From Tailpipe To Smokestack – The Dirty Secret Behind Electric Vehicles In Mongolia
To: The Governor's Office of the Capital City of Ulaanbaatar, Mongolia

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Executive Summary: Residents Mongolia's capital, Ulaanbaatar, face two constants: exposure to particulate matter smog at unsafe levels during the winter and vehicle congestion on roads designed to accommodate a fraction of the current amount of traffic. The two issues are linked, as vehicle exhaust contributes to approximately 20% of the city's air pollution. In January, 2017, the air pollution crisis prompted the Government of Mongolia to declare a national emergency. While coal-based heating in the city's low-income neighborhoods is far and away the main contributor to particulate matter smog, policies targeting vehicle emissions will be a facet of the air pollution policy framework in the coming years. However, the recent directive to promote electric vehicle (EV) uptake to achieve supposed emissions benefits is problematic: analysis shows the net results of EV uptake would be mixed – and particularly undesirable with regards to particulate matter emissions – due to the grid's reliance on high-emission coal-fired generation. While the EV market is currently negligible in Ulaanbaatar, it is important to acknowledge the ineffectiveness of a purely EV-uptake oriented policy framework and the particulate matter consequences it could pose if EVs become more prevalent in the short-to-medium term. Policies such as a car allowance rebate system (CARS) or incentives for pairing EV charging infrastructure with on-site renewable energy (e.g., solar photovoltaic) generation are better-suited to reduce vehicle emissions in Ulaanbaatar.

I. Introduction

In August 2017, the City Governor of Ulaanbaatar, the capital of Mongolia, announced a policy to promote electric vehicle (EV) uptake. EVs are now exempt from both Road User Charges (RUCs) and road space rationing regulations (i.e., odd-even license plate usage restrictions meant to reduce daily vehicle congestion).[1] The World Health Organization consistently ranks

Ulaanbaatar as highly polluted due to its high concentration of particulate matter (PM) of 2.5 micrometers in diameter or less, also known as "smog."[2] Ulaanbaatar's annual average microgram-per-cubic-meter concentration of PM 2.5 is 7 to 35 times higher than air quality standards, depending on the season.[3] Approximately 20% of Ulaanbaatar's air pollution comes from vehicles (predominantly passenger vehicles).[4] While the recent policy's RUC waiver provides a small monetary incentive, the behavioral incentive of being allowed to drive all days of the week, along with the market signal of current, and potentially strengthening, preferential treatment towards EVs, could spur Ulaanbaatar's wealthiest consumers to choose an EV in their next purchase – particularly if global and regional market dynamics continue to put downward pressure on EV prices. This would have the obvious benefit of eliminating tailpipe emissions associated with vehicles having an internal combustion engine (ICE). However, given UB's current context, EV uptake-oriented regulation overlooks a critical fact that undermines policy efficacy: *all electricity is not equally green.* This will lead to counter effective emissions consequences if EVs gain market traction above current low adoption rates.[5]

The following analysis examines the issue using emission factors. It concludes that emissions from Mongolia's predominantly coal-fired power plants significantly undermine the intended environmental and health benefits of EVs, to the extent that EVs only present benefits when they replace ICE vehicles, and even then, they only reduce emission of some pollutants (e.g., CO_2 and NO_x) and not others (e.g., PM2.5 and SO_2). The objective of this analysis is to encourage consideration of alternative policies to adopt in place of EV uptake-oriented regulation. Furthermore, this analysis is intended to promote a holistic understanding of Mongolia's energy market and highlight the potential role of EVs in the system-wide shift towards various forms of emission reduction.

II. The emission factor methodology

To begin, it will be helpful to establish a methodology for thinking about emissions in the context of EVs. One common indicator of anthropogenic emissions is carbon dioxide (CO_2) levels. There are a large amount of global public data available CO_2 emissions because of the attention CO_2 has garnered as the primary driver of climate change. Initiatives to reduce transportation sector greenhouse gas emissions have increasingly focused on mass transit system development or adoption of EVs that do not emit CO_2 through an exhaust system. Unfortunately, EV-oriented efforts often overlook the fact that the electricity that powers EV batteries must be generated *somewhere*.

In Mongolia, over 95% of electricity is generated in coal-fired combined heat and power plants (CHPs).[6] Mongolia's CHPs have a high CO_2 "emissions factor" (the quantity of a specific pollutant that results from a given process). Emissions factors serve as a tool for comparing sources of pollution. Mongolia has one of the highest CO_2 emissions factors in the world, meaning each kilowatt hour of electricity generated in its grid produces a high amount of CO_2.[7] Over ninety-one percent of Mongolia's electricity generation comes from three high-emission CHPs located directly within Ulaanbaatar city.[8] This has an important implication for EVs charged via Ulaanbaatar's grid: increased CO_2 emissions from CHP smokestacks could undermine any reduction in tailpipe emissions from EVs – and thereby nullify environmental benefits expected when switching to an EV. For all intents and purposes, the emissions are transferred from vehicle tailpipes in the city to CHP smokestacks that are also located in the city.

