&P spudding (starting to drill) the well, and ownership of the well will be established. Force Pooled parties are offered terms in line with the leases obtained by other mineral and leasehold owners within the Unit (or surrounding areas). Additionally, in lieu of leasing or selling to the E&P company, a mineral or leasehold owner can elect to participate in the well and pay their fair share of the drilling costs.

Finally, each owner is put into a comprehensive final (and slimmed down) ownership database called a JIB (Joint Interest Billing) or Pay Deck for the Unit. The Pay Deck shows how the revenues generated from sales of petroleum product are to be distributed. This step is usually performed by an in-house landman who works for the E&P company rather than an external service provider or law firm which typically perform all the preceding steps.

Associated Costs: Proven v. Unproven

The costs associated with performing the services discussed in the preceding section vary greatly from play to play. To begin discussing the costs, a brief history of the two areas of interest is in order.

McClain and Grady Counties in Oklahoma (now part of the SCOOP and STACK plays) are heavily explored oil fields in central Oklahoma that have seen extensive exploration and production since soon after the state's founding. As a result, landowners quickly learned the value of the minerals in the area and the rights became severed from the surface as early as the 1920's through 1940's. In many cases minerals were bought, sold, and broken up into tiny fractions. One of the authors has examined fractions as small as 1/42,972nd of 1.00 acre mineral interest.

Most of the early, shallow, wells drilled between 1920 and 1950 are no longer producing. However, a later round of exploration, mostly drilled in the 1960s, 1970s, and 1980s, resulted in numerous countless successful traditional style oil and gas wells that are still producing. Consequently, the oil and gas leases taken prior to these wells being drilled are still valid and effective. In these instances, not only do the Title Landman and Title Attorney need to determine the current mineral ownership, but they need to determine who owns the rights to the oil and gas leases taken 50-70 years ago as well. From a title perspective, this increases the level of difficulty, time and possibility of mistakes exponentially.

Further, this area was one of the first targets and played a huge role in the development of the modern "shale boom" or advancement and increase in prevalence of deep horizontal drilling and fracking techniques. Competition between E&Ps was rampant. Many companies, in an effort to acquire as much acreage, as quickly as possible, resulted in bad leases, bad assignments, and assignments of various depths. This compounded the problems and added a whole new complex layer to the ownership of oil and gas rights in the area.

On the other hand, the Powder River Basin in Wyoming was completely unexplored until the late 1960's; it does have some older traditional wells from that period but the number of them and their production quantities were far less than those in Oklahoma and the overall "gold rush" effect was not near as great, with only a few major companies controlling the area (Gordon et al, 1990). This has resulted in much simpler ownership and in many cases the minerals remain unsevered and in the hands of surface owners. The play's potential for horizontal shale wells began to pique the interest of E&P companies as early as 2009 and title is beginning to get more complex, but it pales in comparison to the SCOOP.

Combing through countless file folders containing images from both areas reveals that on average in the SCOOP there are anywhere from 1,500-10,000 images per section and in Campbell county Wyoming the folders contain around 7,000-14,000 on average. However, the online data bases in the SCOOP are more complete (or useful/better organized) resulting in less required imaging.   Also, it should be noted that in the Powder River Basin, landowners typically own huge swaths of land and there can be hundreds of pages to each instrument consisting of only legal descriptions. This can occur in the SCOOP too though to a much lesser extent. Further, the image folders examined in the SCOOP did not contain these "long docs" (instruments with more than 25 images), while the folders for Wyoming did; so the discrepancy may not be as high as indicated here. Imagers typically shoot around 500 images a day and their services usually cost around $250 per day. Being conservative for the SCOOP and liberal for the Powder River Basin an E&P company is probably looking at around $1,500 and $3,500 per section for preliminary imaging services in each area, respectively.

Moving onto the generation of ownership reports is where the costs really start to look starkly different for each play. Sections in the SCOOP usually contain hundreds of different mineral owners and numerous leasehold and overriding royalty owners; while sections in the Powder River Basin may contain as little as one mineral owner (who also owns the surface) and one lease with two leasehold owners. It typically takes a landman around 1-3 months to generate an ownership report in the SCOOP while only 1-3 days in Wyoming. Simple explanations of the contents of two real ownership reports for the SCOOP and the PRB area are attached hereto as Exhibit "A" and Exhibit "B" respectively. Landman services are typically around $450 per day to the E&P company so an average report on a section in the SCOOP costs anywhere from $15,000 to $50,000 while only around $1,000 in the Powder River Basin. The story is similar when looking into the leasing, curative and payment portions of the process.

Finally, the bulk of the land management costs come in the form of legal fees for the generation of title opinions. Attorneys usually bill around $250 per hour and they typically take longer than landmen to generate reports due to being more thorough and writing lengthy comments and requirements. A typical title opinion for a section in the SCOOP is anywhere from 500-3,000 pages long depending on the complexity of title and the wordiness of the attorney and takes around 4-6 months to generate. Further, E&P companies must obtain multiple title opinions during the process, namely an original title opinion containing the groundwork, a drilling title opinion prior to drilling and a division order title opinion prior to payment. After all these are completed opinions on a typical section in the SCOOP can cost on average anywhere from 200,000-600,000 dollars depending on the complexity of title and the attorney. In stark contrast this process usually costs around 35,000-50,000 in Wyoming.

Limitations

The present work fails to address the stark differences in leasing and acquisition costs between the two areas. Owners in the SCOOP typically demand much higher prices for purchasing leases and minerals, easily driving pre-drilling costs into the millions. Further, average burdens on the leases are typically higher in the SCOOP as well, as mineral owners demand higher royalties and preceding leasehold owners commonly reserve overriding royalty interests.

Future studies could go more in depth into these costs in the subject plays and break down where the E&P company needs to percentagewise break even on the well. High royalties and high participation rates in the SCOOP dramatically eat into the profitability of an oil and gas well and play a role just as important, if not more important than the costs of services analyzed in this article.

Conclusion

Commonly overlooked costs necessary in drilling oil and gas wells are attributed to services involved in the land management process. These costs can vary greatly from play to play, this article has focused on these costs in two starkly different areas: the Oklahoma SCOOP and the Powder River Basin in Wyoming. The table below summarizes the findings (associated costs per Section [i.e., one square mile]):

Service	SCOOP - OK	Powder River Basin - WY
Imaging	$1,500	$3,500
Ownership Reports	$20,000	$1,000
Leasing and Acquisition	$20,000	$1,000
Curative	$20,000	$1,000
Title Opinions	$300,000	$50,000
TOTAL:	**$366,500**	**$56,500**

As shown the costs of land services in areas with proven reserves like the Oklahoma SCOOP are dramatically higher than those in newer developing plays like the Powder River Basin in Wyoming. A typical horizontal well will have a unit consisting of two sections, so by doubling the numbers shown above one can get a rough idea of the per well costs; though it should be noted that these can vary widely and the estimates above are based on broad generalizations and may lean rather conservative. Compounding this problem further, leasehold burdens are typically much higher in areas proven reserves as well.

Trusting the gut of a geologist and getting into a play early can save oil and gas exploration companies hundreds of thousands on land management services per well. Being that a large company will typically drill tens to hundreds of wells in a play, these savings can add up and start to look real tempting for anyone in the finance department.

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Exhibit "A"

Example of Title in the SCOOP Play:

The index for one Section in the SCOOP Play shows 1688 individual instruments (deeds, mineral deeds, leases, and assignments) to examine to determine current ownership. This Section had 10 wells that were drilled in 1953, 1954, 1955, 1961, 1983, 1984, and 1985. Only two of the wells were active and producing, and these Units only encompass 80.00 acres each. However, due to the terms of the leases, and the formerly producing wells, these two wells held the leases covering 420.00 acres by production.

The ownership report:

- has 17 mineral tracts
- is 182 pages long
- has more than 50 notes regarding title issues

The title was so complex, and the first Title Opinion obtained was so erroneous that a new Title Opinion from a different attorney had to be obtained (each costing more than $500,000.00).

The Second Title Opinion:

- has 17 minerals tracts
- is 867 pages long
- contains 97 Curative Objections and Requirements

The Pay Deck for the client's well has:

- 1297 Royalty owners
- 620 Leasehold owners
- 118 Overriding Royalty Interest owners

Exhibit "B"

Example of Title in the PRB Play:

In one Section in Campbell County, Wyoming, there were 312 individual instruments (deeds, mineral deeds, leases, and assignments) to examine to determine current ownership. This Section had 9 wells that were drilled between 2011 and 2019. All of these wells are still producing.

The ownership report:

- has 3 mineral Tracts
- is 49 pages long
- has 5 title notes regarding title issues

The Title Opinion the client obtained:

- is 53 pages long
- contains 16 Curative Objections and Requirements

The Pay Deck for the client's well has:

- 5 Royalty owners
- 3 Leasehold owners
- 2 Overriding Royalty Interest owners

The Chicken and the Egg Dilemma for Charging Infrastructure and Electric Vehicle Diffusion: A Developing World Case Study

BY JESSICA ARIAS-GAVIRIA, VERONICA VALENCIA-HERNANDEZ, SANTIAGO ARANGO-ARAMBURO, YRIS OLAYA M, ERIK R. LARSEN, RICARDO SMITH

Introduction

The sustainable development goals (SDGs) were established as a guide which exhort societies to look at their 2030 horizon (UN, 2015). Although synergies exist between several goals, there are also a number of trade-offs between SDGs that makes sustainable development an even harder challenge (Nerini et al., 2018). Reaching the SGDs requires a broad and multidisciplinary vision, as well as carefully planned actions to minimize these trade-offs. The transport sector is a fundamental driver of economic development and is necessary for human wellbeing, but it consumes 65% of oil products (IEA, 2019a), is responsible for 14% of global CO_2 emissions (EPA, 2020) and for 10 % of total anthropogenic PM10 and PM2.5 emissions (IEA, 2018), and accounts for up to 25 % of black carbon (Klimont et al., 2017).

There are several problems associated with the transport sector and urban mobility that emphasize the need to think about sustainable mobility. The concept of sustainable mobility encompasses safe, affordable, accessible, and efficient services and infrastructure while minimizing GHG emissions and environmental impacts (UN, 2016). Although the sustainable mobility scheme covers a wide spectrum of alternatives, this document focuses on one of the alternatives aimed at mitigating the problem of air quality, extensive use of fossil fuels and GHG emissions: electromobility. In this paper we discuss measures that can facilitate the adoption of electric vehicles and the development of supporting infrastructure such as charging stations.

To fully achieve the environmental benefits of electromobility, societies need to simultaneously develop renewable energy generation and distribution and charging infrastructure. Additionally, societies focused on this solution need to develop new business models and consider the beliefs and choices of individuals. This coevolution is represented in Figure 1 as a reinforcing loop between electric vehicles (EV) and charging infrastructure. In this phenomenon, the adoption of EV depends on the population's preference of EV over fossil-fueled vehicles (FFV). With more EV circulating, the demand for charging infrastructure increases, creating the opportunity for new business models focused on the EV service. However, the construction of charging points may take time, and the increase in charging point availability could be delayed. This availability is necessary, not only for increasing the preference of EV over FFV, but is also needed to provide confidence to consumers about the reliability of the system.

As Figure 1 shows, providing incentives to the EV demand only, is not enough to increase the use of EV. This "chicken and egg" causal dilemma requires action from all fronts within a system's thinking perspective to guarantee that the growth of both EV and charging points are balanced.

In developing countries such as Colombia, the transport sector accounts for 40% of the total fossil fuel demand of the country, and 11% of the total GHG emissions (DNP & enersinc, 2017; IDEAM & PNUD, 2016). The rapid growth of Colombian cities has brought another challenge regarding air quality. Cities like Bogota and Medellin must deal with several environmental contingency strategies during the year as a result of high concentrations of particulate material and other pollutants. Although these episodes are strongly correlated to meteorological conditions, the direct causes come from the large quantity of emissions from transport and industry (Isaza, Hoyos, & Herrera, 2019; Zapata, Cano, Ramírez, Rubiano, & Jiménez, 2015). Electromobility is an innovative solution to both GHG emissions and air quality problems. In this vein, the Colombian government started to promote electric

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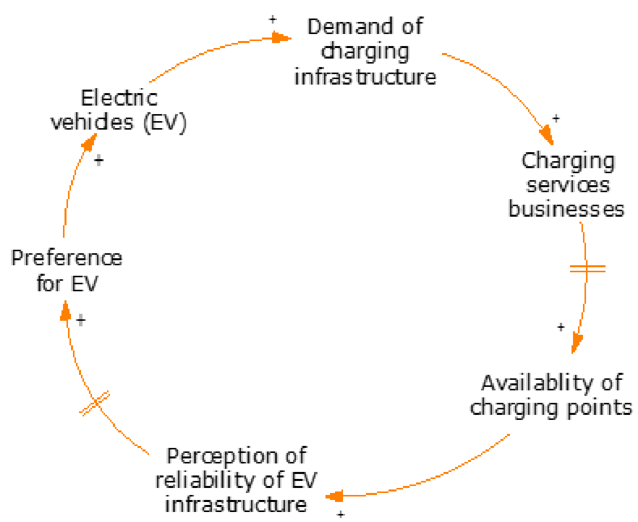


Figure 1 - Reinforcing loop between demand for electric vehicles and electromobility infrastructure.

and hybrid vehicles in 2010, as shown in Figure 2. With the coalition of several of its institutions such as the Mining and Energy Planning Unit (UPME), the Ministry of Environment and Sustainable Development (MinAmbiente), and the National Planning Department (DNP), the Colombian government has established goals regarding EV such as 17500 hybrids and EV by 2021 (UPME, 2016), and 600000 for 2030 (CONPES 3934, 2018). However, Colombian cities still have major barriers to a massive electrification of transport. To this end, the national government has authorized territorial entities to promote electric mobility through government incentives and tools. Cities such as Bogotá, Medellín and Cali have implemented policies engaging public transport and private incentives that promote the electrification of the transport sector (ANDI, 2019; FENALCO & ANDI, 2020).

Despite breakthroughs regarding electric mobility, Colombia is lagging behind other countries in the Latin American and Caribbean region, particularly in terms of standardization and operability (BID, 2019). Efforts have been insufficient, the targets are far from being met (today, the country has achieved only 37% of the goal for 2021) and many barriers are yet to be overcome. In addition to common barriers (financial, regulatory and legal, technical and technological barriers of public acceptance and market availability), developing countries such as Colombia have additional problems. Some examples of these national issues include: the fact that the initial investment for an electric car is not viable for the majority of the population, the lack of specific legislation, incentives, planning restrictions, standards, and R&D, cultural barriers such as a resistance to change and risk aversion to new technologies, and above all, barriers at the infrastructural level such as limited charging stations (Ardila, 2014).

In Medellin and its surrounding metropolitan area (The Aburra Valley Metropolitan Area - AMVA), mobile sources are responsible for more than 86% of NOx and 91% of PM2.5 emissions (UPB & AMVA, 2019). Local authorities are rather strict, and have been working in recent years to formulate and implement action plans for both air quality and sustainable transport, along with several citizen initiatives which monitor air pollution in the Valley and demand further governmental actions. These governmental plans and social demands seek to promote cycling, walking and public transport, as well as introducing electromobility to replace fossil-fueled private vehicles and buses. Although Medellin is the Colombian city with the largest progress in sustainable transport and many action plans are already in place, (an electric metro system among them) there is still a lot of work to be done. The main pending piece of these initiatives is the development of an electromobility infrastructure and the design of effective incentives. As an example, from the 64 buses bought in 2019, only 22 are currently operating because, in the words of the 2020 Secretary of Mobility, "there is nowhere to charge them" (Caracol Radio, 2020). In this vein, in this paper we intend to review the status of EV in Medellin, discuss the main opportunities and barriers for the transport sector, as well as the electricity sector, and recommend some actions to accelerate the adoption of EV in the city.

The case of Medellin Metropolitan Area

Medellín is the second largest city in Colombia (after the country capital, Bogota), the main city in the AMVA valley along with other nine municipalities, and the

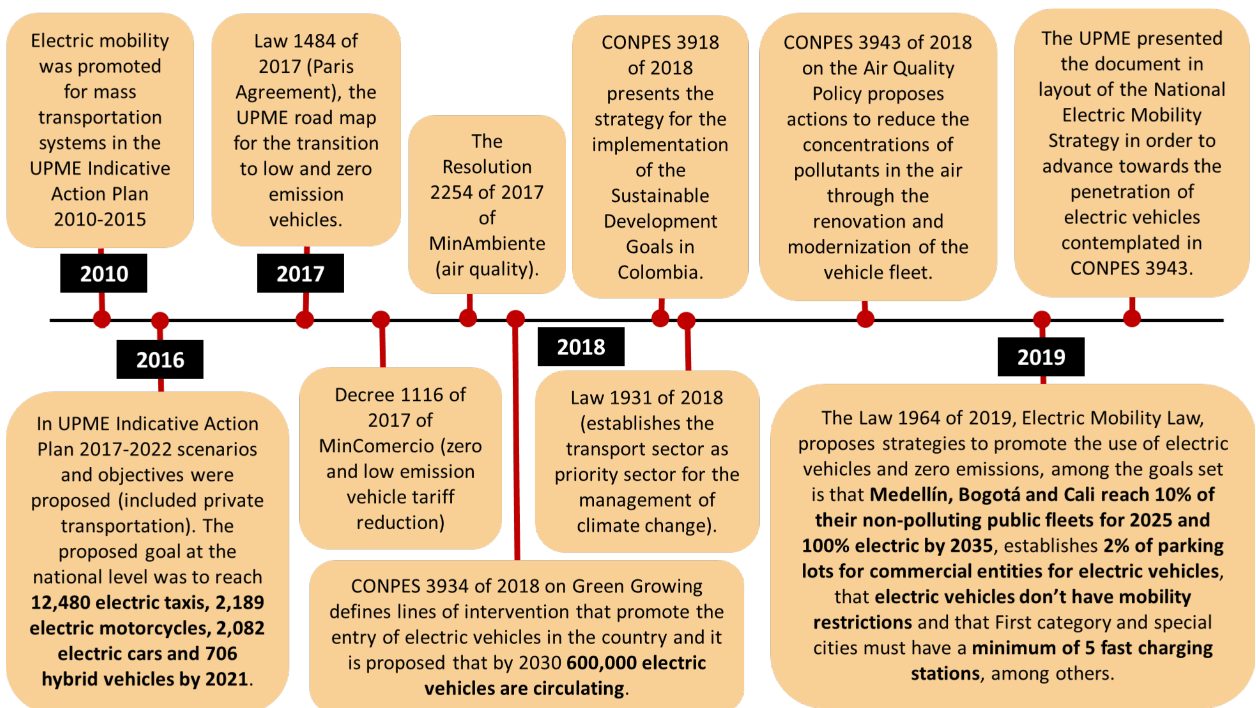


Figure 2 - Timeline of Colombian electromobility policies and incentives.

largest urban area and economic center of the Antioquia region. The valley is located in the central Andes mountain range, has an average altitude of 1495 meters above sea level (Alcaldía de Medellín, 2006), and is characterized by being a narrow, semi-closed, deep depression surrounded by high mountains. This characteristic prevents normal air circulation under certain weather conditions, which causes a trapping of particulate matter and pollution through a phenomenon of thermal inversion and atmospheric stability (Gómez, 2017).

The shape of the valley, the meteorological conditions, and anthropogenic emissions, where the protagonists are mobile sources, cause two environmental emergency episodes every year. One of these emergencies arises in April and another in November. Each episode can last up to more than one month. In these episodes, the concentration of PM2.5 and PM10 particulate matter exceeds the guideline values recommended by WHO (MinAmbiente & Fundación Cardiovascular de Colombia, 2012; UPB & AMVA, 2019; WHO, 2005). In fact, around 4500 people die each year in the city from Acute Respiratory Diseases (ARD), mainly in areas of increased vehicular traffic (Contraloría de Medellín, 2019).

In 2016, 74% of the emissions of the land transport in the Antioquia region were due to cargo transport and public passenger services (IDEAM & PNUD, 2016). In the AMVA, the transport sector emits more than 4.4 Mt/year of equivalent CO_2 (including CH_4 and N_2O), and most of the NO_x and PM2.5 emissions come from trucks and private vehicles, as shown in Figure 3 (UPB & AMVA, 2019). Since mobile sources are a main contributor to air quality problems in the metropolitan areas, some measures have been implemented to promote electric vehicles. The Colombian EV fleet has grown consistently in the past 10 years (see Figure 4), but EV still have a minor share, with only 0.04% of the country's total fleet (MinTransporte & RUNT, 2019). More than half of these EV are two wheelers (33% mopeds and 25% motorcycles), 26% are large vehicles such as trucks, buses and vans, and the remaining 16% are automobiles (MinTransporte & RUNT, 2019).

Antioquia is the region with the most registered electric vehicles in the country with approximately 24% (concentrated in Medellin and its metropolitan area), followed by Bogota with 21%, Cundinamarca with 20%, Valle del Cauca with 14% and Bolívar with 4%(FENALCO & ANDI, 2020; MinTransporte & RUNT, 2019). In 2018 the AMVA had more than 1.5 million private vehicles in circulation: 54.6% two-wheelers and 38.3% automobiles (DANE, 2019; UPB & AMVA, 2019). There are currently only a total of 25 electric vehicle charging points in the AMVA (See Figure 5), for an approximate

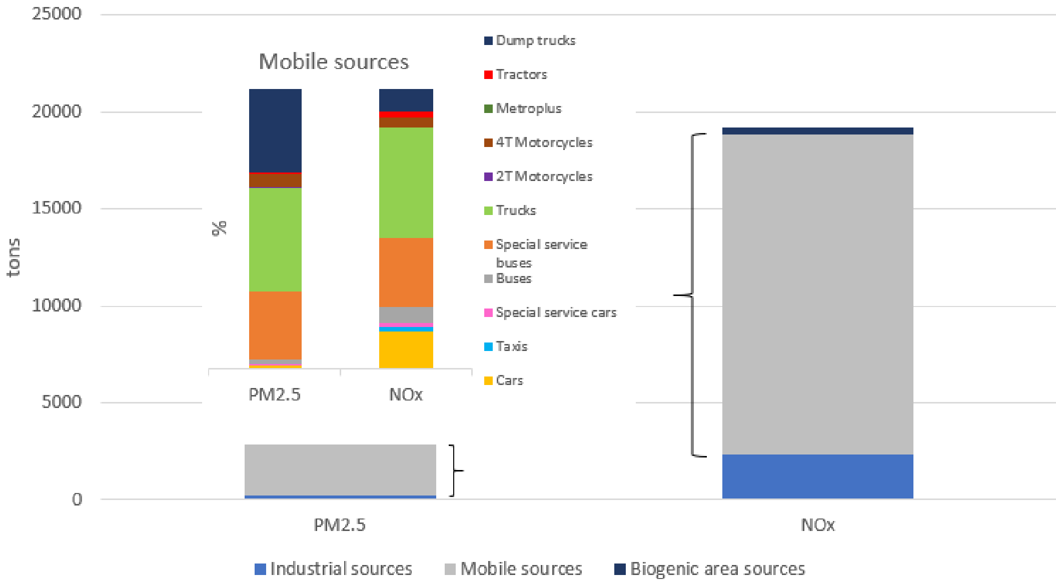
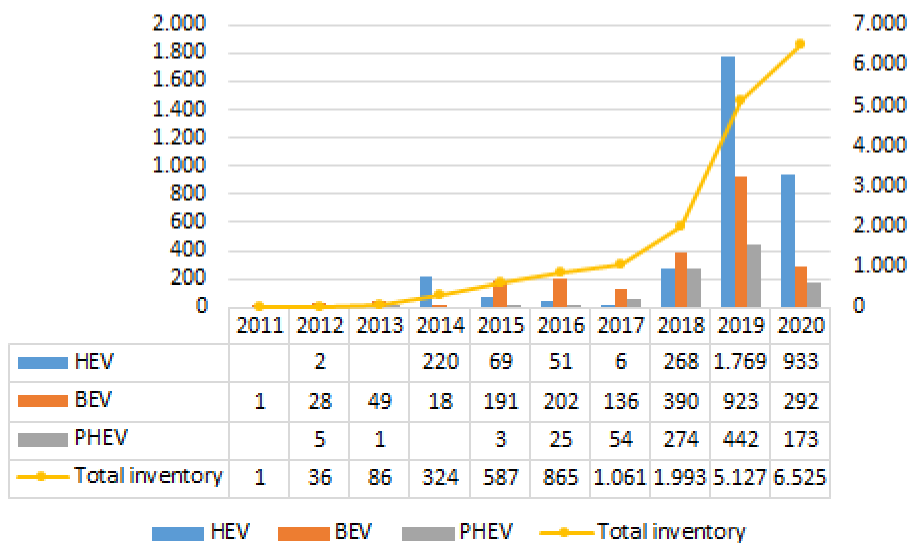


Figure 3 - Particulate matter emissions by type of source. Data from UPB & AMVA (2019).



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HEV		2		220	69	51	6	268	1.769	933
BEV	1	28	49	18	191	202	136	390	923	292
PHEV		5	1		3	25	54	274	442	173
Total inventory	1	36	86	324	587	865	1.061	1.993	5.127	6.525

Figure 4 - Evolution of annual sales (bars, graphed in left axis) and total inventory of electric vehicles by April 2020 (graphed in right axis) in Colombia. Data from ANDEMOS (2020). HEV: Hybrid Electric Vehicles, PHEV: Plug-in Hybrid Electric Vehicles, BEV: Battery Electric Vehicles

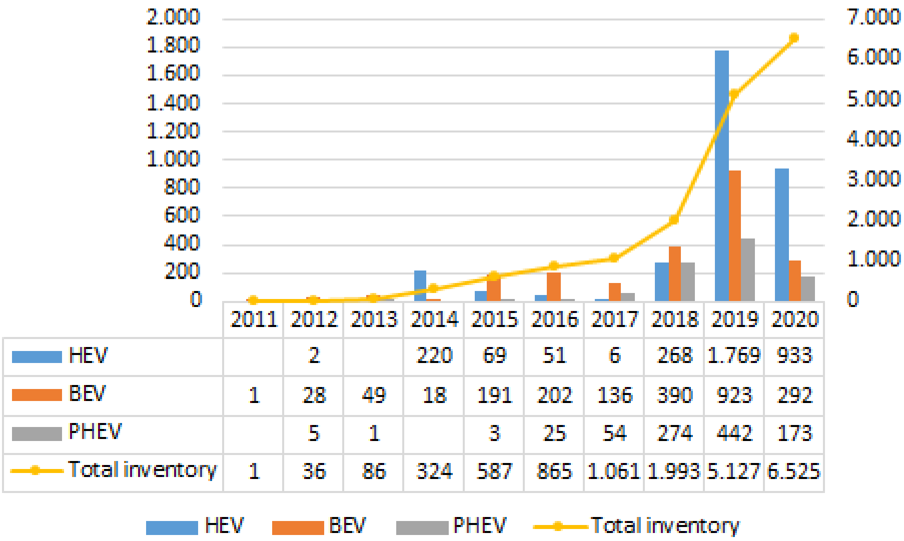


Figure 5 - Charging points in AMVA (Revista vec, 2020).
Green indicates normal stations and orange indicates high powered stations.

ratio of 1 charging point for every 60 electric vehicles (Revista vec, 2020). This is a very low rate compared to the recommendation of the European Union Alternative Fuels Infrastructure Directive ratio of 1 charging point for every 10 electric vehicles (EC, 2014; IEA, 2019b).

Recent efforts made by the Medellin Municipality to keep increasing the number of EV, include the introduction in 2018 of seven 100% electric vehicles for traffic police (Secretaría de Movilidad de Medellín, 2018), the acquisition in 2019 of 64 Padron-type buses for the public transport fleet, with a capacity of 80 passengers per bus (of which only 22 are circulating today), and the introduction in 2019 of a subsidy for the replacement of fossil-fuel taxis, which grants beneficiaries around 4900 USD per taxi. This last incentive has the target of replacing 1500 taxis by 2022 (7,5% of the taxis fleet) (Secretaría de Movilidad de Medellín, 2019b, 2019a).

To achieve a net decrease in emissions, it is also important to align decisions such as the introduction of new electric buses with the renovation of the internal combustion bus fleet. In the case of private transport, the factors that influence the individual purchase decision and cultural barriers such as the idea of the lack of autonomy and the higher cost of electric vehicles must be addressed. Additionally, there is an enormous opportunity to be found in electric motorcycles, as this type of vehicle represents almost 60% of the total number of vehicles in the national inventory (55% in AMVA) and are an accessible investment option for low and middle-income people, in a country where 47% of the population earns less than minimum wage (235,7 USD per month) (DANE, 2020; RUNT, 2020).

Policy recommendations

Despite the opportunities for EV, the high costs of electric vehicles and the lack of charging infrastructure are a barrier for adoption, particularly within the private sector. Table 1 compares measures adopted in different regions to promote electromobility. The most successful countries have developed incentives not only for EV, but also for charge infrastructure, local industries, and accurate standards for hardware (i.e., charger geometry) and buildings (EIA, 2019). Although Colombia has progressed in its definition of targets and fiscal incentives for vehicles, there are many barriers yet to be overcome. The main obstacles include adopting standards, incentivizing electric infrastructure, and promoting local industry. Government incentives have been insufficient. Tax exemptions and having no barriers with regard to mobility, among other incentives implemented, do not generate a preference for electric vehicles because the acquisition costs are still much higher than combustion vehicles. Another important factor is the limited grid capacity in households for charging an electric vehicle,

Table 1 - Promotion policies for EV in different countries. Data from IEA (2019).

		Canada	China	European Union	India	Japan	United States	Colombia
Regulations (vehicles)	ZEV mandate	x*	x				x*	
	Fuel economy standards	x	x	x	x	x	x	x*
Incentives (vehicles)	Fiscal incentives	x	x	x	x		x	x
Targets (vehicles)		x	x	x	x	x	x*	x
Industrial policies	Subsidy	x	x			x		
Regulation (chargers)	Hardware standards	x	x	x	x	x	x	
	Building regulations	x*	x*	x	x		x*	x**
Incentives (chargers)	Fiscal incentives	x	x	x		x	x*	
Targets (chargers)		x	x	x	x	x	x*	x*

* Indicates that the policy has only been implemented at a state/province/local level.
** Indicates partial implementation.

where adapting the electrical network is very costly for a single owner. Moreover, existing chargers in the market have different geometries which could make it difficult to find the right charging point for a particular type of vehicle in public places.

Figure 6 presents a roadmap of policy recommendations to tackle the chicken-egg dilemma discussed in the introduction from different perspectives, and accelerate the adoption of electromobility in Colombia, and particularly in Medellin. These policy recommendations are made considering the potential health benefits for urban centers, such as lower emissions, more efficient public transport, and less noise. However, a rigorous cost-benefit analysis is needed to be able to complement the design and be able to prioritize these policies. We have classified these recommendations as: short-term (those that could be addressed with the existing knowledge and information of the transport sector), and mid-term and long-term (that need further analysis and detailed studies to inform them). At a national level, Colombia has several fiscal incentives such as VAT reduction from 19% to 5%, however, additional incentives and regulations are needed to equal the ownership costs of EV to the costs of combustion vehicles (Decreto 1116 de 2017).

Safety and emissions standards for vehicles in Colombia are below the best available technologies, and while all vehicles are required to pass emission tests, there are difficulties in enforcing this regulation. In this vein, an upgrade of vehicle standards could support the adoption of technologies with lower emissions, including EV (IEA, 2019b). The deployment of electromobility must be accompanied by the evolution of the charging infrastructure. This entails that it is also crucial to establish clear targets for charging stations and evaluate the pertinence of fiscal incentives to reduce the costs of electrical infrastructure. Moreover, the country needs to enforce the adoption of a unified standard for EV chargers, and to align building standards with electricity standards to ease charging in residential buildings. To remove perception barriers regarding the performance of electric vehicles, it is important to continue with the demonstration pilots in the public transport sector (i.e., buses and taxis). More sustainable transportation models can be achieved by involving stakeholders in the planning processes and policy design.

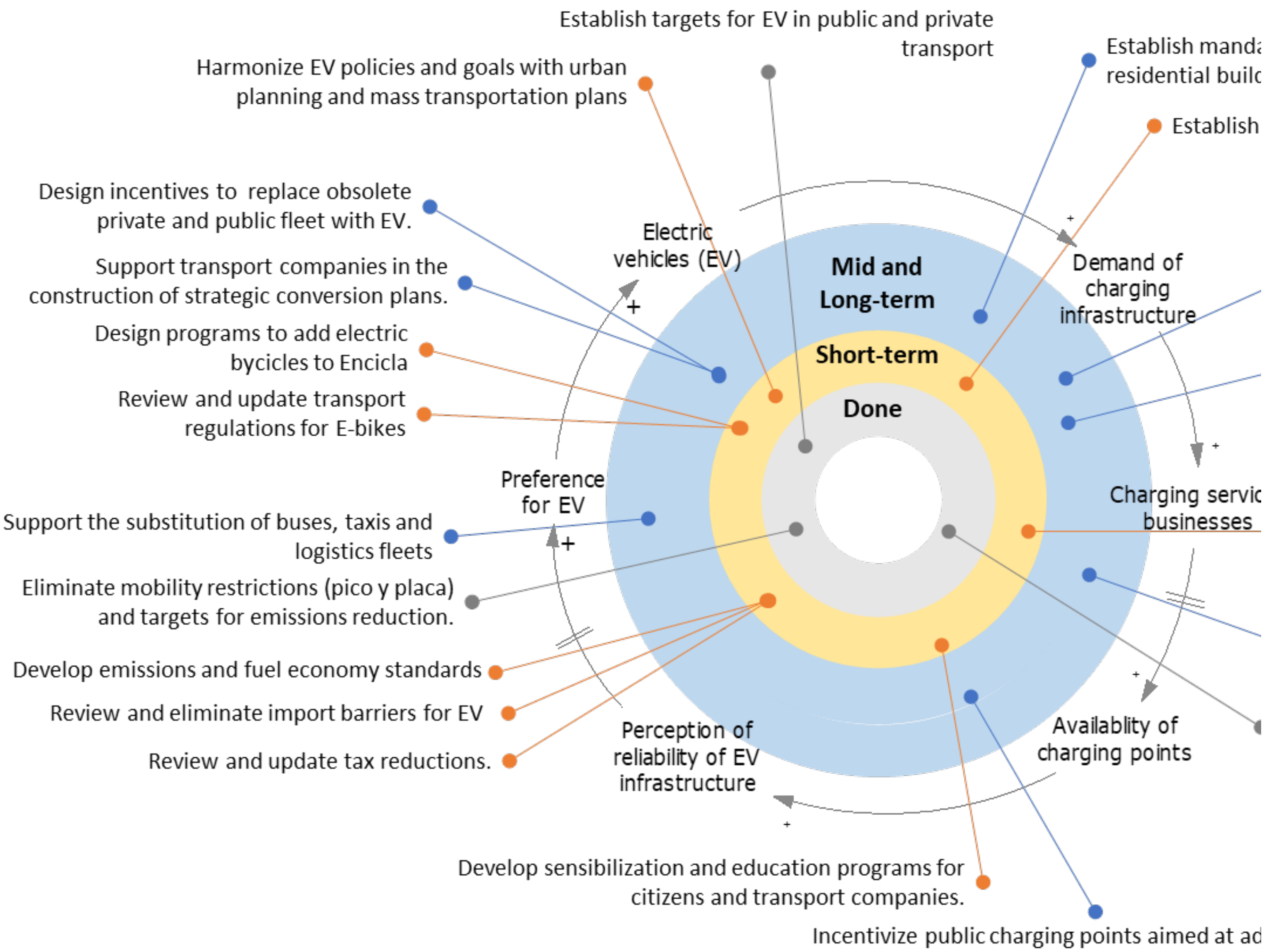


Figure 6 - Roadmap of policy actions for promoting EV in Medellin

Given that the infrastructure requires immediate attention, in the short term the government and companies can continue promoting charging points in existing parking lots in public places such as shopping centers and universities. In addition to this measure, in the mid-term the local authorities should evaluate the pertinence of including mandatory requirements for charging points in new buildings and address the limited grid capacity that prevents charging in households and older buildings.

Medellín needs to continue developing a sustainable, integrated public transportation system, supported by electric buses, taxis and bicycles, rather than just introducing more cars to the already congested city. There are opportunities to adopt EV in sectors such as last-mile delivery (movement of goods from a transportation center to the final destination) and school transportation, renewing an ageing fleet. Lessons from fast motorcycle adoption in the past suggest that this is a segment of private transportation with high growth potential for EV and that this sector needs to be given the attention it is due in order to ensure the safety of drivers and pedestrians. In the private vehicles sector, motorcycles are strategic; we cannot ignore that motorbikes provide a cheap and efficient alternative to transportation, especially for the low-income population that lives on the hillside neighborhoods of Medellin. The most strategic vehicles in the commercial sector are buses, trucks, and cargo and logistics vehicles (significant contributors in emissions from mobile sources, see Figure 3). It is also paramount for the local authorities to support transport companies in the construction of their own strategic plans for conversion towards sustainable fleets.

Medellín also has a free public bicycle sharing program called "Encicla". A discussion that could take place in the mid-term is the design of a tariff program for including electric bikes to the "Encicla" fleet. Electromobility, beyond encouraging the use of EV, should be part of a sustainable mobility program. In this regard, schemes for shared EV and alternative models that do not include vehicle ownership (renting) must be integrated into the sustainable mobility scheme, and could even be an important part of the task of breaking down cost and cultural barriers regarding electric vehicles, that is, as part of the promotion or marketing of electromobility.

Acknowledgments

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Electric Vehicle (EV) Charging Infrastructure and Repercussions of EVs on Household Electricity Load – What Can We Learn From Research Findings?

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See footnotes at end of text.

Governments worldwide perceive electric vehicles (EV) as one possible option to decarbonize transport systems. However, the adoption of this new technology among households is still in its infancy. As such, even though the stock of electric cars worldwide reached 7.2 million in 2019 (IEA, 2020) and displayed a 40 per cent year on year increase, EVs still represent only around 1 per cent of the global car stock.

A number of questions thus arise. First, how does the development of the charging infrastructure affect technology adoption in the market of EVs. Second, what is the effect of EVs on electricity demand and the shape of the electricity load?

Current empirical research can help industry practitioners and policy makers understand the aforementioned interdependencies by providing in depth analyses of the experiences of different countries.

EV Charging Infrastructure

The first question has been addressed in a number of recent studies such as Li, Lang, Xing and Zhou (2017), Springel (2019), Delacretaz, Lanz and van Dijk (2020) or Sommer and Vance (2020). These studies employ data from different countries such as Germany, Norway or the United States and adopt different econometric approaches. However, the majority of these studies shares a common denominator. In particular, due to network effects, a subsidization of the deployment of charging stations is more cost effective and efficient compared to a subsidization of the EV purchase price.

Li et al. (2017) use data for 353 Metropolitan Statistical Areas in the United States between 2011 and 2013 and find indirect network effects due to the interdependence between EVs and charging stations. The interdependence between the two sides of the market (EVs and charging stations) can be characterized as the well-known chicken-and-egg problem since the benefit of adoption/investment on one side of the market increases with the network size of the other side of the market. The authors furthermore show that subsidizing charging stations deployment could have been much more effective in promoting EV adoption than the subsidization of EV buyers through tax credits.

Using Norwegian large-scale vehicle registry data from 2010 until 2015, Springel (2019) finds strong positive feedback effects implying that cumulative EV sales affect charging stations entry and public charging availability impacts consumers' vehicle choices. Her findings also reveal that a subsidization of charging stations leads to a much higher adoption of EVs compared to a subsidization of EV prices. For instance, whereas every 12 mn USD spent on station subsidies resulted in 835 additional EVs, the same amount spent on price subsidies led to only 387 EVs. However, she also highlights that this relationship inverts with increased spending since station subsidies reach diminishing returns quicker. Hence, she suggests that for a given level of government spending, policymakers should use both types of policies. Using more recent data for the same country, Delacretaz et al.(2020) document a non-linear relationship between EV adoption and the size of the charging infrastructure network. They show that initial infrastructure provisions have long-lasting impacts on the demand for EVs and hence make a case for government support for the early investments in this network infrastructure.

Sommer and Vance (2020) also find a significant effect of charging infrastructure on EV uptake for Germany. Over the course of a year, one additional charging station is associated with 0.312 to 0.744 additional EVs. The authors show that grants for the expansion of the charging infrastructure are more cost efficient than a subsidization of the EV purchase price.

Repercussions of EVs on Household Electricity Load

The second question considering the effects of EVs on electricity load has been less scrutinized in the literature thus far. Muratori (2018) or Burlig, Bushnell, Rapson and Wolfram (2020) are among the few exceptions. Muratori (2018) uses model simulations of residential power demand and plug in vehicle use whereas Burlig et al.(2020) resort to real time residential electricity data and EV car registrations for California. Both papers underline that EV charging could change the shape of the aggregate residential demand and hence affect the electricity infrastructure. Muratori (2018) shows that even with low adoption levels, the penetration of EVs can increase peak demand. Burlig et al.(2020) find low magnitudes of the absolute effect meaning that EVs increase household load by 17-25 kWh per week or by around 20 per cent compared to the load of non EV owners. However, they also emphasize that the load impact is concentrated in the late night and early morning hours and the shape of the load is important for future grid investments. For instance, even an increased expansion of renewable solar energy is less helpful if EV charging occurs at night when the sun does not shine. However, one can expect that this effect can be attenuated with an improvement of battery storage technologies.