This emissions factor methodology can be extended to pollutants with health impacts rather than climate impacts: the grid-wide emissions factor of each pollutant can be used to estimate emissions (in grams) per distance traveled via EV, which can then be compared to emissions from other vehicle types over that same distance. Generally, such an analysis must be location-specific in that any given location's electricity supply comes from a unique generation mix.

With this analytical framework in our toolkit, we can now compare the emissions factors of three vehicle types: electric vehicles (charged exclusively via the electricity grid), vehicles with conventional ICEs, and hybrid vehicles (which cannot be charged via the electricity grid, unlike "plug-in" hybrid vehicles). We will consider four pollutants: CO_2, PM2.5, nitrogen oxides (NO_x), and sulfur dioxide (SO_2). These pollutants vary in the manner and degree that they adversely affect health and the environment. As discussed, CO_2 is the primary driver of the planet's greenhouse gas effect, and therefore impacts climate directly and human health indirectly. The latter three pollutants have more direct, immediate, and harmful impacts on human health, contributing to smog formation, respiratory irritation, and heart attack incidence.[9] It is important to be cognizant of these health effects when evaluating a policy's efficacy at relieving Ulaanbaatar's air pollution crisis.

III. Pollution from EVs in Mongolia

Figure 1 uses this analytical framework to quantify the emission of each pollutant associated with driving one kilometer in each type of vehicle. The grid-wide emission factors for CO_2 and PM2.5 used here are specific to Mongolia, whereas data from coal-fired CHPs in the U.S. are used as a proxy for NO_x and SO_2 emissions factors due to lack of Mongolia-specific public data. See Figure 1's footnote for a detailed description of data sources and methodology.

As illustrated in Figure 1, EVs generate 55.2% lower CO_2 emissions than vehicles with an ICE, but 7.5% higher CO_2 emissions than hybrid vehicles. In other words, replacing a hybrid vehicle with an EV will *increase* the net emission of CO_2. This is due to the EV's reliance on emissions-intensive coal-powered electricity. With regard to NO_x, the data present a similar pattern: though better than a vehicle with an ICE, the EV will produce higher emissions than a hybrid vehicle. Taken together, PM2.5 and SO_2 emissions indicate a conclusively negative outcome: an EV will increase PM2.5 and SO_2 emissions significantly, regardless of the type of vehicle it replaces.

We can therefore conclude that the net impact of an EV in Mongolia depends on the type of vehicle it is replacing and, therefore, on the existing makeup of Ulaanbaatar's vehicle fleet. Approximately 13% of vehicles on the road in Ulaanbaatar were hybrid models as of mid-2015.[10] This level has increased since then due to the growing trend of importing used hybrid vehicles from Japan.[11] In contrast, only 13 passenger EVs were registered in the city as of April 2017.[12] Favorable trade agreements, falling prices (due to rising supply in Japan's secondhand EV market), and EV uptake-oriented directives (such as the August EV policy) should put upward pressure on EV uptake in the future. While that uptake may be limited to residents at relatively higher income levels, the EVs can be expected to replace a portion of the approximately 24,000 ICE and hybrid vehicles that are purchased each year in the medium term (assuming a 15-year turnover for Ulaanbaatar's vehicle fleet).[13] The above conclusions indicate that the August policy, and any other future EV uptake-oriented policies, will drive CO_2 and NO_x pollution reduction *only if* EVs are replacing vehicles with an ICE. In all cases, EVs will increase particulate matter emission, which is particularly significant given PM2.5's known contribution to smog and negative health impacts.[14]

The bottom line is clear: in Mongolia, incentivizing EV adoption is not a guaranteed way to reduce vehicle emissions. The efficacy of EV uptake in reducing emissions is critically dependent on a systemic transition away from high-emission electricity generation. Progress on this front is underway: the Government of Mongolia has targeted 20% renewable energy generation capacity nationwide by 2020, increasing to 30% by 2030.[15] Wind and solar power plants with a total capacity of approximately 170 MW have begun commercial operation or secured financing in the last few years, a significant portion of the amount required to meet the 30% target. The extent to which achieving the 30% target would reduce the grid-wide emissions factor and improve the emissions tradeoffs for an EV in Mongolia merits further analysis, though a paradigm shift would be necessary to change the particulate matter outcome given the 50 to 100-fold gram-per-kilometer emission increase associated with EVs, as shown in Figure 1. Regardless, grid-charged EVs adopted in the interim decade before the 30% target is achieved will continue to rely on electricity from a high-emission (albeit improving) generation mix. Thus, any EV uptake-oriented policies to spur EV adoption in the next decade would do so on a shorter time scale than that of the systemic transition necessary to wholly provide electricity with low-PM2.5 emission. Such EV uptake-oriented regulation would be misguided in the face of Ulaanbaatar's current smog crisis. Fortunately, there are alternative vehicle emission abatement policy options to consider during Mongolia's long-term transition away from CHPs.