The following graph depicts the evolution of the monthly electricity consumption (right axis) and stock of electric vehicles (left axis) in Switzerland between January 2015 and December 2019. We can see that the more than threefold increase in the stock of EVs from around 16000 in January 2015 to around 57000 at the end of 2019 is not matched by an increase in monthly electricity consumption. This can be explained by the still relatively low uptake of electric cars and the low electricity consumption of each car. Using data for households in the Swiss Canton of Bern, our empirical estimates show that a household's annual electricity consumption is by 14 per cent higher once it owns an EV controlling for a number of household characteristics such as income, family size, size of the flat, heating system etc.[1,2] Assuming a median annual household electricity consumption of 4000 kWh, a 14 per cent increase means 560 kWh increased annual electricity consumption. A back of the envelope calculation implies that the stock of 60000 EVs at the end of 2019 increases annual household electricity consumption by only 33.6 GW or by 0.05% of Switzerland's overall electricity consumption in 2019.[3]

Hence, this descriptive evidence for Switzerland confirms the results of Burlig et al.(2020) suggesting only a rather limited effect on overall electricity consumption. As long as the adoption of EVs is low and the electricity usage of each car rather limited, we should not expect substantial repercussions on overall electricity demand. Still, the daily load profile is considerably affected. As shown by Burlig et al. (2020), EV owners charge their cars in the late evening and early morning hours when environmentally friendly energy is rather scant.

To sum up, state of the art research in the field documents network externalities between EVs and charging stations. Most papers find that subsidizing charging stations is a cost effective instrument in the deployment of EVs. The preliminary results related to the impact of EVs on electricity demand find at the moment a small effect on overall electricity demand, albeit considerable effects for the shape of electricity load.

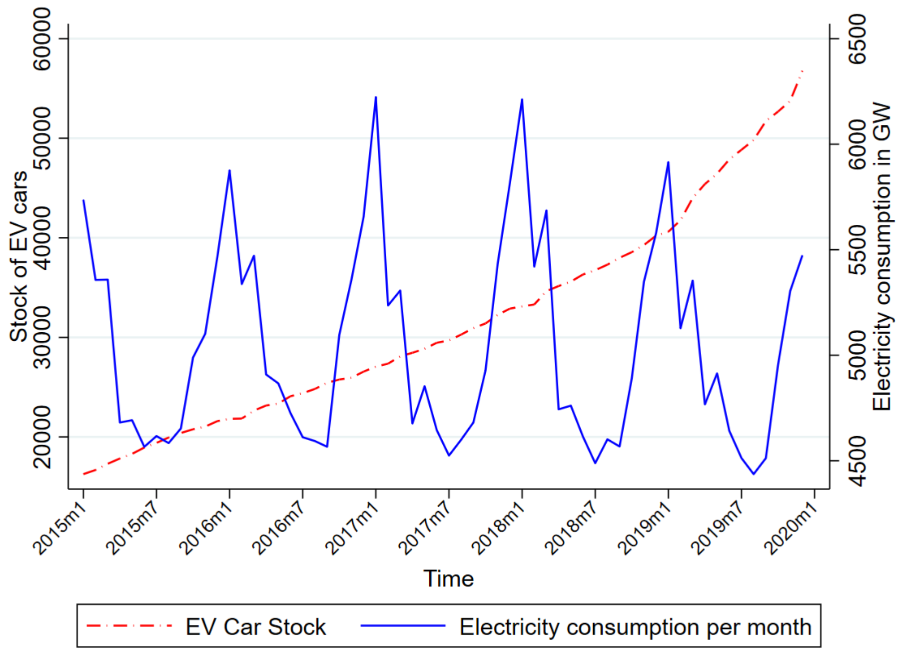

Figure 1: EV Stock and Monthly Electricity Consumption in Switzerland between 2015-2019
Source: Own calculations using information from Swissgrid and MOFIS.

Footnotes

[1] We should note that in our data only around 121 out of 51000 households that we can observe over a number of years and for which we observe electricity consumption, car ownership and other socio demographic characteristics, own an EV.

[2] This research is part of a project financed by the Swiss National Foundation entitled "Household Preferences for Electric Vehicles and Renewable Energy and the Effect of These Technologies on Electricity Demand", SNF grant 100018_192554.

[3] In our dataset covering 52000 households in the Canton of Bern we only observe household level electricity consumption so we can only infer something about charging EVs at home. The monthly data used in the graph should however capture charging of EVs all over the country.

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Estonian Experience with Electric Mobility: Is There a First-Mover Advantage with EVs?

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Introduction

Electrification of the transportation sector is an important strategy in Estonia, as the country needs to honor its international climate commitments. Estonia, a country the size of Switzerland but with a population of 1.3 million, is a signatory to both the Paris Agreement (UN, 2015) and the pan-European plan to achieve net zero emissions by 2050 (Bloomberg, 2019). Estonia's energy sector is facing two main challenges: integration of renewable energy (RE) into the transportation sector and elimination of the country's reliance on domestic oil shale, a carbon-rich fossil fuel (European Commission, 2020). To strategically plan for its energy future, Estonia has developed an ambitious energy and climate plan with 11 energy-related targets for 2030, which include a substantial increase of RE in the transportation sector (Ministry of the Environment of Estonia).

Known for its vibrant start-up culture, Estonia has been widely recognized as a hub for digital innovation in multiple domains (Forbes, 2017), including e-governance (World Bank, 2016), blockchain (Digigeenius, 2018), and smart cities (National Geographic, 2018). The country was among the top OECD performers with respect to environmental R&D and related technologies in 2005-2015 (Pliousis et al., 2019). Universal adoption of smart meters in the Estonian distribution grid has offered insights into user behavior, consumption patterns, and use predictive analytics to evaluate impacts from higher EV adoption. Prior to that, in the early 2010s, Estonia pioneered the adoption of country-wide electric vehicle infrastructure, ahead of most other countries. Contrary to expectations, early adoption of EV technology did not create a vibrant market for EVs, even though this 'experiment' resulted in positive knowledge and climate benefits. This article examines lessons learned from Estonia's early endeavors in the EV landscape and discusses opportunities for future developments.

Did Estonia misaddress barriers to EV adoption?

Many researchers have grappled with the barriers to EV adoption, listing range anxiety, lack of charging infrastructure and high upfront costs as the main factors that slow EV adoption (Rezvani et al., 2015). All of these challenges were also relevant to Estonia in the early 2010s: (1) most EV driving ranges did not exceed 100 km (Pearre et al., 2011); (2) unlike abundant petrol stations, charging infrastructure was non-existent; and (3) upfront cost for EVs was considerably higher than conventional fossil-fueled cars (Rezvani et al., 2015).

As early as 2010, Estonian policy-makers decided to address two of the above-mentioned barriers: increase availability of the charging stations, as well as create a subsidy scheme to reduce the price tag for EVs. By 2013, Estonia had built the world's first nation-wide fast-charging network for EVs that included 165 charging stations (ABB, 2013). It was believed that the consumers' range anxiety could be considerably reduced if the charging infrastructure strategically covered both urban centers and rural areas (Figure 1). At the same time, acquisition of EVs was subsidized: up to €18,000[1] (ca. $25,000) or 50% of the EV's listed price was reimbursed, with an average subsidy of €16,500 (ca. $23,000) (KredEx, 2018a). This program was funded by trading 10 million tonnes of Estonia's CO_2 emissions quota with Japan. The transaction yielded €12 million (ca. $16.7 mln), which were earmarked to be spent on electromobility in Estonia (Mitsubishi, 2011). The initial program was extended with an undisclosed amount of additional funds until the end of 2014 (KredEx, 2012). As a result, in the period 2011 to 2014, 650 EVs were purchased for private use and 507 EVs were acquired by the Estonian government. An additional EV rental program was implemented to make Estonian drivers more familiar

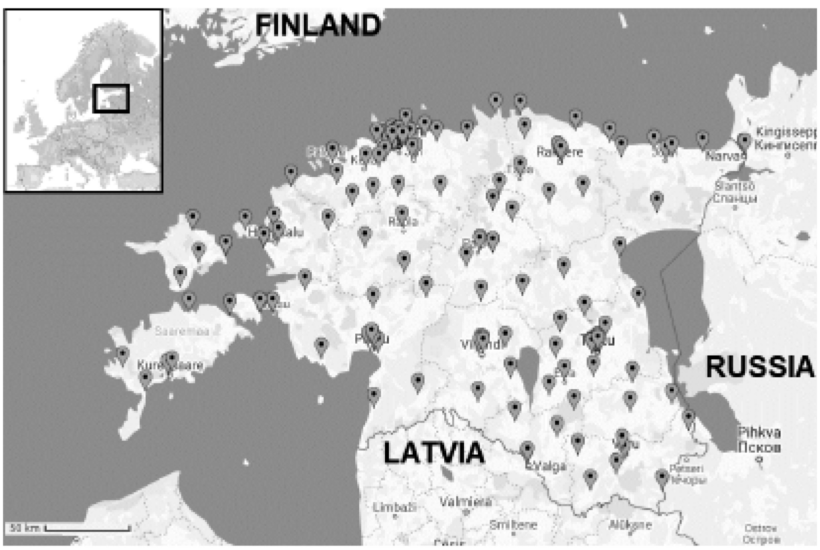

FIGURE 1: Map of Estonia's public fast-charging stations, as built by 2013. Source: authors' depiction based on Google Maps.

with electric mobility. This was achieved by allowing Estonian drivers to rent EVs as short-term rentals. The program attracted over 8,000 users, who cumulatively drove 2.5 million km spread over 255,000 rental hours. However, only 24 customers used rental EVs more than occasionally, that is more than once a week (KredEx, nd). Lacking a long-term financing strategy, the designated funds were depleted by the end of 2014. Thereafter, EV market growth tapered off quickly, especially when compared to Estonia's northern neighbor Finland, see Figure 2. The rental service and EV fleet were subsequently privatized via an auction (KredEx, nd).

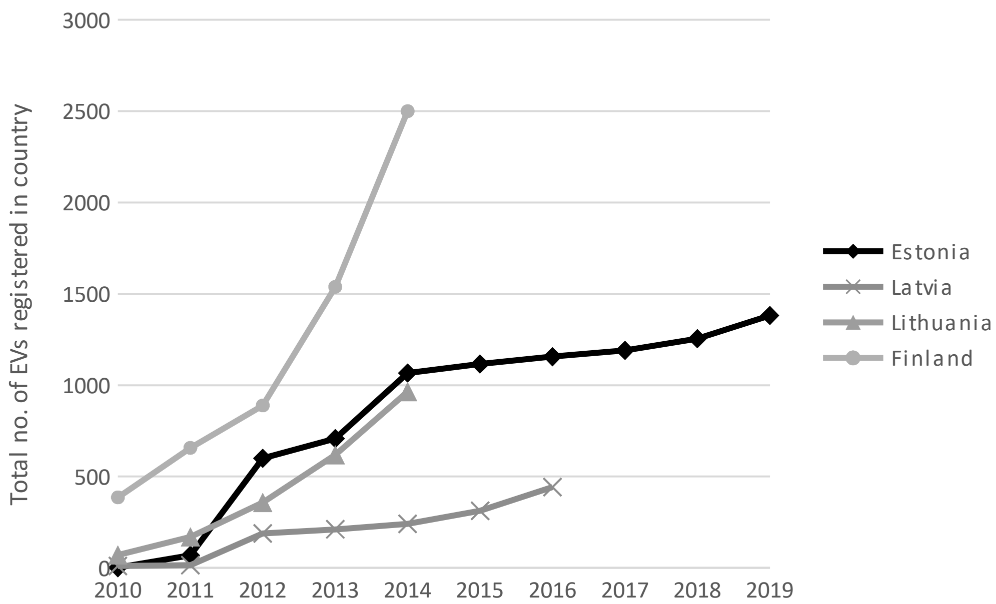

FIGURE 2: Number of registered electric vehicles in Estonia and neighboring countries. Source: Eurostat

In hindsight, in spite of its pioneering efforts, Estonia based its EV program on several assumptions that failed to materialize. First, it was expected that EV prices would drop much faster and that subsidies would not be necessary after a few initial years. In reality, car sales prices remained comparatively high in 2014, when the program ended. The importance of subsidies is evident from the growth of EV markets in the Netherlands and Norway, where a subsidy or a tax benefit will be offered until the end of 2020 and 2021 respectively, helping put tens of thousands of EVs on the road (Norsk Elbilforening, 2012, Cleantechnica, 2019). Estonia could not keep up with the public investment needed for this effort. According to a recent survey most Estonians still see higher acquisition cost of EVs (relative to fossil- or biogas-fueled cars) as the highest barrier to electric mobility (Postimees, 2019).

Secondly, the EV program incorrectly interpreted core consumer preferences with respect to range anxiety and the convenience of charging. In spite of relatively high gasoline and diesel prices in Estonia, car owners were not ready to accept relatively short EV driving ranges and frequent charging, which lasted several times longer compared to visiting a conventional gas station. EVs were mostly purchased by those who had the opportunity to charge at home, while the residents of apartment buildings, which are numerous in Estonia's largest cities, did not purchase EVs regardless of the availability of the public charging infrastructure.

Next, the program adopted a Japanese charging standard. In the early 2010s, there was no universal charging standard in Europe, and Estonia chose to build its fast charging network based on the ChaDeMo protocol, which had been successfully implemented in Japan and has been used in several other countries (Mitsubishi, 2011). In hindsight, the decision turned out to be ill-fated, as European policymakers nominated the Combo-2 standard to be the new European-wide standard in 2014 (EU, 2014).

Finally, equity considerations could have received more attention. Subsidies were designated for purchases of passenger vehicles (either privately or publicly owned), while they could have been dedicated to further electrification of Estonia's public transportation, which is mostly utilized in urban centers by low- and moderate- income populations. Estonia's capital city, Tallinn, already had electrified 9 trolleybus lines, 4 tram lines, and a suburban rail network, resulting in 40 GWh of annual electricity consumption (Eurostat, 2020).

From the grid operator's perspective, demand for electricity that stemmed from electric transportation at that time was small, predictable and easily manageable, and was dwarfed by the country's total annual electricity consumption of 8 TWh (Ibid.). After the program's end in 2014, the impact from the use of 1,100 EVs on the electricity distribution grid was almost non-existent. By 2018, ca. 1 GWh of electricity was consumed per year by the public EV charging network (KredEx, 2020). EV charging in private locations (e.g., homes, office buildings) has not been officially tracked, but it is possible to attempt a back-of-the envelope calculation for electricity consumption by adopting the popular 20-80 ratio (McKinsey, 2018). If 20% of charging occurs in public locations and it amounts to 1 GWh of electric consumption per year, then the remaining

80% - private EV charging - would consume about 4 GWh annually. To reiterate, at that point in time, the electricity consumption by EVs was several orders of magnitude smaller than consumption of the remainder of existing electrified transport (trolleybuses, trams, and trains).

It can be argued that Estonia's early adoption of EVs was a bit 'ahead of its time'. After about 10 years of use, older EV batteries are now due to be recycled, which is another challenge that wasn't strategically considered upfront. On the other hand, learning-by-doing in the early 2010s allowed the country to gather non-monetary knowledge about the necessary EV and charging technology, grow human capital, and support further innovation (Porter Hypothesis). Clearly, addition of EVs on the road instead of fossil-fueled cars resulted in climate benefits in the form of avoided CO_2 emissions, since only electricity from RE sources was used in the public chargers.

Second Wave: Outlook for EVs in Estonia

Nearly a decade later, the EV market has experienced a dramatic change: driving ranges have increased to well over 200 km, with several car models stretching a single charge to 300-400 km (EV Database, 2020). Model selection now includes small city cars to family sedans to cargo vans and SUVs, with manufacturers from different parts of the world (Ibid.).

In an attempt to boost the EV market and create significant carbon savings, the Estonian government recently re-introduced subsidies to EV owners who commit to driving at least 80,000 km over a 4-year period (KIK, 2020a). The subsidy has been popular and the available funds for the full year 2020 were depleted in a matter of days. As a result, 232 new EVs were added to Estonian roads, partially balancing out the fleet of retiring decade-old EVs (KIK, 2020b). Although a second round is planned (KIK, 2020c), this subsidy scheme contributes to the stop-and-go cycle in EV development.

In 2018, the Estonian government held an auction to sell the nation-wide public charging network that was built in 2011-2014 to the highest bidder (KredEx, 2018a). There was only one qualified bid – from Estonia's largest distribution grid operator, Elektrilevi (KredEx, 2018b). Lack of additional interest in bidding could be explained by high investment needs to maintain and upgrade the charging infrastructure. Namely, the new owner needed to commit to operating and maintaining the charging service at 165 charging stations for at least the 5 following years, which effectively meant updating the aging technology that has evolved since 2011, and upgrading the network to a new European standard (Combo 2) to allow newer EVs to charge. Elektrilevi, as a grid operator, has a long-term investment perspective – the company became an owner and operator of the aging charging network so that it could learn more about its customers (e.g., where and how often Estonian EV drivers require charging) to facilitate long-term grid planning.

Next, electric car ownership has also been criticized as regressive, benefitting relatively wealthy consumers (Holland et al., 2019). Electrification of public transportation with strong government involvement might be a good alternative to the current approach. Most cities in Estonia have a developed network of buses that provides reliable transportation to all members of society (not only to those with lower incomes, but also schoolchildren, senior citizens and other white- and blue-collar commuters working in the heart of the city, where limited parking places discourage personal car use). Utilization of electric buses and further development of other electric public transportation lines – such as trams and suburban railways – could result in urban air quality improvements, especially if electricity came from renewable energy sources. Construction of new tram and railway lines is costly and time-consuming, while switching to electric buses would likely be faster and more cost-efficient, since buses do not require rail infrastructure. Despite a nearly twofold difference in sales price between an electric and a diesel bus (Quarles et al., 2020), usage of electric busses on routes with the heaviest traffic can be economically viable already today, even with low or no subsidies to bus acquisition (Ibid.). Introduction of electric buses would require fast chargers at bus terminals, as well as planning of grid connection with sufficient capacity. If government's intensions for electrification are clearly delineated, grid planning can be optimized compared to planning based on private EV purchases, which tend to fluctuate depending on subsidy availability.

Conclusions

Estonia was a pioneer in building a nation-wide fast-charging network for EVs in early 2010, which was paired with subsidies for EV purchases. However, without a long-term funding source, the EV market failed to grow after the initial 1,100-odd vehicles were purchased. Currently, Estonia's EV penetration is comparable to its Baltic neighbors, which didn't develop public charging infrastructure this aggressively. In hindsight, EV adoption in Estonia has been slowed by a number of challenges, ranging from technological (short driving range), to economic (high upfront cost), to consumer preferences (long charging times, limited model selection). Being the first mover has not created a vibrant EV market in Estonia, but it has likely resulted in positive knowledge spillovers about electric mobility (learning by doing) and non-market benefits (reduced air pollution, carbon savings).

Neary a decade later, the importance of these past barriers has decreased significantly. This might create a possibility for renewed EV momentum in the country. With improvements in battery technology, range anxiety has decreased. On the other hand, the country's fast-charging stations require renewed attention due to aging technology. Estonia spent millions of euros on a fast-charging network that needs to be rebuilt, in order to integrate a different charging standard, Combo-2, used by most new EVs (EV

Database, 2020). This upgrade is underway, as several local companies have started installing fast and ultra-fast chargers, and large multinational players (Tesla, Ionity) have announced plans to build their charging stations in Estonia (TechCrunch, 2018; The Baltic Course, 2020).

As private actors re-build the public charging infrastructure and car manufacturers introduce new, more cost-effective EV models, governments could focus on electrification of public transportation, which offers lucrative opportunities for large-scale electrification of the transportation sector. Value-for-money considerations also favor electrifying public rather than private transportation. From a grid operations' perspective, a clear long-term transportation electrification policy is paramount for planning grid investments, so as to keep up with increasing demand for electrification.

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Strategic Development of Electric Vehicles in Canada

BY PATRICK O. ADOBA AND MICHAEL O. DIOHA

Introduction

Transportation has been at the core of man's daily activities over the centuries as it catalyzes socioeconomic development. From hauling of goods for human survival to deployment of services, mankind is constantly developing different methods to ensure that his transit across various locations is as seamless as possible. However, today, the transport sector accounts for around 25% of the anthropogenic global CO_2 emissions which contributes to climate change (IEA 2016). Using alternative fuels and improving transportation efficiency is no doubt a perfect place to commence efforts in decarbonization which primarily entails curtailing the combustion of fossil fuels—a prominent activity in the transport industry. As the second-largest country in the world, Canada faces unique transportation challenges especially in view of the fact that the automotive industry is continuously evolving. Coupled with the continuous increase in global energy demand, the issue of climate change and Greenhouse Gas (GHG) emissions poses a significant threat to the growth of the country's transport industry.

Figure 1 highlights the transport sector as the second highest GHG emitter in Canada, contributing to a quarter of the country's total GHG emissions. In light of these disturbing trends, there is a continuous global call for a paradigm shift towards relatively eco-friendly, rechargeable and efficient vehicles with a view to fostering a greener environment (Dioha & Kumar 2020). While the transport and warehousing sector amount to a significant 3.19% to Canada's Gross Domestic Product (GDP) (Statistics Canada, 2019), the importance of using clean and viable energy sources to aid the transportation process and curb climate change cannot be overemphasized. In keeping with this motive, the past decade has witnessed notable exploration and development of alternative technology options for transportation emission reduction in form of various types of Electric Vehicles (xEVs). These trends are geared towards enhancing the effectiveness of the transport sector in line with the decarbonization "agenda".

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While the transition from fossil fuel-powered internal combustion engine (ICE) vehicles to xEVs is well-underway, the adoption of xEVs varies from country to country due to existing factors such as consumer demand, government incentives and market prices. Globally, electric vehicle sales account for 2.3% of the total vehicle sales (EV-Volumes 2019, Global EV Outlook 2019). Since the introduction of xEVs in the commercial market, there has been a 46-69% year-over-year growth in the number of light-duty EVs between 2010 and 2018 culminating to a global fleet of 5.1 million units – a 63% rise from 2017 (EV-Volumes 2019). Two million units of light-duty xEVs were sold in 2018 - a significant 68% increase from the previous year (EV-Volumes 2019). In total, eight countries - China, the

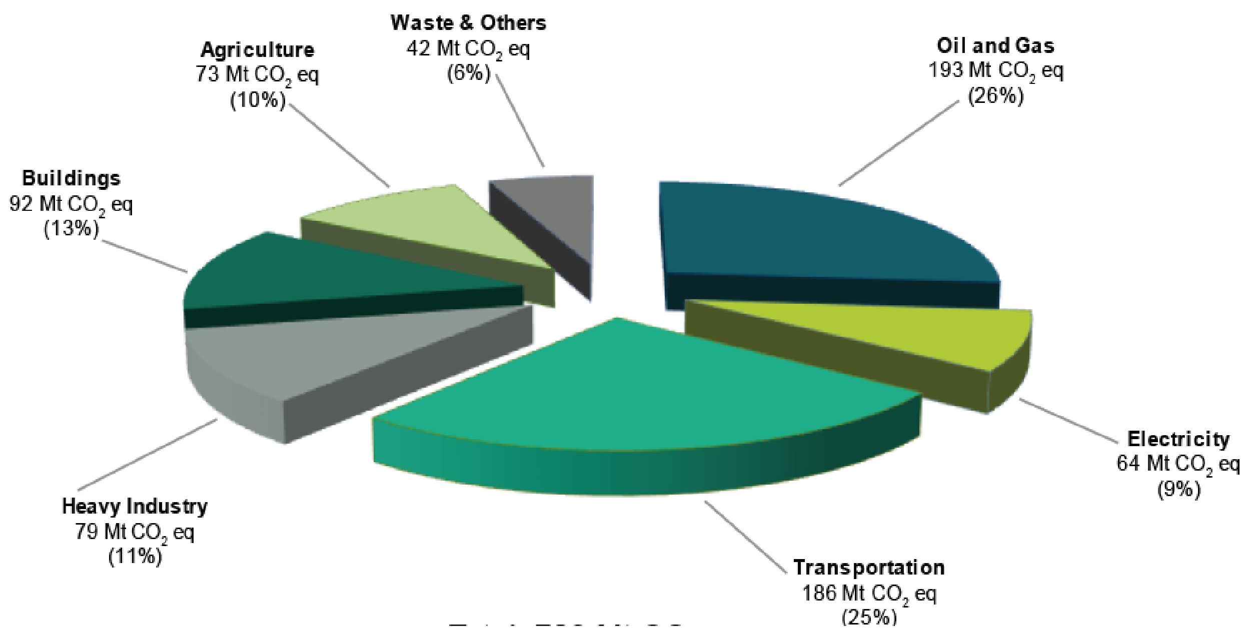

Figure 1: Canada's 2018 Greenhouse Gas Emissions Breakdown by Sector (Source: Environment and Climate Change Canada, 2020)
**Mt = Megatonnes*

United States, Norway, Germany, the United Kingdom, Japan, France and Canada - account for about 90% of the total global plug-in EVs sales (Global EV Outlook 2019, Kim et al 2020). Experts' notion that there is huge revenue accruable from the xEV market if properly harnessed. A large number of ICEs are relatively inefficient at converting fuel into usable energy, averaging between 20-40% efficiency (Fuel Economy 2018) accompanied by pollution and GHG emissions, high maintenance costs and a short car life expectancy. On the other hand, xEV technology exhibits no tailpipe emissions and improved viability resulting from low maintenance requirements. Additionally, "refuelling" xEVs can be carried out via renewable sources, such as wind, hydropower and solar outlets which are relatively cleaner and efficient. As such, the deployment of xEVs has been identified as a global strategy in tackling GHG emissions; it aids in improving air quality, while also serving to reduce noise pollution and increase energy security.

To mitigate transport-related emissions, a host of European nations have outlined plans to obsolete fossil-fuel-powered engines in the near future. India, California and China have also laid out blueprints to ensure that existing vehicles emit no more than trace amounts of air pollutants and GHGs (Planète Énergies 2019). France equally announced plans to totally phase-out ICEs in 2040 (Planète Énergies 2019). Canada is no exception (PlugIn BC 2019, Transport Canada 2019); in order to significantly lower GHG emission in the long run, the government introduced the Federal iZEV Program initiative to encourage more zero emission vehicles (ZEV) on Canadian roads by offering financial incentives on xEV purchase (Transport Canada 2019). This is reflected in its 2019 budget allocation of $300 million targeted at introducing a new federal purchase incentives program on the purchase of ZEVs across the country (Transport Canada 2018, 2019). To further encourage transition to a low-carbon system of transportation, specific targets for ZEV sales have been put in place: 10%, 30% and 100% of new light-duty vehicle sales are expected to be ZEVs by 2025, 2030 and 2040, respectively (Plug-In BC 2019, Transport Canada 2019). As a show of support, the province of British Columbia currently operates with three vehicle incentive programs - the Clean Energy Vehicle Program, BC SCRAP-IT Program and the Specialty-Use Vehicle Incentive Program – adopted by the government in order to lower the cost of purchase for electric vehicles (Plug-In BC 2019). Despite the giant strides made over the years in Canada, less than 1% of its on-road light duty vehicles (LDV) are electric. Also, Canada accounts for about 2.2% of global LDVs made, but only 0.4% of global electric vehicles made (Kim et al 2020). Consequently, this article examines the current developments in the Canadian xEV market. It assesses the possible challenges hampering the deployment of xEVs in Canada and then puts forward some recommendations to accelerate the deployment of xEVs in the country.

Status of Electric Vehicles in Canada

The adoption of electric vehicles in Canada is hinged on consumer demand, product innovations and sustainable initiatives (EY Strategy Report 2020). Despite ranking as the 10th fastest adopter of xEVs, eighth largest plug-in electric vehicle market and 12th in xEV production globally (Global-EV Outlook 2019), the ICE automobiles have exerted significant dominance in the Canadian automotive market given that only 2.32% of xEVs were accounted for on Canadian roads at the close of 2018 (Global-EV Outlook 2019). In the same year, Canada's vehicle sales peaked at 43,000 - equivalent to a 2.5% contribution to global xEV sales (BC Hydro 2018). A 165% year-over-year growth has seen the Canadian electric vehicle fleet rise to 2.2% in 2018 (Kim et al 2020). Nonetheless, of the 2 million vehicle sales, xEVs make up 0.4% of this total - a significant 80% below the global average (BC Hydro 2018).

There are currently two categories of Plug-in Electric Vehicles present in Canada: all-electric or battery electric vehicles (BEVs) running on rechargeable batteries powered solely by electricity, and plug-in hybrid electric vehicles (PHEVs), equipped with rechargeable batteries (or other storage devices) and ICEs which are powered by a combination of electricity and gasoline, respectively. Regarding the available units of xEVs recorded on Canadian roads in 2018, 51% of the 90,100 units of light-duty electric vehicles were BEVs with PHEVs accounting for the remaining 49% (EY Strategy Report 2019, Global EV Outlook 2019). Figure 2 depicts the breakdown of BEV and PHEV sales in Canada for the last five years. The share of light- duty xEVs has seen a significant increase from 0.3% in 2014 to 2.2% in 2018.

Available data highlights a significant number of light-duty EV manufacturers in the Canadian automotive industry. As referenced in Table 1, Tesla Model 3, Nissan Leaf and Mitsubishi Outlander lead the way accounting for a joint 40% of total electric

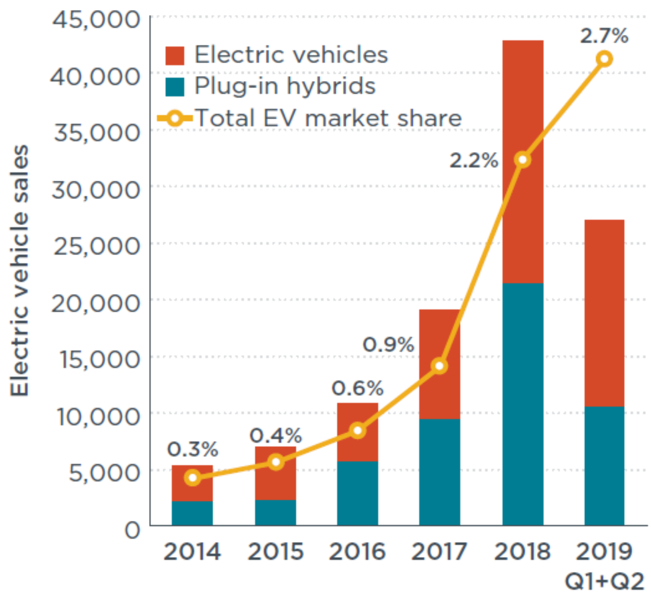

Figure 2: Breakdown of PHEV and BEV sales in Canada (Source: International Council on Clean Transportation, 2020)

Table 1: Top 10 highest – selling electric vehicle models in Canada in 2018.

Rank	Model	Sales (Units)	Assembly
1	Tesla Model 3	6,300	U.S.A
2	Nissan Leaf	5,700	U.S.A
3	Mitsubishi Outlander	5, 300	Japan
4	Chevrolet Volt	4,300	U.S.A
5	Toyota Prius Prime	3,500	Japan
6	Chevrolet Bolt	2,500	U.S.A
7	Ford Fusion Energi	1,900	Mexico
8	Tesla Model X	1,600	U.S.A
9	Chrysler Pacifica	1,400	Canada
10	Hyundai Ionic PHEV	1,400	S. Korea

Based on statistics from EV-Volume 2019. Values are rounded to the nearest hundred.

vehicle sales - about 17,300 units. PHEVs made up about 49% of the total volume electric vehicle market in 2018, with Mitsubishi Outlander, Chevrolet Volt and Toyota Prius Prime accounting for over 60% of HPEV sales. Additionally, 97% of Canada's 2018 xEV sales were imports, implying that only about 12,900 of the 43,000 xEV volume sales were domestically assembled. A breakdown of Canada's xEV sales by manufacturer (as depicted in Figure 3) details that Tesla, Nissan and General Motors (GM) are at the forefront of xEV automakers, accounting for over 27,000 units in 2018 - representing about two-thirds of xEV sales in Canada with Toyota, Ford, Volkswagen and other manufacturers rounding up the remaining one-third of the market. From 2014 to the close of the second quarter of 2019, Tesla, GM and Nissan sold roughly 30,000, 26,000 and 22,000 cumulative units of xEVs respectively. The second quarter of 2019 also witnessed the growth of Tesla's market share to 40% with Nissan, GM and Toytota accounting for 15%, 12% and 8% of the total market share respectively.

Factors Inhibiting Electric Vehicle Adoption in Canada

Following the iZEV initiative, every new vehicle purchased in Canada is expected to be zero-emission by 2040. Although the blueprint for the achievement of this milestone is detailed and clearly outlined, there are a host of factors barricading the adoption of xEVs. The relatively higher upfront cost of xEVs remain a limiting factor. Although cost parity between xEVs and gasoline models is expected by 2025 (Bloomberg 2017), the initial cost of xEVs still remains a huge barrier to its adoption in Canada. A survey conducted by British Columbia (BC) Hydro revealed that 56% of British Columbians perceive xEVs to be too expensive. Data from NREL further suggests that individuals with an annual income of over $100,000 are more likely to purchase xEVs in Canada compared to lower income earners (NREL 2018). To further buttress this notion, Tesla S and Tesla X - valued at $96,000-plus and $110,000-plus, respectively - capped off 2017 as the top two highest selling BEV models in British Columbia (BC Hydro 2018). As with most commodities, the change(s) in demand for xEVs is directly linked to change(s) in cost attributes - encompassing purchase cost, running cost and total cost of ownership (TCO). Individuals in suburban and rural areas - majority of which are low and middle - income earners - will be much less willing to venture into the purchase of xEVs because even though they are much easier to maintain than conventional ICEs in the long run, the cost of purchasing or leasing xEVs are substantial. While declining battery costs and the introduction of cost incentives is a progressive step in the adoption of xEVs, the purchase of gasoline models in the current market is still more or less a viable option from a sticker cost perspective.

Limited charging infrastructures is also another factor limiting the deployment of xEVs in Canada. Apparently, the increasing units of xEVs present in Canadian roads has been seemingly overshadowed by a low return on investment (ROI) in charging infrastructure relative to crude oil infrastructure.

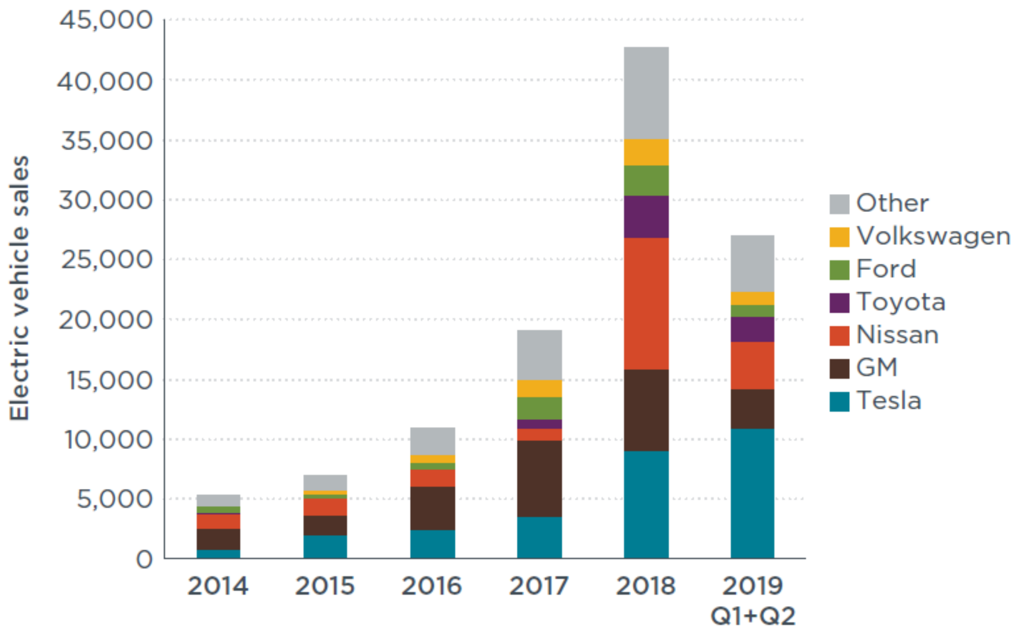

Figure 3: Breakdown of light-duty plug-in electric vehicle sales by manufacturer in Canada (Source: International Council on Clean Transportation, 2020)

In 2018, a total of 7,940 public xEV supply equipment (EVSE) - 840 fast chargers and 7,100 slow chargers (Warner 2019) - were available across urban, suburban and rural municipals in Canada, accounting for a mere 0.56 charging points per hundred kilometer (EY Strategy 2019). This figure - when analyzed against the 90,100 units of xEVs recorded on Canadian roads in the same year (EY Strategy 2019, Global EV Outlook 2019), unravels a meager 0.09 charging point per xEV plying Canadian roads. Lack of charging infrastructure will result in consumers being heavily reluctant to purchase new xEVs because they are unwilling to sacrifice their driving convenience. Moreover, the accessibility and performance of charging points - measured in terms of availability, visibility and the percentage of fast-charge units has a direct impact on the customers' decisions to purchase xEVs. In British Columbia, over six in ten surveyed individuals are reluctant to purchase or lease xEVs because they believe the province lacks adequate charging infrastructures (BC Hydro 2018). The reason for this perspective is not far-fetched. Quite clearly, there is a distinct lack of substantial investment in existing power grids by power and utility (P&U) companies to enable home and public charging, in addition to inadequate distribution networks (power grids) to foster power transmission across the country, particularly in rural districts.

Range anxiety is another issue of serious concern. Although driving range is also dependent on weather conditions, road conditions and driving habit, various models of xEVs are not adequately equipped for long-distance travel due to the state of their batteries. About 40% of surveyed British Columbians are of the opinion that the current fleet of xEVs have limited battery range for longer trips (BC Hydro 2018). While some models of BEVs can travel 200-250 km when fully charged, others are capable of 400+ km on single charge (PlugN' Drive 2019). Similarly, PHEVs, depending on the model, have a travel range spanning 20-80 km on full charge coupled with gasoline engines designed to travel an additional 500+ km after the batteries are used up (PlugN' Drive 2019). However, the range of xEVs can drop by as much as 50% under extreme conditions of cold temperature, such as - 25°C during winter (CAA 2019, EY Strategy 2019). Conventional ICEs, on the other hand, offer greater driving range by virtue of a huge tank making for convenient driving without having to worry so much about road trips. Because transportation is an integral part of the Canadian lifestyle, existing proven technology will most times overshadow the adoption of new technology, particularly considering the inherent setbacks, unless steps are deployed to convince consumers otherwise.

Lengthy charging period is another important factor inhibiting xEVs adoption in Canada. A general issue for xEVs has been the lengthy period required for charging these automobiles. For level 1 charging (otherwise referred to as slow or trickling charging) - charge using a regular wall socket - 1 hour of charging is equivalent to approximately 8 kilometers of driving range using a standard 120-V outlet (Hydro Québec 2018). Charging with a 240-V EV station (Hydro Québec 2018) - level 2 charging - ensures that approximately 30 kilometers of driving range is stored after 1 hour of charge (Hydro Québec 2018, Plug-In BC 2019). With rapid DC chargers of 400-V or higher, the charging period is reduced significantly to as low as 30 minutes for a full charge (Hydro Québec 2018). The bad news is that not every xEV is equipped with rapid charge features. While there are significantly several other factors that may influence the charging rate, the size of the battery, maximum charging rate of the charge point or vehicle and environmental factors - delays in charging time often force HPEV drivers to rely on existing oil and gas (O & G) products and infrastructure because the battery component has a limited range of 20-80 km on a full charge (EY Strategy 2020). As such, owners of ICE vehicles will be reluctant to switch to electric vehicles resulting in skepticism on the part of prospective buyers.

Options and Priorities for the Future

The growth of the Canadian xEV market has been hampered by a huge lack of demand resulting from the relatively high purchase price of xEVs. In order to foster rapid transition from the conventional ICEs to the more sophisticated and eco-friendly xEVs - in line with achieving the targets of the Federal iZEV agenda - appropriate financial and non-financial incentives should be emplaced and its execution should be judiciously monitored by relevant government parastatals. A promising move would be the practice of providing tax incentives, such as sales tax exemptions, rebates and income tax credits upon purchase of xEVs in order to buffer the sticker cost for prospective consumers. Despite being easier to operate and maintain than conventional ICEs, discounts in utility rates (or the provision of charging rebates) will also go a long way in further alleviating the burdens of upfront costs relating to operation and maintenance of xEVs. Furthermore, rules encouraging the mandatory procurement of zero or trace - emission vehicles for government institutions creates public appeal for the vast consumer base if enacted. Increase in the units of xEVs in the government's vehicular fleet results in subsequent elevation of local demand culminating in the eventual phasing-in of these eco-friendly automobiles. For urban and suburban areas where parking space and traffic congestion is often times a daily issue, preferential treatment - free parking, designated parking spaces and designated lanes - for xEV owners can serve as motivation to encourage purchase of xEVs.

On the supply side, the relevant parties should ensure the development of battery science which is the major contributor to cost disparity between xEVs and conventional ICEs. Measures should be adopted to encourage robust investments in the Research and Development (R&D) of various xEV batteries to improve battery efficiency in order to lower the cost of xEVs and improve their driving range. The provision of tax credits, loans and grants as R&D incentives by the government is a necessary tool to aid battery and vehicle manufacturers develop cheaper and better batteries in ensuring a smooth, swift and efficient transition to xEVs. In addition to providing financial support for xEV manufacturers and suppliers, the government can encourage the circulation of xEVs in the Canadian automotive market by adopting a differentiated tax system - taxation of new vehicles on the basis of their GHG emission levels, to foster demand and procurement of energy-efficient and low emission xEVs. Additionally, workforce programs geared towards training workers in a host of new skills encompassing design of xEV batteries and relevant infrastructure, grid upgrade and servicing of xEVs should be adopted by government and relevant business owners to boost its widespread adoption.

There is little doubt that improvements in the accessibility and performance of charging infrastructures is a key instrument in the growth of xEV market. Given the plethora of gas stations available in practically every location in Canada, the xEV industry will require adequate checks and balances to eventually rival the catholicity seemingly inherent in gas stations. The sparse density of charging points in public locations - typically concentrated in urban municipals - and limited driving range of xEVs makes it difficult to accommodate both short and long distance travel. Expansion of the current charging infrastructures requires high-ticket investments and intensified cooperation amongst relevant parties while also allowing the forces of time and patience to play their part. On the part of private investors, the hesitance to invest in public charging infrastructures is due in part to the obvious massive upfront cost required and the lack of substantial local demand by consumers. Nonetheless, this circumstance creates a casualty dilemma: customers will be unwilling to purchase xEVs unless adequate and accessible charging points are duly installed. To combat this issue, local and state governments should intensify efforts geared towards investment in public charging infrastructures. Government should foster policies encouraging the provision of grants, tax credits or rebates and low-interest loans to prospective investors who are interested in the installation of new changing stations or the repair of faulty existing chargers. Additionally, local communities can liaise with the private sector to increase the density of charging stations accessible to xEV road users. The public-private partnership will serve not just to ensure that adequate xEVs are available for consumers, but it will also drive down the purchase cost of xEVs due to economics of scale.

Although a host of factors - battery performance, range anxiety, inaccessibility to charging stations and higher upfront cost all contribute to suppressing demand for xEVs in Canada, the role of consumer perception cannot be overlooked. Regardless of the notion that consumers often site the aforementioned challenges as primary reason(s) halting their switch to xEVs, some of these factors are merely perceived by individuals owing to the fact that humans are skeptical to change, more often than not. This is where an efficiently outlined consumer education plan steps in. By educating prospective buyers on the latest trends in xEV technology, dedicated government and economic development agencies can help to dispel myths relating to xEVs. Emphasis on fuel savings offered by xEVs is a major selling point to ordinary consumers who are attuned to the status quo that conventional ICE vehicles offer more reliability. In the short-term, dissemination of information regarding the location of public charging stations will help ease range anxiety. The private sector can play a role in keeping drivers updated about required charging needs and options by developing innovative applications - as seen in “My Ford Mobile” - which will aid to locate nearby charging stations, provide details on current state of battery charge, estimate charging time required for various charge levels and provide users with calculated information about various probable travel distances depending on the battery charge level of the xEV. Economic developers should ensure that they stay abreast with the various means deployed towards executing these polices, while also keeping up with latest and advanced trends in battery science and technology.

In sum, Canada’s transport sector accounts for about a quarter of the country’s total GHG emissions. Although the past decade has witnessed a relatively slow transition to energy-efficient and low emission vehicles in Canada, the Canadian automotive market still remains a potent tool in the achievement of the United Nations SDGs and the provision of lucrative investment opportunities for the private and public sector. To accelerate the adoption of xEVs in Canada, there should be a national call for heightened emphasis on the importance of R&D in xEV technology, and the provision of robust fiscal policies and financing mechanisms geared towards curbing transport GHG emissions as well as enhancing the demand for xEVs in the country.

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Positive energy territories and electromobility: Highlights from EVER Monaco 2020

BY ICARO SILVESTRE FREITAS GOMES, Ph.D. Student At Vedecom/Paris-Saclay University

The decarbonization of both power and mobility sectors are two main goals established during international environmental summits. Those two sectors contribute together with 66% of all greenhouse gas emissions on the planet. Fossil fuels used to produce electricity in power plants account for 42% of the total CO_2 emissions and internal combustion engines in vehicles account for more 24%.

EVER Monaco and the International Association for Energy Economics (IAEE), organized discussions in round table format about "*Positive energy territories and Electromobility*." Various stakeholders from different fields of expertise, such as automakers, regulators, original equipment manufacturers (OEM), and grid operators, all contributed to the debate.

These round tables took place on September 10 and 11, 2020 at the Grimaldi Forum located in the Principality of Monaco, under the High Patronage of H.S.H. Prince Albert II of Monaco.

Several protective measures like a mask-wearing obligation, a limited number of people allowed, and social distance were mandatory during presentations. After a confinement period post-COVID-19, all the events and scientific conferences were postponed, including EVER Monaco, or had an online format. In the end, EVER Monaco could safely take place being one of the first events to happen after that unexpected period.

Different topics were addressed during round tables regarding positive energy territories and electromobility:

- conditions of successful implementation;
- synergies between electric vehicles (EVs) and the grid; governance;
- finance and regulation;
- technology and energy efficiency.

Conditions of successful implementation

The "*positive energy territories*" aim to reduce their energy needs as much as possible, through energy efficiency and cover them with local renewable energy over the year. However, achieving this final goal needs effective coordination between energy suppliers, policymakers, and consumers. According to Mr. **Alexandre Roesch**, general delegate of the French Renewable Energy Union (SER), public investments in renewable energy have a leverage effect in the French scenario. According to his data, each 1€ invested in renewables will create 2.1€ of added value in the territories benefiting all the regions. All territories are eligible for at least one adapted renewable solution making the investment possible. Besides the public support as a condition, the solidarity between regions is also an important aspect that could accelerate renewables' development. For instance, the biomass and heat network domains could benefit from shared infrastructures and costs between territories.

Moving towards the electromobility perspective, it is known that French people would substitute their internal combustion engine cars for electric or hybrid vehicles. However, the lack of information about charging infrastructures, public subsidies, and the lack of diversity in the offer of car models slow their adoption. Mr. **Clément Molizon** from the National Association for Electric Mobility Development (AVERE-France), argues that communication toward the public is indeed a critical condition to success. In this matter, public awareness campaigns are already being done mostly by energy unions and the collectivity in the territory, but more actors should get involved. The key message should be that the whole ecosystem of electric mobility (cars, two-wheels, boats, etc.) is a trigger for rethinking the entire mobility around and its synergies.

Synergies between electric vehicles and the grid

EVs raise special attention from the grid operators due to the rise in electricity consumption, especially in power demand during peak periods. To avoid critical damages to the grid, mainly to the distribution grid, coordination between the grid and the vehicles must be put in place. Automakers and original equipment manufacturers influence the synergy by modulating the offer of car models and charging stations on the market over the years.

A top-bottom approach makes possible to analyze the synergy starting from the grid operators until the end-customers. The first actor involved is the distribution system operator (DSO), who has all the EVs directly connected to their grid. All the projects for charging station installation should have their approval in some sort. Mr. **Régis Le Drezen**, responsible for electromobility studies at ENEDIS, the largest French and worldwide distribution system operator, confirms that all projects having their involvement since the conceptualization part guarantees the project's smooth running. Their main goal is to work with all stakeholders involved in the energy transition and propose innovative solutions to manage the grid more efficiently. For him, the new smart meter Linky will allow dynamic pricing, vehicle-to-grid, renewable generation coupling and smart charging. Linky is allowing ENEDIS to have essential information about the load of each part of their grid in real-time. Those improvements will prepare the distribution grid to cope with the uptake of vehicles connected, avoiding congestion issues. Another DSO delegate, Mr. **Thomas Vanquaethem**, director of evZen development at the Monegasque Society of Electricity and Gas (SMEG), raised attention to EVs' flexibility opportunity. Although they are expected to increase maximum demand to risky values during specific charging periods, they can also help integrate renewables via smart charging and vehicle-to-grid.

The physical interface between the electric grid and vehicle is mainly the charging infrastructure. **Philippe Adam**, group vice president global executive account at ABB, affirmed that welcoming renewables are linked to bidirectional solutions once they can restore the energy produced intermittently, and ABB is ready to feed the market with those products. Electromobility goes beyond private cars. That's why OEMs like ABB invest in electric trucks and electric ferry charging infrastructure as well. Technologies are there, but there is a high dependence on grid (transmission and distribution) robustness to introduce the products massively.

The last physical element of the synergy to be analyzed is the vehicle. **Vincent Salimon**, president of BMW-France, stated that the entire value chain for vehicle construction should be more efficient regarding CO_2 emissions. This is the way EVs could achieve its highest potential to reduce emissions since their production. Their goals rely on lowering emissions from three sectors: production, replenishment of car parts, and final usage. The first step is to minimize the factories' emissions by 80% over ten years, using only renewable energy. Then, lower 20% more of the parts sector by manufacturing battery cells in Europe using only hydropower. Finally, the electrification of 50% of the fleet market offer by 2030 will contribute with a 40% decrease in final usage compared to today's emission levels. Even if the group does not fully achieve the established goals, looking into EVs' whole supply chain is essential to reduce its carbon footprint.

In France, the great majority of the electric distribution grids are property of local public bodies or municipalities, which in most cases grants the exploitation rights to a DSO. Representing the energy unions in this round table, Mr. **Laurent Favreau**, the vice-president of the Vendée department energy union (SyDEV), affirmed that their objective is twofold: invest in innovative experiments and communication. The small scale of a department is an adapted ecosystem to test innovative projects linked to renewables and electromobility. For example, solar photovoltaic parking lots with charging stations using solar energy and public charging stations connected to the public lighting electric grid. The communication role done by them is crucial to passing the messages coming from DSOs, OEMs, automakers to the general public in a simplified way.

Governance: From actors to users

The second day of discussion was opened by H.E Mr. **Bernard Fautrier**, plenipotentiary Minister, reaffirming the importance of having meetings like EVER. He argues that fueling the discussions to create a better environment for future generations should be the priority. The governance was tackled in two complementary forms: two academic-oriented presentations and two testimonies from the action field.

As co-organizer the Mr. **Christophe Bonnery**, Executive Vice-President of IAEE and director of economics and prospective at ENEDIS thanked the Government of Monaco to host this event. Mr Bonnery stated that academic studies should systematically help decision-makers to support their actions based on elaborated scientific models. Those models can find mobility patterns, optimal charging infrastructure location, optimal subvention programs, adapted electricity tariffs, etc. Mr. Bonnery presented a gravity-based model adapted to the mobility sector to estimate travel needs in French communities. The results showed disparities between territories in the country regarding average distance traveled per inhabitant, and total distance traveled per municipality. Consequently, the governance to build an adapted infrastructure for electric vehicles should take these disparities into account.

EVs in a positive energy territory will continuously interact with other distributed energy resources (DER) like batteries and photovoltaic panels. The second academic work by Mr. **Icaro Silvestre Freitas Gomes**, Ph.D. student at Paris-Saclay University and PhD-researcher at VEDECOM focused on those interactions and possible consequences. He argued that the synergy should be analyzed multidimensionally, considering technical, economic, and societal aspects. From his simulation model, he concluded that the electricity tariff design is the most appealing aspect to reformulate in the short term rapidly. Thanks to his research, he shows that, as DERs create cost-shifting issues from users who have not them installed and those who have, the classical way electricity is charged today around the world needs to be upgraded to efficiently tackle this synergy.

The field experiences show that local users and municipalities are generally the most interested in investing in renewable energies or charging stations. Mrs. **Alice Alessandri** from Energie Partagée, a citizen association created to invest in renewable energy projects, and communicate about their importance, defended the governance of locally driven investments. Citizens from a particular municipality can collaborate with a joint fund to invest in wind or solar farms using local labor. The selling of this green energy will bring profit to local shareholders, which will benefit the local community and boost the economic fabric of the territory. Finally, **Jean Noël Laury**, the president of the Yonne Departmental Energy Union (SDEY), shared his point of view about the union's governance-related role. The experimentations on the field carried out by the unions in many territories are the adapted governance since the local syndicate knows the needs and the particularities of their environment. Projects, including charging stations, multi-service stations using hydrogen and power-to-gas concepts, are present in the Yonne department to help the development in other communities with the lessons learned.

Finance and regulation

There are several ways to finance a renewable project in French territory. It can be via a citizen fund using crowdfunding methods like the one used by Energie Partagée, or it can be implemented benefiting from bank loans. Mr. **Richard Curnier**, regional director of the Territories Bank, raised attention to the importance of climate financial plans to accelerate companies' and regions' environmental transition. Those plans boost the economy by investing and following greentech companies that innovates a lot in the field. On top of that, Mr. **Adrien Fourmon**, a lawyer from Jantet Associated Lawyers, explored renewable energy support regulation. A system of additional remuneration has been replacing the contracts stating purchase obligation by the public utility of the electricity produced by one renewable power plant. These systems rely on the wholesale market price of electricity to reach the electrical installation's break-even point. The public utility intervenes with financial help in case the power plant does not reach this point. Once the system is in place, the aggregators appear to manage the contracts for the producers, while the banks transfer part of the project's uncertainty to this new entity. Moving to the public sphere, Mrs. **Virginie Haché-Vincenot**, responsible for the Monaco principality's energy transition, insisted on the importance of public regulation to incite new technologies. In Monaco, for example, subventions for electric vehicles have been present since 1994, contributing to the EVs' rapid development at the principality.

Technology and energy efficiency.

The last round table was about the relation between the new technologies and their efficiency from a societal point of view. From the Agency for Ecological Transition (ADEME) mobility studies department, Mrs. **Ariane Rozo** pointed out that technological progress should be carefully followed to avoid more damage to the environment. For example, the battery size increases when battery cells become cheaper, which can be harmful to the ecosystem due to their production process. The focus should be on changing behaviors and think about mobility as a myriad of choices (carsharing, two-wheels, scooters, etc.). The general public must keep in mind that EVs are different from combustion cars, so their behavior should be different as well. Then, Mrs. **Cécile Goubet**, general secretary of the National Association for Electric Mobility Development (AVERE-France), states several propositions about public policies to incite new technologies. In the electromobility sector, a French pilot aware of the national market's specificities should be created to explore smart charging and vehicle-to-grid concepts. They also should allow non-discriminatory data diffusion from electric vehicles, electric networks, and third part buildings and engage standardization initiatives.

Conclusion

Each round table could have been the main theme for discussion for the whole event because of their complexity and importance nowadays. In conclusion, there is no universal answer and receipt to develop positive energy territory and electromobility quickly. The issues should be tackled on several fronts at the same time by different stakeholders like it was done in the event. The EVER Monaco 2020 event served well the purpose of being an environment where academics, industrial players and regulators can exchange information, experiences and contribute to the clean mobility evolution. Bringing together renowned experts during a conference around the decarbonization of the mobility sector concomitantly with the power one is an example to be followed to make a sustainable future for everybody.

Mr Christophe Bonnery, and the plenipotentiary Minister of Monaco, H.E. Bernard Fautrier, announced next year EVER conference will take place in May 2021 in collaboration with IAEE.

Electric Vehicles, the Future of Mobility

BY JAMIL KHAN

Since the debut of the very first electric vehicle (EV) in the late 18th century in Europe followed by its introduction in 1889-1891 by William Morrison in the USA (Des Moines, Iowa), it has come a long way. By the turn of the century, EVs became so popular in the USA that by some accounts about one third of all the vehicles were electric! But this phenomenon did not last for long as it did not capture any significant market share of the later times. The last opportunity for capitalizing on the EVs came during the oil embargo period of 1973-1974 when the policy makers as well as the auto industry seriously thought about EVs as the viable solution in keeping the auto industry alive. However, once the oil embargo was over, the oil industry lobbying interests ferociously fought to stop the internal combustion engine (ICE) replacement programs and as a result, additional funding by the government and the private sectors for the EVs development disappeared.

Now, with the continued increase in the middle class everywhere, the traffic is increasing at such an alarming rate that it is creating nightmares for the urban (traffic) planners, health officials, environmental agencies and the policy makers alike as the traffic congestion, traffic jams, traffic management challenges and dense pollution (smog, smoke) have become major issues in the mega cities around the world. In turn, it is creating chronic respiratory health problems (COPD, asthma, etc.) global warming, permanent thick clouds of polluted air with harmful particles, greenhouse gases emission, ozone layer depletion, glaciers disappearance, oceans' temperature & levels rise; and are some of the major drivers for the EV's revival. All these issues are not exclusive facing with the developed countries but are also quite common in the developing countries as well, particularly in the urban settings.

As described earlier, the EV industry seems to be as old as the auto industry itself but it is hard to imagine that why the EVs are taking so long for their wide scale adoption to become an integral part of our primary means of mobility. Even though the EVs offer one of the best solutions not only for reducing the atmospheric pollution and improving the air quality, but also for saving the planet by replacing the traditional combustion engine (ICE) with the electric motor-based automobiles. If we look closely, we will find there are still many challenges that are contributing to the slow penetration and adoption of the EVs in the society. The major challenges that are critical for the mass adoption and fast penetration of the EVs are the following:

Cost
Design
Battery life
Recharging infrastructure
Incentives

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These are the major drivers that are controlling the large-scale success of the EVs in the USA as well as abroad. Even though the EVs were introduced in the US a long time ago, but it did not catch any sustainable momentum, except for its limited successes. The EVs got some lifeline when the environmentalist pushed their policy makers to pass legislations to support/accelerate the EV technology. As a result, the entrepreneurs, the OEMs, research institutions (Universities) and the private sector, all started thinking seriously to come up with the most economical vehicle that can save the planet.

Based on the EVs current cost structure, the costliest part is its battery system. Currently, there is no approved universal battery system and is still evolving. According to the Department of Energy data, the cost of the battery (Lithium-ion battery in terms of the $/KWH) has come down substantially and is currently trailing to less than 40% compared to 2008, as the baseline. The life of the battery depends on many factors, like the operating conditions (at higher temperatures battery life is reduced while at lower temperatures, performance is affected), the depth of discharge, etc. In general, the life of the battery can be as long as eight years or 100,000 miles (160,000 kilometers). The weight of the batteries is another major factor that affects the distance travelled per charge by the EVs. Currently, the batteries represent from 25 to 50% of the total weight of the EV. With the continued research in designing and finding new compositions of the battery materials, the battery weight reduction is making great strides for reducing the costs and improving the performance of the EVs.

There are many new players in the industry who are specialized in the battery designing for the weight reduction and improved safety features, that are the backbone for the success of the EVs. Also, with the continued battery costs reduction, charge storage capacity increase, faster charging time and longer life (longer distance driven) on a single charge has infused new momentum in the industry. Currently, there are several Lithium (Li) based batteries available, like Nickle Cobalt Aluminum Oxide (NCA), Lithium Manganese Oxide (LMO), Lithium Nickle Manganese Cobalt (NMC), Lithium Titanate (LTO), Lithium Iron Phosphate (LFP), etc. However, today, the most used battery in the EVs is the Lithium ion battery in addition to some other batteries that are getting some applications in the EVs sector, also.

Elon Musk, the famous entrepreneur and remarkably successful businessman in 2003 founded Tesla Motors in Fremont, California for building an all-electric vehicle and clean energy company, just like Henry Ford did with the Model T. Initially, he used all his personal wealth that he created by selling off his PayPal business to eBay. He also tried to encourage other auto manufacturers (OEMs) to collaborate with him in mass production of the EVs but did not see much interest from the established automobile manufacturers. After a limited success and facing daunting challenges in the battery performance, he realized that in order to be successful, he must get involved directly in the battery manufacturing, the lifeline for the EVs. He approached the established battery manufacturers, in the US as well as in Asia. Finally, in cooperation with the Panasonic, he built his own battery factory to support the changes & the research needed for timely delivery and continuously improving the battery performance. This decision proved to be the major milestone of his success and generated a lot of interest and demand not only by the USA customers but also abroad. This phenomenon pushed Tesla car production to its limits and wait time for the car deliveries extended into months.

Now, Tesla is considered among the top five Lithium-ion battery manufacturers in the world. This strategic decision brought more trust, making Tesla the leader of the EVs sector within the mobility industry. With the continued demand outpacing the capacity, building of new factories, called “Giga Factories” started becoming realties. Even though the company was still not profitable and burning a lot of cash, but Tesla models’ popularity and continuously capacity additions made Tesla the new darling of the investors and of the Wall Street, alike.

With the rapid success of the Tesla brand EVs, other major OEMs also got interested to build their own brands to compete against Tesla. Today, almost every major OEMs has EV in their portfolios. The continued success of the Tesla brand and commitments by the other major OEMs is transforming EVs as the best technology for tackling the environmental and the pollution related challenges.

In many EU countries, and some GCC region, the taxis for hire fleets are mostly consists of the EVs or are planning to phase out the internal combustion engine (ICE) vehicles with the EVs soon by offering hefty incentives. In the Northern EU countries, EVs penetration is very pronounced and with the attractive incentives by their governments, the consumers are embracing the change and adopting the EVs at a much faster pace than other parts of the world, including the USA. China, one of the most populated country in the world with over 1.4 billion people has been suffering with the worst pollution in their major cities due to the extremely high concentration of the vehicles, has embarked on this path.

In the recent times, private sector has been investing heavily in the ecosystem like the charging stations that are popping up at the supermarkets, public parking places, recreation centers, and some gas stations also. However, there are still many challenges remained for the industry to address like how to improve and reduce the recharging time why people are traveling long distances on the Inter-States and the Autobahns. Like in the IndyCar and F1 car racings, the tires are replaced on the fly in a matter of few minutes. Similar model can be used for the recharging stations either by expanding the existing gas stations services or by building a brand new recharging service system, whereby the drivers can pull in their vehicles inside the station and the workers or the robots (AI) can quickly replace the old batteries with the fully charged batteries in a matter of few minutes. This model has great potential for its success in the recharging stations due to the breakthroughs in the technology and the AI introduction into the manufacturing and the service sectors very successfully.

Another recharging model that also has good potential is the induction charging. This means that by leaving the EVs in the parking lots, they can be recharged while the drivers are gone for shopping or having meals, attending any event, etc. However, this model will require building of an ecosystem from the grass root levels, requiring a lot of capital! Additionally, it will require new parking rules, liability exposures and upkeep of the parking lots.

As we all know, the ICE based vehicles require regular maintenance, which is overly complex and expensive, mostly due to many moving parts under the hood. With the EVs, comparatively, there are very few moving parts under the hood as the major part is the electric motor. This means that in the long run, purchase of an EV is more economical as not too often it will require maintenance and expensive parts replacements.
In other words, the EVs market will greatly help the consumers not only in cost savings but also for improving the environment by reducing the carbon dioxide emission, the major pollutants for the health related concerns and the climate change exposure and depletion of the fossil fuel, melting of the glaciers, rise of the sea levels, increase in temperature of the ocean waters and reduction in the COPD and asthma causing elements, like the solid particle sizes. This will be a win-win situation for all the stakeholders involved in the mobility chain.

In the commercial sector, the adoption of the EVs will be more visible in the delivery/multi seater vanes and light duty trucks. The major retailer and online market leader, Amazon, has already committed to use EVs as the preferred choice for all its delivery fleet. Similarly, the major courier services like USPS, UPS, FedEx, DHL and public transit will be the first adapters of the EVs. These initiatives will provide the solid foundation for the success of the EVs market and will attract and commitment from the major technology firms to continue to push the boundaries for the overall performance of the EVs and bringing the costs down faster, either lower or at par with the ICE vehicles

Until recently, the rate of penetration of the EVs has been the highest in China, the biggest single market in the world. The second biggest market currently is the EU. The Scandinavian countries are leading the race in faster adoption of the EVs mostly due to their deep environmental concerns and lucrative offers by their governments in replacing their ICE vehicles.

Marketing data shows that in 2018 the US had the highest penetration of the EVs mostly due to Tesla's model 3 introduction and federal tax credit offering to the EVs buyers. However, with the expiration of the tax credit, the sales of the EV have declined and now, the EU market has become the major adoption market. Also, Chinese market has been growing at a particularly good rate until the government phased out the incentives.

According to a recent Bloomberg's report (BNEF), currently EVs penetration in the global automotive market is about 3% and is projected to increase by 28% by 2030 and almost 55% by 2040. However, this penetration may be accelerated at a faster pace if the government incentives on federal as well as state levels are going to be more generous, prices will be less or equal to the ICE based vehicles not only for owning the cars but also for the total operating costs throughout its life (10 years or 100,000 mile) will come down significantly!

In 2019, nine out of the top 10 EVs markets were in EU. In some of the Scandinavian countries and in the GCC region, taxi fleets have adopted the EVs as the choice of their selection. Market data shows that Tesla is by far the market leader in the EVs segment and its model 3 has been the bestselling car on a global scale. Additionally, Tesla is building its ecosystem across the major markets and is also expanding its footprint in the markets where pollution is one of the major concerns for the citizens and the policy makers, alike. Recently, Tesla has built its own factory in China, surprisingly without any local JV partner, a very first of its kind manufacturing ever allowed! In addition to the assembly line, the factory also has the battery manufacturing and product development. Initially, the factory will service the fast growing domestic EVs demand.

As the self-driven vehicles (SDVs) make their inroads into the everyday use by the consumers, it will further accelerate the momentum for the EVs market. All these changes in the industry which continue to make big inroads to make the lives of the occupants not only safer but will also address the environmental sustainability and improving the quality of lives for the benefit of the humanity in the generations to come.

If the above described trends and adoption incentives will continue, it will pick up great momentum by the other global auto manufacturers also who have heavily invested already in the development and commercialization of the EVs to meet the growing demand of their brands' loyal customers. With all these rapid developments, it seems that those days are not far away when in the metropolitan and mega cities we will see more EVs at the expense of the traditional vehicles. This trend will continue to help not only the growth of new technologies and industries but also to reduce the pollution and the pollution-based chronic diseases which are getting profoundly at serious levels in the major cities of the world.

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California's Outages Blamed On Warming Climate Extreme heat played a role but it was the "Duck Curve" that ultimately got CAISO

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See footnotes at end of text.

Following a request by the California Governor **Gavin Newsom** to find the root cause of the outages in mid Aug 2020, the 3 agencies responsible for keeping the lights on released a report on 6 Oct. titled **Preliminary root cause analysis: Mid Aug 2020 heat storm**. Apologetically, the **California Independent System Operator** (CAISO), the **California Public Utilities Commission** (CPUC), and the California Energy Commission (CEC) said that they recognize their "… shared responsibility for the power outages many Californians unnecessarily endured." Good way to start, with an apology and a pledge not to let it happen again.

They said several factors, in combination, led to the need for the CAISO to order the rotating outages including:

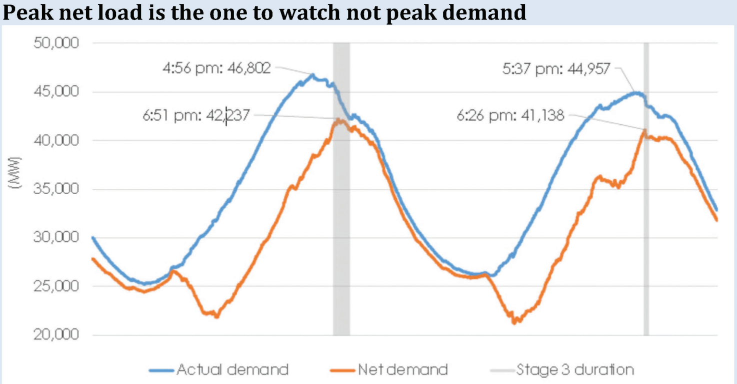
- The **climate change-induced extreme heat** across the western US, which resulted in the demand for electricity to exceed the planning targets and available resources;
- Admission that the actual resources have not kept pace with the demand, particularly in the early evening hours – the neck of the **California "Duck Curve;"** and
- Some deficiencies in the **day-ahead energy market**, which exacerbated the supply shortages under highly stressed conditions.

The joint report said, "… it is our responsibility and intent to plan for such events, which are becoming increasingly common in a world rapidly being impacted by climate change."

With the recent devastating wildfires, still burning, the impact of climate change is not disputed in the West.

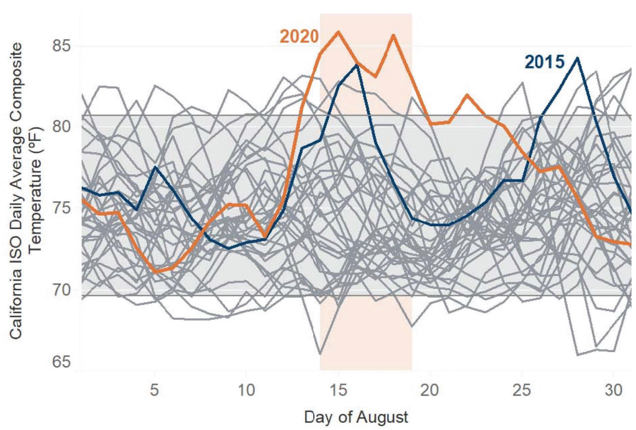
- "From August 14 through 19, 2020, the Western US as a whole experienced an extreme heat storm, with temperatures 10-20 degrees above normal. During this period, California experienced 4 out of the 5 hottest August days since 1985; August 15 was the hottest and August 14 was the third hottest. This heat event was the equivalent of the hottest year of 35."

Peak net load is the one to watch not peak demand



Source: Preliminary root cause analysis: Mid Aug 2020 heat storm, 6 Oct

6 hot days from hell, much worse and persistent than in 2015



Source: Preliminary root cause analysis: Mid Aug 2020 heat storm, 6 Oct 2020

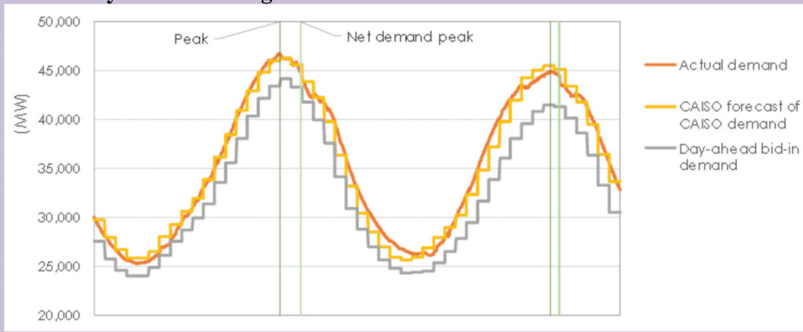
What happened on 14-15 Aug is not in dispute either. CAISO has to maintain minimum reserves at all times, approximately equal to 6% of the load. At 6:38 pm on 14 Aug it was forced to initiate rotating outages for about an hour affecting roughly 492,000 customers for 15 to 150 minutes (Table).

As often happens, CAISO's **net demand**, that is demand minus solar and wind generation, peaked at 6:51 pm after the sun had already set.

On the following day, Saturday 15 Aug, a Stage 3 Emergency requiring rotating outages was declared at 6:28 pm for 20 minutes, 2 minutes prior to the net demand peak at 6:26 pm, affecting 321,000 customers for 8 to 90 minutes.

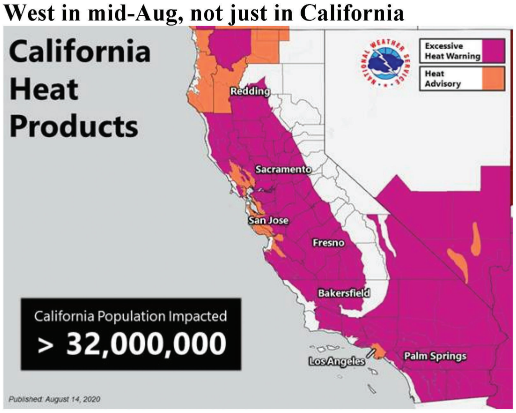
To be sure, mid Aug was unusually hot and not just in California. Between August 14 through 19, California experienced state-wide extreme heat with temperatures ranging 10-20 degrees F above normal exposing 32 million residents to extreme heat. Across the West, some 80 million people fell within an excess heat watch or warning (map below).

Fix the day-ahead bidding in CAISO market



Source: Preliminary root cause analysis: Mid Aug 2020 heat storm, 6 Oct 2020

80 million people exposed to extreme heat in the West in mid-Aug, not just in California



Source: Preliminary root cause analysis: Mid Aug 2020 heat storm, 6 Oct 2020

The report is a must read for the technical types, perhaps a tad too technical for others. Its main message is that

- CAISO – who is ultimately responsible for keeping supply and demand in balance – underestimated the resources it needs;
- Forecasts by CAISO, and everyone else, were off especially given the extreme heat;
- Resources that are normally available to meet the peak demand, both natural gas and renewables, fell short;
- Imports from out of state, which typically fill the gap, were constrained because the entire Western US was experiencing unusually high demand; and
- CAISO, having talked incessantly since 2012 about the challenges of meeting the neck of the dreaded "**duck curve**" fell victim to it at last.

The report notes that it is not the **traditional peak demand**, which occurs in midafternoon, that breaks the system but **net load peak**, which happens in the early evening hours after the sun has gone down – while the demand remains high. It said, "The net demand peak is becoming the most challenging time period in which to meet demand." This, however, should not have come as a surprise to anyone at CAISO.

On Aug. 14, the *net demand peak* of 42,237 MW at 6:51 pm was 4,565 MW less than the *peak demand* 2 hours earlier while solar (and to a less extent, wind) generation had decreased by 5,431 MW, according to the report.

Other major deficiencies of the current market is the lack of adequate **demand response** (DR) – many reasons why this is the case. While the details are still being investigated, DR programs reduced load by an estimated 1,200 MW on Aug. 14 and about 1,000 MW on the following day, a fraction of the technical potential. Why so little? Perhaps the retail prices are not right. It is a long story.

Other factors contributed. During the 2 critical days, a transmission line sending power from the Pacific Northwest went offline because of the heat, reducing the flow by 330 MW while other lines were threatened by raging forest fires. Wind was more-or-less non-existent when it was needed, and solar output was adversely affected by smoke from the fires and the clouds. Making matters worse, some practices in the CAISO's day-ahead energy market exacerbated the challenges – it is complicated (Box).

What needs to be done? The agencies said they would work together to:

- Update current resource adequacy (RA) and reliability planning targets to better account for future heat storms;
- Expedite on-time construction of generation and storage projects including additional procurement by non-CPUC jurisdictional entities;

Glitches in market rules and software allowed exports out of California

During California's last **electricity crisis in 2000-01**, manipulating power traders including **Enron**, were able to take advantage of loopholes in the market rules that allowed them to fictitiously ship power out of state at low costs and buy it back at much higher prices, making obscene profits in the midst of the power shortages.

As it happens, unintended market rules in the CAISO day-ahead market bidding plus glitches in the software allowed scarce resources to be shipped out of California while the reverse should have happened. Buried amidst technical details, CAISO said that its **Residual Unit Commitment** (RUC) model erroneously led dispatchers to believe that approx. 4,000 MW of power *exports*, could be supported during the crisis days in mid-Aug. We now know that should not have happened.

Starting on Sunday 16 Aug, CAISO began to cut the erroneous exports and suspended the so-called **convergence bidding.** It apparently took 3 weeks for CAISO programmers to detect the technical flaws and fix the glitch. It says the software has been fixed, fingers crossed. ■

- Expedite procurement of additional DR and flexible resources by summer of 2021; and
- Amend CAISO market rules in the day-ahead market to better reflect the actual balance of supply and demand during stressed operating conditions.

None are easy to do. All will be needed if California is to avert future outages in the years ahead. **Elliot Mainzer**, the new CEO of the CAISO said, “We are committed to working with the Governor’s office, state agencies, and the broad set of stakeholders in California and across the Western US to accelerate our efforts to reliably decarbonize the electricity grid.” Just what you expect the CAISO’s CEO to say after an embarrassing outage.

Not everyone was pleased with the assessment. According to a 13 Oct article in the ***CA Current***, **Jim Patterson**, the vice-chair of the **California Assembly Utilities & Energy Committee** publicly castigated the state’s 3 energy agencies, claiming their report was essentially finger pointing and excuses. The agencies blamed the extreme heat – a 1 in 35-year event – as the main culprit. Patterson insisted that the outages were because of reductions in fossil fuel capacity and the rise in renewables. The former is true, the latter not – renewables were not to blame.

Numbers of customers affected by mid-Aug outages in California

	Customers	MWs	Time (in mins)	Start	Finish
SCE	132,000	400	63	6:56 PM	7:59 PM
PG&E	300,600	588	~150	6:38 PM	~9:08 PM
SDGE	59,000	84	~15-60		
Total	**491,600**	**1,072**	**15 to 150 mins**		

Source: Preliminary root cause analysis: Mid Aug 2020 heat storm, 6 Oct 2020

CAISO’s outgoing CEO **Steve Berberich** begged to differ, noting that renewables have served up to 80% of the system load. Other experts also testified on remedies to prevent future outages, including additional flexible resources specifically available after sundown, more DR, more and longer duration storage, and so on.

CPUC President **Marybel Batjer** said 2,400 MW of additional resources are expected to be online by next summer with plans to increase RA levels by 2022. ■

http://www.caiso.com/Documents/Preliminary-Root-Cause-Analysis-Rotating-Outages-August-2020.pdf

Footnotes

[1] The original appeared in the Nov 2020 issue of EEnergy Informer newsletter available at http://www.eenergyinformer.com

Western Green Energy Mania Will Not Doom Oil and Gas Industry

BY DR. TILAK K. DOSHI

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It would seem that the Middle East oil producers cannot get enough of bad news these days. The coronavirus pandemic and the collapse in global energy demand in the first quarter of 2020 led to oil prices plunging into the mid-teens as Saudi Arabia launched the oil price war against Russia in early March. Despite the subsequent historic OPEC+ deal in April to slash output by an unprecedented 9.7 million barrels per day (Mbd), oil prices have been stuck around $40/barrel since June. Prospects for an economic recovery for the Middle East – which already looked precarious after the steep fall in oil prices since mid-2014 as the US "shale revolution" took hold in global oil markets -- now look significantly worse than that of other emerging market regions.[1]

BP and Shell: Cutting Oil and Gas Output

In the midst of this calamity, BP made its bombshell announcement in early August of its intentions to slash its oil and gas output by 40% by 2030 from 2019 levels, by actively managing its investment portfolio in favour of low-carbon renewable energy.[2] The leading international oil company -- known for its influential annual global energy statistics reports – had come out with its latest 2020 energy outlook that suggests that oil demand may already have peaked in 2019. As if on cue, the other European oil major, Royal Dutch Shell, reported last week a similar 40% planned cut to its oil and gas exploration and development budget to "prepare for the energy transition".[3]

BP's outlook presented three scenarios – "business as usual" (BAU), "rapid (transition)" towards a low-carbon renewable energy future and "net zero" carbon emissions by 2050, of which the last two postulate 2019 as marking the global oil demand peak, steeply falling from 100 Mbd to 55 Mbd and 30 Mbd by 2050 respectively. In contrast, after recovering from the impact of Covid-19, the consumption of oil in BP's "BAU" scenario plateaus at around 100 Mbd for the next two decades, before declining to around 95 Mbd by 2050. Evidently both BP and Shell are convinced that the likely outlook for global oil demand growth is better approximated by either the "rapid transition" or "net zero" scenarios.

Despite repeated claims about the cost competitiveness of solar and wind energy, BP's scenarios of a "rapid transition" or a "net zero" world of carbon emissions by 2050 are ultimately founded upon government subsidies for solar and wind energy and electric vehicles, carbon taxes and policy mandates such as renewable portfolio standards.[4] Whether the developed economies will go all out for a Green Recovery – as called for by leading figures such as European Commission President Ursula von der Leyen,[5] chairman of the World Economic Forum Klaus Schwab[6] and Executive Director of the International Energy Agency Fatih Birol[7] – remains to be seen in the cold light of economic recession, record budget deficits and the need to kick-start their economies from their current Covid-19-induced comatose state. One has only to appreciate Poland's reaction to the EU's climate goals to be somewhat sceptical.[8]

Middle East: Under Existential Threat?

The Middle East accounts for 48% and 38% of proven global reserves of oil and gas respectively.[9] The announcements by BP and Shell to cut their oil and gas investments by 40% by 2030 would seem to signify an existential threat to the future viability of the region's oil and gas producers. Yet it would take a distinctly European view of the global energy future to pay credence to such an outlook.

A senior executive of U.S. oil producer ConocoPhillips said last week that he sees global demand returning to 100 Mbd and growing from there, with oil an "important part of the energy mix in any scenario" going forward.[10] The CEO of Chevron, Mike Wirth told an audience that the global push for clean energy "doesn't mean the end of oil and natural gas…it will be a part of the mix, just as biomass and coal are still enormous parts of the mix today".[11] These views are consistent with an IMF econometric analysis of the determinants of oil demand which predicts that global oil demand will peak around 2041 at about 115 Mbd.[12]

On the high road of the climate change crusade, sign-posted by corporate brochures extolling social responsibility and environmental sustainability, BP and Shell may be the first among the big oil majors. But that is not what makes the oil world tick. When Ali Naimi, the Saudi Arabian oil minister from 1995 to 2016, was asked in 2018 whether he saw a threat to oil demand from climate change policies and the increasing use of electric vehicles, he replied that "I would like to put everyone at ease, there are no such worries". Cynics will say that he spoke "his book". Yet history might be his best witness.[13]

Developing Asia: The Need for Oil (and Gas and Coal)

Developing Asian countries accounted for just over 70% of global oil demand growth in the five years to 2019.[14] That is, out of 7.3 Mbd growth in global oil demand over the period, developing Asia consumed 5.3 Mbd. In any credible scenario where governments retain legitimacy by delivering higher standards of living for their people, the Asian developing countries' appetite for oil (along with gas and coal) will mount for at least a few more decades to come.

It is implausible to believe that the developing countries in Asia, Africa and Latin America will undertake costly subsidies and infrastructure investments on intermittent and low-density "renewable" technologies – in the wake of the devastating Covid-19-induced lockdowns -- rather than invest in established energy system that has been developed over the past century.[15] China, for instance, approved nearly 10GW of new coal-fired power generation capacity in the first quarter of this year, roughly equal to the capacity approved for all of 2019.[16] In mid-June, India opened up coal mining to the private sector half a century after bringing it under state control, in a bid to boost the coronavirus-hit economy.[17] The International Energy Agency found that "global approvals of new [coal] plants in the first quarter of 2020 (mainly in China) were at twice the rate seen in 2019", with a long pipeline of projects under construction.[18] Wood Mackenzie, a consulting company, estimates that there will be a net increase in global coal-fired power capacity this year, with 22 gigawatts of closures in Europe and the US more than offset by 49 gigawatts of plants opening in Asia.[19]

If there is bad news for the Middle East oil producers, it has little to do with peak oil demand. It would be that they failed to exploit their treasure of energy reserves to help themselves while their oil sales rescue the rest of humanity in the developing countries from the ravages of energy poverty.

A version of this article was published in the *South China Morning Post* on 30 September 2020

Footnotes

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Enrichment's Critical Role in Nuclear Fuel Supplies

BY Y. LYDIA HSIEH AND JEFF COMBS

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Most academic articles that deal with nuclear fuel focus on the uranium resource aspect of the fuel.[1] This is especially the case when examining the long-term prospects for the fuel, as the adequacy and price of the fuel becomes more of an issue.[2] However, the enrichment technology dimension of nuclear fuel is critically important since most reactors are of the light water variety and require enriched uranium to operate. Importantly, uranium and enrichment are substitutes, and this degree of substitutability only increases with advances in enrichment technology, as history has demonstrated.

Enrichment Technology: Impact on the Need for Uranium

The impact of enrichment technology on nuclear fuel has not been completely ignored. In 1989, Combs noted the potential for technology to substitute for uranium resources in the making of nuclear fuel, an observation made when examining the potential for investing in advanced enrichment technology.[3] Combs pointed out that enrichers could not only expand their share of the enrichment market by investing in advanced technology and achieving cost advantages, but they could also gain business at the expense of the uranium market as well, as newer technology could displace the need for uranium to a greater degree.

With a more advanced technology, the enrichment process can be more efficient and recover more of the fissile content of the uranium, the isotope that sustains a nuclear reaction. In this way, it is like the fracking development in recovering oil and natural gas. This efficiency or effectiveness of enrichment is denoted by the tails assay, the fissile contained in the waste stream. In nature, the portion of U-235 contained in uranium is 0.711%. Uranium is typically enriched to 4-5% for light water reactors. As the tails assay drops, relatively more enrichment is used compared with uranium in the make-up of the fuel. When the operating tails assay (the assay at which enrichment occurs) is less than the transaction tails assay (the assay on which the quantity of uranium delivered to the enricher is based), it creates a situation known as underfeeding, where the enricher keeps the additional uranium that is not used in the enrichment process. The net effect of this greater use of enrichment is that less uranium needs to be produced to make an equivalent amount of enriched product.

Figure 1 presents the isoquant curve of EUP production using uranium (or feed) and enrichment (measured as separative work unites or SWU) as two inputs. In this example, we assume the feed is enriched to 4.50% of 1 kgU EUP at a tails assay ranging from 0.10% to 0.30%. The isoquant curve provides an illustration of using the substitutability of uranium (or feed) and enrichment to produce a fixed amount of EUP. At each level of tails assay, the amount of uranium and SWU required to produce EUP are derived from mass and energy conservation equations based on feed-to-product ratio (F/P) and SWU-to-product ratio (S/P), respectively. For example, at a tails assay of 0.25%, the combination of 9.219 kgU of feed and 6.871 kg SWU is required to produce 1 kgU of EUP with a content of 4.5% U-235. If the tails assay is lowered to 0.20%, we could produce 1 kgU of EUP using less feed of 8.415 kgU and more enrichment of 7.691 kg SWU. At lower tails assays, even less uranium would be required.

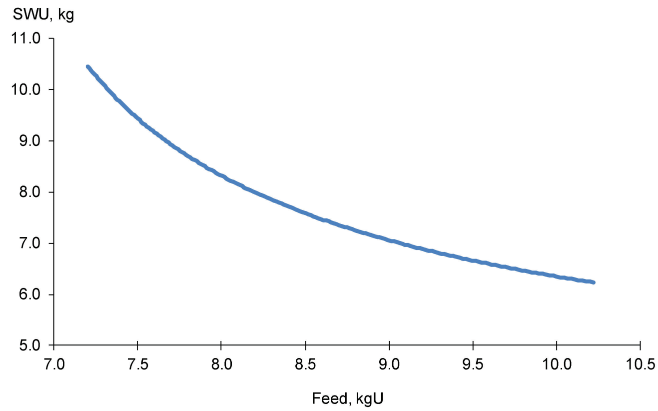

Figure 1. EUP Isoquant: Uranium and SWU Substitution

Tails Re-enrichment: Second-Order Effect of Enrichment for Uranium Substitution

Tails material – the waste product of the enrichment process – can be enriched to the level of natural uranium to further reduce the need for newly produced uranium, as long as the enrichment occurs at a lower tails assay than the assay of the material being enriched. For example, tails with a content of 0.25% U-235 can be enriched to 0.711% (the equivalent of natural uranium). If the operating tails assay is 0.10%, a 1 million SWU enrichment plant can produce 1.5 million pounds U_3O_8 equivalent. This re-enrichment of the waste stream has the impact of reducing the demand for newly produced uranium (i.e., the demand on uranium resources) by augmenting the supply of uranium. Thus, enrichment technology not only can economize on the need for uranium resources in the first instance by reducing demand but can more completely process tails material to augment uranium supply, further reducing the need for uranium resources.

Recent Developments

Now that three decades have passed from the Combs' paper, it is instructive to examine the extent to which this substitution has taken place. Over this time, advances have been made in centrifuge technology that have lowered costs and allowed enrichment to take place at lower tails assays. As a result of this and greater competition, higher-cost gaseous diffusion enrichment technology has been phased out. Also, a new laser enrichment technology has been developed that promises even lower costs and a greater ability to physically substitute enrichment for uranium. In addition, during this time the Fukushima reactor accident occurred, resulting in the shutdown of a number of reactors and slower nuclear power growth, creating an environment for an even greater substitution of enrichment and uranium due to the relative economics of each and an abundance of excess enrichment capacity.

One of the results of this technology change has been enrichers operating their enrichment plants at very low tails assays both because it is more economical to do so and to utilize their excess capacity.[4] The net effect of this greater use of enrichment is that less uranium needs to be produced. As discussed, the substitution of enrichment for uranium has not just been limited to underfeeding, tails re-enrichment has also played an important role in recent years. In this regard, Russia converted its Angarsk enrichment plant with a 3 million SWU capacity to the enrichment of tails material, producing an equivalent of 4.5 million pounds of U_3O_8 equivalent per year.[5] URENCO, a major multinational enrichment corporation, also increased its ability to enrich tails material, while also engaging in considerable underfeeding. In June of 2013, it announced its "SWU for U" program where excess capacity is used to supplant or create uranium.

Figure 2 below shows the growth of enrichment demand or usage relative to that of uranium over the 1990 to 2017 period. Enrichment usage includes both enrichment of natural uranium and enrichment of tails material to the level of natural uranium.

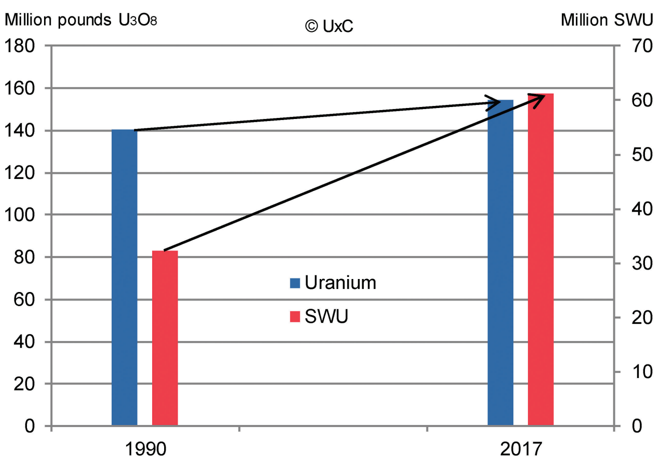

Figure 2. Relative Growth in Uranium vs. Enrichment Demand

Because of the increasing role that enrichment has played, it is estimated that only slightly more uranium production is needed today than was the case thirty years ago, even though installed nuclear capacity has grown 20% over this period. This explains why uranium prices, until recently, have been lower in real terms than they were in 1990, after suffering a price spike associated with the entry of China into the market to fuel its ambitious nuclear power expansion plans and related hedge fund speculation, disruption of mine production, and the existence of trade restrictions that have since been relaxed.

The substitution of enrichment for uranium was accelerated by the reaction to the Fukushima reactor accident in 2011 and the subsequent drop in nuclear fuel demand that resulted in considerable excess enrichment capacity that has been used to create uranium and supplant its use. This substitution also explains why uranium inventories have grown so much. Current uranium inventories are estimated at 1.7 billion pounds, up considerably over the past decade. Not nearly as much uranium needed to be produced to meet reactor requirements, and it is likely that uranium producers did not fully understand the impact of this development, resulting in considerable overproduction. The massive inventory level coupled with the decline in forecasted demand is the reason that uranium prices have fallen. Uranium prices now reside below $30, down from above $70 before the Fukushima accident due to the reduced demand for uranium and the large inventory overhang. Enrichment prices have similarly suffered a large drop.

It is important to note that commercial laser enrichment technology, the advanced technology being discussed thirty years ago, still has not been introduced. Laser enrichment has even greater efficiency than centrifuge, able to operate at lower tails assays and thus requiring even less uranium to make a given quantity of enriched uranium.[6] Because of its enhanced abilities, laser enrichment can more efficiently process tails material as well. In this regard, in 2013 the U.S. Department of Energy (DOE) selected a non-binding proposal by Global Laser Enrichment (GLE) to construct a tails enrichment facility using the SILEX technology at the DOE site in Paducah, Kentucky. DOE currently has about 114,000 MTU of high-assay tails material. Processing these at the proposed tails enrichment plant would result in another 5 million pounds U_3O_8 of natural uranium equivalent being produced on an annual basis, similar to the output of the Angarsk plant. However, due to poor economics related to depressed uranium prices, which ironically was in large measure due to enrichment supplanting the need for uranium, the GLE venture is not proceeding at this point.

It is noteworthy that a SILEX laser enrichment can also be used to perform normal toll enrichment in addition to enriching tails material. It thus can further economize on uranium usage while creating equivalent natural uranium by processing tails, thus both reducing uranium demand and augmenting uranium supply. In this respect the Silex technology would result in even further substitution of enrichment for uranium in the future when it is deployed.

Implications for Modeling

The ability to substitute enrichment and uranium has important implications for modeling and forecasting uranium and enrichment demand and prices. UxC has applied this concept to develop its two proprietary price forecasting models, U-PRICE® and SWU-PRICE® models.

Both U-PRICE and SWU-PRICE models are recursive econometric simulation models that consider the inter-relationships among key factors influencing the uranium and enrichment markets, respectively. This type of modeling allows us to incorporate related market and economic variables as an integral part to forecast uranium and SWU prices. Specifically, our models measure how changes in various market variables (which could also affect other variables included in the model) will impact future prices of uranium and SWU. Because of the recursive nature, when these models are simulated as a complete system, the value of each endogenous variable is determined sequentially. In addition, most exogenous variables in these models represent data of qualitative nature. These variables help measure the impacts of market uncertainties on both uranium and SWU prices.

Figure 3 presents the basic structure of the U-PRICE Model.

As illustrated in the above diagram, while the outlook of the nuclear industry is the key factor affecting both uranium demand and supply, economic and political factors external to the uranium market will also impact its price. For example, on the supply side, exchange rates between the U.S. dollar and home currencies of enrichers could affect enrichers' production cost and thus their cost competitiveness. On the demand side, changes in utility's fuel procurement and inventory strategies could have a significant impact on the timing and volume of uranium demand.

One factor that could affect both uranium demand and supply at the same time is the SWU price and SWU production capacity. This is because the substitutability between uranium and enrichment allows the consumers (i.e., utilities) and the suppliers (i.e., enrichers) to vary tails essays to achieve intended operating goals. For utilities, when uranium becomes relatively more expensive than enrichment, shifting to lower transaction tails as allowed in an enrichment contract will help save fuel cost. For enrichers, using lower operating tails assay will help reduce excess production capacity. However, it should be emphasized that the key driver of these business practices is the relative price of uranium (or feed) to SWU, and not just the level of the uranium or SWU price. Figure 4 provides a more detailed look at how the model handles the uranium/enrichment interaction.

This brings up an important aspect in modeling the uranium and enrichment markets. Due to persistent oversupply in the uranium market and excess capacity in enrichment production, competition between uranium and enrichment has intensified in recent years. Accordingly, uranium and SWU prices are not truly independent of each other but depend on what the other market does. In both U-PRICE and SWU-PRICE models, the price ratio of uranium to SWU is used as one of the input variables that links the interactions of the two markets. Early work has shown when the term price of SWU is used as an independent variable in modeling uranium prices, the resulting uranium price forecast is notably lower than when this variable is not taken into consideration. The same is true when the spot price of uranium is used as an independent variable when modeling enrichment prices. Therefore, linking the U-PRICE model to the SWU-PRICE model will form an integrated framework that explicitly models the impact of the substitutability, and more importantly, the price interdependency between uranium and SWU. With a fully integrated model of the front-end market, the prices of uranium and SWU will be solved and forecasted simultaneously.

Policy Implications

Understanding the relationship between enrichment and uranium continues to be important for policymakers as well as nuclear fuel suppliers and consumers. In the past, fears have been expressed that the world is running out of uranium or that uranium prices will be pushed to extremely high levels as demand for nuclear energy rises.[7] This concern may be voiced again if nuclear energy

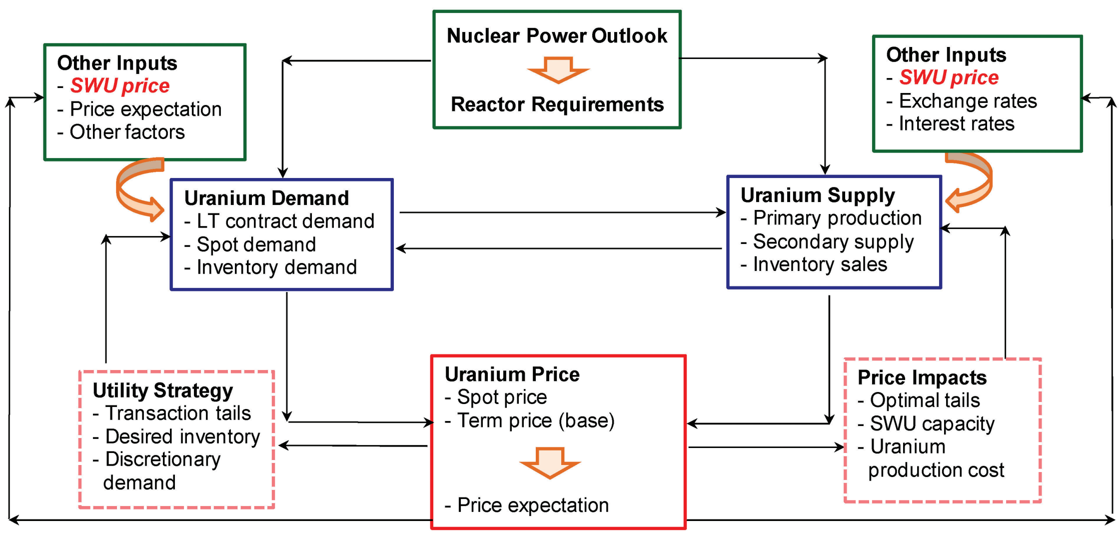

Figure 3. Basic Structure: U-PRICE Model

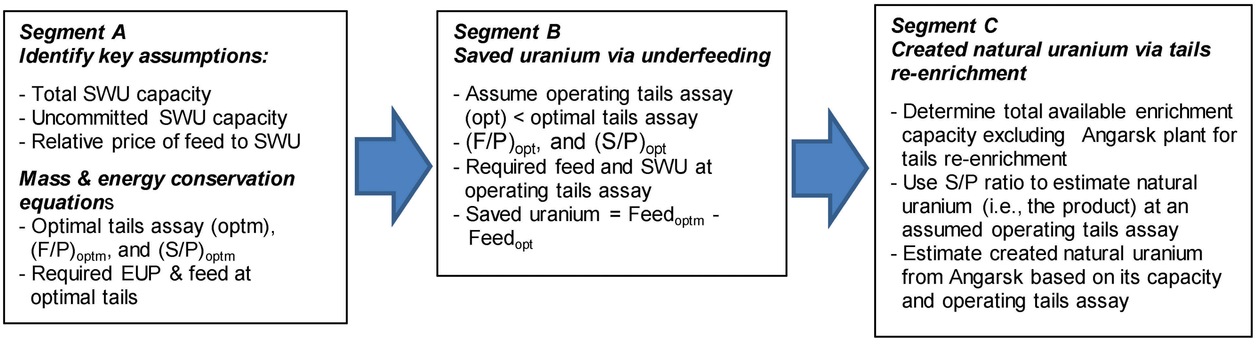

Figure 4. Model Structure: Quantifying Uranium & SWU Substitution

is expected to play an important role in combatting climate change.[8]

Concerns about the future availability of uranium have spurred efforts to develop breeder reactors which create their own fuel, plutonium, raising nonproliferation concerns.[9] Other efforts include reprocessing spent fuel and recycling the recovered uranium and plutonium in reactors. These have been quite expensive and have also raised proliferation concerns.

Incorporating the substitution of enrichment for uranium into the analysis suggests that the need to invest in new reactor technologies for fuel efficiency reasons is less pressing although investments for increased reactor safety continue to be important. This is especially true if nuclear power is not growing to any great degree, which is currently the case. Of course, a key question is the degree to which nuclear power grows in the future. Here, climate considerations and other factors play a key role. If nuclear power is to continue to have prominent role in energy and environmental security, enrichment will need to play a key role in fuel availability and security.

Related to the outlook for nuclear energy, there is a danger in shuttering enrichment capacity prematurely, as it represents a resource hedge and to some degree a nonproliferation hedge. There exists considerable potential for enrichment to substitute for uranium, and this potential only will increase with advances in enrichment technology. The question is how the market and governments value these hedges. The United States has its "gold standard" when it comes to signing nuclear cooperation agreements (so-called 123 agreements) with other countries. This standard involves countries forswearing the development of uranium enrichment capabilities in exchange for access to U.S. reactor technology. There are also several fuel banks of enriched uranium around the world.[10] Of note, the International Atomic Energy Agency has instituted such a fuel bank in Kazakhstan, as a way of helping to assure countries of future enriched supplies. However, these approaches depend on having an adequate base-line supply of enrichment capacity. If there is a reduction in this enrichment capacity, countries may be compelled to build their own enrichment plants, as a fuel bank does not represent a long-term source of enrichment supply but is only a stopgap measure.

Enrichment may have an even more important role to play when it comes to advanced reactors, which can make use of high assay, low-enriched uranium (HALEU) where uranium is enriched above the 4-5% currently used in light-water reactors, potentially up to 20%. Smaller advanced reactors may be more amenable to countries just entering the nuclear power space, like those in Africa that are considering nuclear energy. What is interesting is that reactors loaded with HALEU can operate for many years, making fuel supply assurance less of an issue and, in essence, becoming mini fuel banks themselves. Thus, enrichment technology may become even more important in the future, not just because of its ability to extend uranium resources, but because of how reactor technology and related fuel needs are likely to change over time.

Footnotes

[1] One of the earliest papers was by Owens, A.D. (1985), "Short-Term Price Formation in the U.S. Uranium Market," The Energy Journal, July 1985.

[2] See, for example, Gabriel, Sophie, Monnet, Antoine, and Percebois, Jaques (2017), "Uranium Resources and Security of Supply," IAEE Energy Forum, Fourth Quarter 2017.

[3] Combs (1989), "The Economics of Strategic Choice: U.S. Enrichment in the World Market: A Comment," The Energy Journal, January 1989.

[4] There are operational issues associated with shutting down and restarting centrifuges as they are designed to keep spinning.

[5] This is based on a tails with an assay of 0.25% being enriched at a tails assay of 0.10%. It should be noted that Russia, which has relatively poor uranium resources but huge enrichment capacity from its military program, has engaged in tails enrichment for some time. See Bukharin, O. (1996), "Analysis of the Size and Quantity of Uranium Inventories in Russia," Science & Global Security, Volume 6, no. 1 (1996)

[6] Reportedly, laser enrichment can operate at well below a 0.10w/o tails assay.

[7] Sharply rising uranium prices was a conclusion of the analysis appearing in "Uranium and Security of Supply," which did not factor in the impact of enrichment on uranium supplies.

[8] A number of studies have concluded that carbon abatement targets cannot be attained without nuclear energy. For example, see "The Future of Nuclear Energy in a Carbon-Constrained World," by the MIT Energy Initiative.

[9] Recently, China has started a fast-breeder reactor.

[10] There are fuel banks in Russia, the United States, and Kazakhstan.

Responding to "An Uphill Battle for EVs vs ICEs": setting the record straight on the status and future of EV adoption

BY MATTEO MURATORI, CATHERINE LEDNA, CHRIS GEARHART, JOHN FARRELL, AND DAVID GREENE

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In its Fourth Quarter 2020 edition, the IAEE Energy Forum published a perspective article authored by Mamdouh Salameh in which he asserts that "...while electric vehicles (EVs) are bound to get a share of the global transport system, they will never prevail over internal combustion engine vehicles (ICEVs). As a result, ICEVs will continue to be the dominant means of transport throughout the 21st century and far beyond." In that article Mr. Salameh makes several assertions to support his conclusions: 1) EV adoption has been negligible as of today; 2) massive investments are required to expand the global electricity generation capacity; 3) EVs have prohibitive purchase costs and higher operational costs relative to ICEVs; 4) EVs have poor charging speeds and availability; and 5) there is a lack of global support for transitioning to EVs, especially from industry. All these assertions, however, are not based on the most recent data and possibly misleading. In this response, we offer up-to-date data and statistics on the state of the global EV market and EV technologies. While we cannot predict the future success of different technologies, we argue that with respect to EVs, Mr. Salameh's outlook is outdated, factually inconsistent and overly pessimistic of the ingenuity displayed in solving seemingly intransigent problems.

EV adoption is growing globally, with more than 7 million passenger electric vehicles on the road

Mr. Salameh claims that EVs and hybrids together make up a negligible share of the global vehicle market, citing 4 million EVs and hybrids globally compared to 1.5 billion ICEVs. Looking only at EVs,[1] and excluding hybrids (which should not be conflated), we find that these numbers are out of date. As of December 2019, there were over 7.2 million electric passenger cars globally (and many more electric 2- or 3-wheelers and buses).[2] Globally, EVs have grown exponentially in the last decade, increasing from 0.23 million in 2013 to more than 7 million in 2019.[3] This is about a 78% increase year over year, on average. Regionally, the growth has been more variable with the U.S. seeing a slowdown in 2019-2020 as model availability has dropped. Yet, all regions are expected to grow dramatically through this decade based on almost every forecast by industry experts who study these markets and gather data from auto companies and their suppliers[4] Sales shares are a better indicator of technology success, and global EV sales in 2019 reached 2.6%. In some regional markets, EVs have already made significant inroads, comprising more than 50% of new sales in Norway in 2019 and approximately 8% in California.[5,6] While one could debate whether 2.6% of global share is consequential or not, vehicle original equipment manufacturers (OEMs) are expecting significant growth in the next decade as they are planning to launch an additional 400 models by 2023 across all light-duty vehicle market segments and more models planned in the medium and heavy duty market.[7,8] For example, on November 19, 2020, General Motors announced it will spend $27 billion on all-electric and autonomous vehicles through 2025, an increase of $7 billion, or 35%, from initial plans announced in March.[9] This increase in spending on EVs is reflected in many projections for EV adoption, with many government, industry, and research sources projecting EV to become the predominant light-duty technology by 2050.[10] Moreover, projections of EV adoption have been consistently revised upwards over the last decade and great optimism is publicly shown by many stakeholders.[11,12]

EVs offer opportunities to support and complement electricity infrastructure investments

Beyond sales, Mr. Salameh cites the challenges of expanding global electricity infrastructure to accommodate demand from EVs, which he estimates to require trillions of dollars of investment. This argument frames these investments as negative for the electricity sector. EVs can actually reverse trends of stagnating electricity demand in countries such as the US, which has seen near-zero growth in the past decade. Even under high growth scenarios, the government-industry US DRIVE partnership assessed that sufficient generation capacity will be available in the US to accommodate large-scale EV adoption, noting that the growth in generation required will be lower than past periods of growth seen historically.[13] Furthermore, with managed charging and vehicle to grid solutions, EVs may serve as a resource to support grid planning and operations and facilitate the integration of intermittent renewables such as solar and wind.[14] Studies have shown that flexible EV charging enables better utilization of electricity assets and could decrease electricity cost for all electricity consumers, not just EV users.[15] Overall, while investments will be necessary to expand generation capacity and update grid infrastructure, these are well in-line with traditional utility growth.[16] Grid investment will be required even in the absence of EV growth as a part of routine maintenance and grid modernization[17], and EVs offer a unique opportunity to synergistically improve the efficiency and economics of mobility and electric power systems.[18] Lastly, it should also be noted that the investments in oil and gas required under an ICEV-dominated future are substantial as well (averaging $500 billion per year for upstream investments alone between 2015 and 2019).[19]

EV purchase price are decreasing with battery costs, and operational cost is already lower compared to ICEVs

Mr. Salameh also argues that high purchase price and operational costs are additional barriers to the adoption of EVs. He cites a cost of $70,000 to $100,000 for an EV with a range of 250-300 miles; but in fact, five of the 11 battery electric vehicles with ranges above 250 miles currently available on the U.S. market have a retail price below $50,000 (without considering incentives). Before incentives, a Chevy Bolt (259 miles of range) costs less than $40,000 in the U.S., and a Tesla Model 3 (290 miles) sells for a base price of around $40,000 in the U.S. and in China.[20] If prices were to stay at this level, we might agree that vehicle cost will limit EV adoption. But battery prices are dropping rapidly along with other key EV components. Battery electric vehicles (BEVs) are expected to reach purchase price parity with ICEVs when battery prices reach ~$80 -100/kWh.[21,22] Battery pack prices are expected to fall below $100/kWh by 2024 and below $80/kWh by 2030 according to projections made by BNEF and others.[23,24] At the same time, ICEVs capable of meeting increasingly stringent fuel economy and criteria emissions regulations are becoming more complex and expensive,[25] and automakers including Daimler, Volkswagen, and General Motors have announced an intent to end research and development on new ICEV platforms in favor of EVs.[26,27,28]

In addition to reductions in upfront purchase cost, EV operational costs are already lower than those of ICEVs, making total cost of ownership cheaper for EVs in some cases.[29] Recent data show that maintenance costs for EVs in the US are up to 50% lower than ICEVs, and differences in fuel prices also offer substantial savings.[30,31] Mr. Salameh argues that savings from maintenance costs will be outweighed by increasing electricity prices. Energy prices, especially for petroleum, have been volatile and heavily influenced by global macroeconomic and geopolitical conditions.[32] While gasoline and electricity prices vary widely across regions and their future trajectory is uncertain, recent US-focused research indicates slightly falling electricity prices over the next decades as a result of declining generation costs.[33] Including charging equipment costs and using current retail electricity prices and future escalation, the cost of charging an EV in the US is estimated to range between $0.08 and $0.27/kWh, resulting in lifetime fuel savings of $3,000 relative to an ICEV under the worst case scenario and over $10,000 in the best-case scenario (considering electricity price escalation).[34] The combination of more expensive ICEVs and cheaper EVs due to continued battery and other technology cost reductions suggest that the lifetime cost of EVs will continue to grow more competitive with ICEVs even in the absence of subsidies.

Charging infrastructure availability and charging speeds are increasing

EV charging speed and public charging availability have also rapidly improved. Far from Mr. Salameh's estimate of 30 miles of range per hour of charging, today's standard commercial DC fast chargers can deliver 60 to 80 miles of range in 20 minutes of charging.[35] Faster charging speeds (150 kW–350kW per car or 600–1400 miles of range per hour) are commercially available and becoming increasingly common.[36] A 2019 Tesla Model 3 Long Range vehicle operating at peak efficiency can recover up to 75 miles of charge in just 5 minutes.[37] Globally, public charging availability has grown rapidly, with the number of chargers increasing by 60% between 2018 and 2019 to reach 862,000 globally—with 263,000 being fast chargers.[38] In the U.S. alone over 75,000 public chargers were available at the end of 2019, with 13,000 being fast chargers.[39] The IEA projects that by 2030 public chargers will expand to 11 million worldwide assuming that existing government policies are fully implemented (supporting 140 million EVs).[40]

Significant current and planned support from industry and governments globally

Mr. Salameh states that "...any mandatory transition to renewable energy and EVs will not achieve the desired outcome without individuals, businesses and governments getting on board." We agree with this sentiment and believe there is strong evidence that such buy-in is occurring. With respect to individuals, in addition to increasing sales growth, surveys in the US have found that the number of consumers intending to purchase an EV has grown over time due to increased experience with the technology and greater appreciation of the financial and environmental advantages to ownership.[41,42] In addition, governments and industry alike have signaled continuing and increasing commitment to EVs. While purchase subsidies declined in some regions in 2019, regulatory measures such as China's New Energy Vehicle mandate, zero emission vehicle mandates in regions of the US and Canada, and European fuel economy and CO_2 standards continue to incentivize EV sales, with existing policies set to grow stricter over time.[43] As of 2020, seventeen countries, including France, the UK, and Norway, have signaled an intent to increase these commitments in the future, with zero emission vehicle targets and goals of phasing out ICEVs by 2050.[44] As a recent example, in 2020 the state of California announced that by 2035 all new cars and passenger trucks sold in the state must be zero emissions vehicles, a category that is dominated by EVs.[45] Automakers have also voiced their support for this transition. Speaking at the Automotive Press Association, Mary Barra, CEO of General Motors, stated "We believe in an all-electric future, and we're moving aggressively," and expressed the belief that electric vehicles will help the company to grow.[46] These sentiments have been echoed by other manufacturers, including Volkswagen and Ford, and supported by expanded EV offerings and R&D.[47,48,49] This support reflects not only recognition of increasing consumer demand for EVs, but also industry engagement and broad actions in response to concerns surrounding local air pollution and CO_2 emissions, which are priorities globally.

Conclusions

Projecting future technology adoption is a daunting task, and no one can know with certainty the future role of EVs and ICEVs. However, in this article we tried to inform this discussion with current facts. Over the last decade, EVs have made rapid progress, including major cost reductions, great expansion of charging infrastructure, and improvements in batteries and other technologies—in many cases outpacing expectations. With a wider variety of EVs coming to market, including medium- and heavy-duty models, as well as strong commitments made by governments and industry, there are reasons to expect that the next decade will see further accelerations in growth, as anticipated by many leading experts, industry leaders, and governments. Still, Mr. Salameh asserts that apart from technological barriers, "...the real challenge facing a deeper penetration of EVs into the global transport system is the realization that oil is irreplaceable now or ever." This assertion rests on the premise that the advantages of petroleum as a transportation fuel are so great that there is no reason for further sectoral transformations to occur. Advantages that EVs provide over ICEVs offer a compelling motivation for such a transformation. These include zero tailpipe emissions (greatly benefiting local air quality) and, if coupled with clean electricity, significant CO_2 emissions reductions. While EVs are part of a larger set of possible solutions to the problems of energy, air quality, and emissions, the commitments to their development made by both governments and industry leaders suggest that the recognition of their advantages is widespread and will be sustained through the coming decades. Moreover, fast acceleration, low noise, and the opportunity of convenient home-based charging also contribute to an overall improved driving experience for EVs compared to the incumbent technology. The biggest customer barrier often cited for EVs, has been range, but even this is being addressed with new models having over 300 miles range and charging infrastructure being expanded. The facts and references reported in this article show that providing affordable and convenient mobility solutions for on-road transportation is indeed feasible without relying predominantly on ICEVs. Electric vehicles are a competitive technology that has seen major technological progress over the last decade and is already seeing significant adoption today. In light of this, and of the massive investments and commitments from multiple stakeholders, EVs are well-positioned to achieve widespread adoption in the coming decades.

Footnotes

[1] EVs are vehicles that are powered with an on-board battery that can be charged from an external source of electricity. This definition includes plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).

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IAEE/Affiliate Master Calendar of Events

(Note: IAEE Cornerstone Conferences are in boxes)

Date	Event and Event Title	Location	Supporting Organizations(s)	Contact
2021				
March 21–23	8th Latin American Energy Economics Conference	Bogota, Colombia.	ALADEE	Gerardo Rabinovich grenerg@gmail.com
March 30–31	BIEE Oxford 2021 Research Conference *Energy for a Net Zero Society: Achieving a Just Transition*	Oxford, U.K.	BIEE	Debbie Heywod http://www.biee.org/
July 4–7	43rd IAEE International Conference *Energy Challenges at a Turning Point*	Paris/France	FAEE/IAEE	Christophe Bonnery https://www.faee.fr/
Postponed to 2021 Dates TBA	3rd IAEE Southeast Europe Symposium *Delivering Responsible Infrastructure Energy Solutions and*	Tirana, Albania		Erlet Shaqe https://see20.iaee.org/
2022				
July 31–August 3	44th IAEE International Conference *Mapping the Global Energy Future: Voyage in Unchartered Territory*	Tokyo, Japan	IEEJ/IAEE	Yukari Yamashita https://iaee2021.org/
September 21–24	17th IAEE European Conference *The Future of Global Energy Systems*	Athens, Greece	HAEE/IAEE	Spiros Papaefthimiou http://haee.gr/
2023				
February 5–8	45th IAEE International Conference *Energy Market Transformation in a: Globalized World*	Saudi Arabia	SAEE/IAEE	Yaser Faquih
Postponed to 2023 Dates TBA	18th IAEE European Conference *The Global Energy Transition: Toward Decarbonization*	Milan, Italy	AIEE/IAEE	Carlo Di Primio https://www.aiee.it/
2024				
June 23–26	46th IAEE International Conference *Overcoming the Energy Challenge*	Izmir, Turkey	TRAEE/IAEE	Gurkan Kumbaroglu http://www.traee.org/
2026				
May–June	47th IAEE International Conference *Forces of Change in Energy: Evolution, Disruption or Stability*	New Orleans	USAEE	www.usaee.org

WELCOME NEW MEMBERS

The following individuals joined IAEE from9/30/2020 to 12/31/2020

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Saleh Al-Faryan
SAUDI ARABIA

Abdullah Alnassar
SAUDI ARABIA

Jabor Al-Thani
Qatar University
QATAR

Filippos Anagnostopoulos
IEECP
BELGIUM

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Christopher Douglas
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Khuong Vu
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SINGAPORE

Yu Kun Wang
Guangdong Ocean Univ Cunjin College
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Menelaos (Mel) Ydreos
Energy Vantage Inc.
CANADA

Calendar

12-14 January 2021, SPE's Reservoir and Water Flood Symposium | 12-14 January 2021, Abu Dhabi at Jumeirah At Etihad Towers, Etihad Towers, Abu Dhabi, Abu Dhabi, United Arab Emirates. Contact: Phone: +44 (0) 20 7299 3300, Email: kdunn@spe.org URL: http://go.evvnt.com/639620-0?pid=204

21-21 January 2021, S&P Global Platts Oil Storage Virtual Conference | January 21, 2021 at Online, United Kingdom. Contact: Phone: +442071760508, Email: alex.baird@spglobal.com URL: https://go.evvnt.com/719653-0?pid=204

26-28 January 2021, Argus Crude Live - Virtual Conference | Online Conference and Networking Event | 26-28 January 2021 at Online. Contact: Phone: 442077804304, Email: anita.agyeman@argusmedia.com URL: http://go.evvnt.com/716590-0?pid=204

26-28 January 2021, European Gas Virtual 2021 at Online. Contact: Phone: +442073847744, Email: sandil.sanmugam@energycouncil.com URL: http://go.evvnt.com/665940-2?pid=204

02-02 February 2021, IX International Academic Symposium: Energy transition and opportunities for global economic recovery at Barcelona, Spain. Contact: Email: ieb.simposium@ub.edu URL: https://ieb.ub.edu/en/event/ix-international-academic-symposium-energy-transition-and-opportunities-for-global-economic-recovery

03-04 February 2021, 4th Virtual Small Scale LNG Summit at Online. Contact: Phone: +32037052080428, Email: neill@wisdom.events URL: http://go.evvnt.com/708627-0?pid=204

23-25 February 2021, Electric Vehicles & the Grid at Virtual Event. Contact: Email: media@infocusinternational.com URL: https://www.infocusinternational.com/ev

02-10 March 2021, EPC Contracts for Energy Industry at Virtual Event. Contact: Email: media@infocusinternational.com URL: https://www.infocusinternational.com/epc-online

02-04 March 2021, World Ocean Summit and Expo 2021 at Lisbon Congress Centre, 1 Praca das Industrias, Lisboa, Lisboa, 1300-307, Portugal. Contact: Email: oceansummit@economist.com URL: http://go.evvnt.com/654560-0?pid=204

08-12 March 2021, SPE/IADC Virtual International Drilling Conference and Exhibition | 8–12 March 2021 at Online, Norway. Contact: Email: ldoyle@spe.org URL: https://go.evvnt.com/642332-0?pid=204

09-11 March 2021, SPE/IADC International Drilling Conference and Exhibition | Norway | 2021 at Stavanger Forum, 13 Gunnar Warebergs gate, Stavanger, Rogaland, 4021, Norway. Contact: Email: ldoyle@spe.org URL: http://go.evvnt.com/642332-0?pid=204

10-12 March 2021, 2021 Coal Association of Canada Conference at Sheraton Vancouver Wall Centre, 1000 Burrard St, Vancouver, British Columbia, V6Z 2R9, Canada. Contact: Phone: 17807579488, Email: info@coal.ca URL: https://go.evvnt.com/632221-0?pid=204

15-18 March 2021, Power Week Asia Virtual Conference at Virtual Conference. Contact: Email: media@infocusinternational.com URL: www.power-week.com/asia

17-19 March 2021, Future Energy Asia Exhibition & Conference at Bangkok, Thailand. Contact: Email: fea.sales@dmgevents.com URL: www.futureenergyasia.com

19-31 March 2021, Mastering Solar Power at Virtual Event. Contact: Email: media@infocusinternational.com URL: https://www.infocusinternational.com/solar-online

21-23 March 2021, 8th Latin American Energy Economics Conference at Bogota, Colombia. Contact: Email: grenerg@gmail.com URL: www.aladee.org

23-31 March 2021, LNG Supply, Demand, Pricing & Trading at Virtual Event. Contact: Email: media@infocusinternational.com URL: https://www.infocusinternational.com/lng-online

23-25 March 2021, SPE Workshop: Complex Reservoir Fluids | 23-25 March | Copenhagen, Denmark at Copenhagen, Denmark. Contact: Email: ldoyle@spe.org URL: http://go.evvnt.com/642328-2?pid=204

24-25 March 2021, Intersolar Summit Brazil Nordeste at Ceara Events Center, 999 Avenida Washington Soares, Edson Queiroz, Ceará, 60811, Brazil. Contact: Phone: +49 7231 58598-0, Email: info@intersolar-summit.com URL: https://go.evvnt.com/643272-0?pid=204

30-31 March 2021, BIEE Oxford 2021 Research Conference - Energy for a Net Zero Society: Achieving a Just Transition at Oxford, United Kingdom. Contact: Email: admin@biee.org URL: www.biee.org/conference-list/energy-net-zero-society

19-27 April 2021, Mastering Renewable Power at Virtual Event. Contact: Email: media@infocusinternational.com URL: https://www.infocusinternational.com/renewable-online

20-23 April 2021, Power Week Africa Virtual Conference at Virtual Conference. Contact: Email: media@infocusinternational.com URL: https://www.power-week.com/africa

20-21 April 2021, Asia Pacific Energy Assembly | 20 - 21 April 2021, Singapore at Raffles City Convention Centre, Singapore, 80 Bras Basah Road, Singapore, 179103, Singapore. Contact: Phone: +442073848060, Email: melanie.richards@oilcouncil.com URL: http://go.evvnt.com/637211-3?pid=204

April 26 - May 07 2021, Mastering Clean Hydrogen at Virtual Event. Contact: Email: media@infocusinternational.com URL: https://www.infocusinternational.com/hydrogen

18-21 May 2021, Electricity Economics in Changing Electricity Markets at Virtual Event. Contact: Phone: 63250254, Email: media@infocusinternational.com URL: https://www.infocusinternational.com/electricityeconomics-online

01-09 June 2021, Energy Storage at Virtual Event. Contact: Email: media@infocusinternational.com URL: https://www.infocusinternational.com/energystorage-online

05-05 June 2021, Virtual Symposium on the Law and Economics of Energy Regulation at Virtual. Contact: Phone: 307-766-6708, Email: serforum@uwyo.edu URL: https://www.uwyo.edu/ser/research/centers-of-excellence/energy-regulation-policy/news.html

09-11 June 2021, EM-Power Europe 2021 at Messe München, Messegelände, München, Bayern, 81829, Germany. Contact: Phone: +497231585980, Email: info@em-power.eu URL: https://go.evvnt.com/603442-0?pid=204

09-11 June 2021, Power2Drive Europe 2021 at Messe Munchen, Messegelande, Munchen, Bayern, 81829, Germany. Contact: Phone: +497231585980, Email: info@thesmartere.de URL: http://go.evvnt.com/603437-0?pid=204

09-11 June 2021, Intersolar Europe 2021 at Messe Munchen, Messegelande, Munchen, Bayern, 81829, Germany. Contact: Phone: +497231585980, Email: info@intersolar.de URL: http://go.evvnt.com/568378-0?pid=204

23-30 June 2021, Mastering Wind Power at Virtual Event. Contact: Email: media@infocusinternational.com URL: https://www.infocusinternational.com/wind-online

25-28 July 2021, 44th IAEE International Conference, Mapping the Global Energy Future: Voyage in Unchartered Territory at Tokyo, Japan. Contact: Phone: 216-464-5365, Email: iaee@iaee.org URL: www.iaee.org

24-26 August 2021, Power2Drive South America 2021 at Expo Center Norte, 333 Rua José Bernardo Pinto, Vila Guilherme, São Paulo, 02055-000 , Brazil. Contact: Phone: +49 7231585980, Email: info@intersolar.net.br URL: http://go.evvnt.com/603525-0?pid=204

24-26 August 2021, Eletrotec + EM-Power South America 2021 at Expo Center Norte, 333 Rua José Bernardo Pinto, Vila Guilherme, São Paulo, 02055-000 , Brazil. Contact: Phone: +497231585980, Email: info@intersolar.net.br URL: http://go.evvnt.com/603529-0?pid=204

24-26 August 2021, Intersolar South America 2021 at Expo Center Norte, 333 Rua Jose Bernardo Pinto, Vila Guilherme, Sao Paulo, 02055-000, Brazil. Contact: Phone: +497231585980, Email: info@intersolar.net.br URL: http://go.evvnt.com/603503-0?pid=204

14-16 December 2021, Power2Drive India 2021 at Bombay Exhibition Centre, Western Express Highway, Mumbai, Maharashtra, 400063, India. Contact: Phone: +497231585980, Email: info@intersolar.in URL: http://go.evvnt.com/604710-0?pid=204

14-16 December 2021, Intersolar India 2021 at Bombay Exhibition Centre, Western Express Highway, Goregaon East, Mumbai, Maharashtra, 400063, India. Contact: Phone: +49 7231 58598-0, Email: info@intersolar.in URL: http://go.evvnt.com/604701-0?pid=204

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