IV. Policy alternatives

We will touch on two promising options: a "car allowance rebate system" (CARS) and the strategy of pairing EV charging infrastructure with dedicated on-site and low-emission energy generation.

Under a typical CARS program, car dealerships create incentives for organizations and individuals to replace old vehicles with newer low-emission vehicles. Consumers receive a subsidy on their purchase if they turn in their high-emissions vehicle to the dealership for permanent disposal. Program benefits include:

1. **Targeted elimination of inefficient vehicles**: older vehicles, which are typically larger contributors to air pollutant emissions than newer vehicles, are permanently eliminated from the country's vehicle fleet.
2. **Improved vehicle fleet fuel economy**: the program can be structured such that new vehicles purchased *must* meet certain fuel economy standards, which ensures the country's vehicle fleet efficiency is improved moving forward.
3. **Economic stimulation**: the program's subsidy can motivate individuals to purchase new vehicles. To the extent those consumers would not have done so in the absence of the program, these purchases increase net tax revenue and business earnings to the benefit of the wider economy.
4. **Short-term efficacy**: emissions can be reduced on a somewhat shorter time scale than that of large-scale fixed infrastructure turnover (e.g., CHPs being retired, commercial-scale renewable energy facilities being developed to wholly provide low-emission electricity to EVs via the grid, or large-scale mass-transit system development).

Given the results of this analysis, a Mongolian CARS program should target the replacement of ICE vehicles with hybrid vehicles to reduce emission of the four pollutants considered here (as opposed to replacing ICEs with EVs, which will moderately reduce emission of CO_2 and NO_x but increase emission of PM2.5 and SO_2). Components of the CARS program could be integrated with existing concessional loan products available from Mongolian banks for hybrid vehicle purchases.

The second policy option calls for pairing on-site, low-emission electricity generation with EV charging infrastructure. Dedicated solar photovoltaic and energy storage battery systems can be placed at the EV charging sites to generate low-emission electricity and store it to ensure supply of clean electricity during charging hours. By remaining unconnected to the grid these sites would serve the singular purpose of EV charging. Such systems would be prohibitively expensive for the average household on an individual basis.[16]

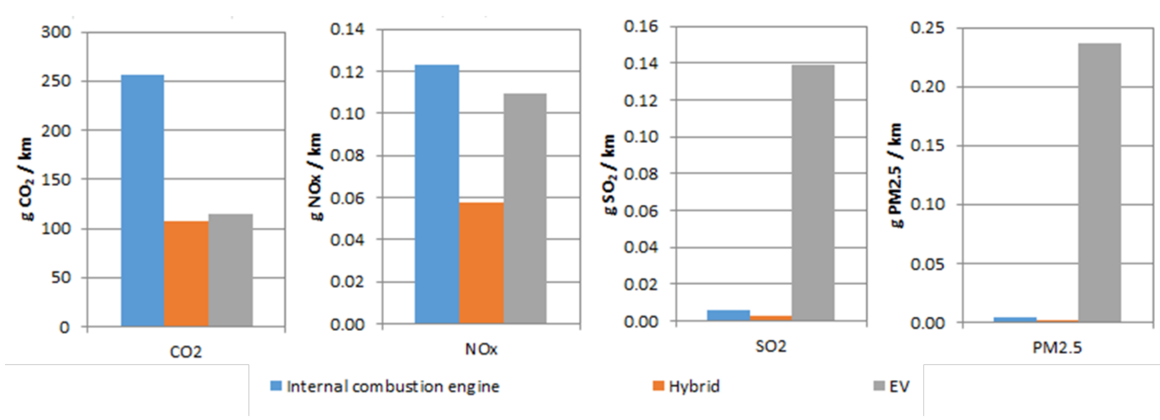
Without subsidies or tax incentives supporting private sector-led installations, these systems would need to be implemented in the city using public funds – a strategy critically contingent on actual and projected EV charging demand in Mongolia. The present low level of passenger EVs registered in Ulaanbaatar suggests that the return on investment for such capital-intensive government spending would be uncertain and merits further study. This option would be particularly valuable if Ulaanbaatar seeks to establish charging infrastructure to support EV market development in alignment with the long-term electricity grid transformation. In other words, investing in grid-unconnected charging stations now would ease the transition to grid-connected charging when the grid is able to provide low-emission electricity.

V. Final observations

It is important to note the limitations of this analysis. While we can conclude that increasing new or used EVs in Mongolia will lead to reduction in some vehicle emissions, the net results will be mixed due to the country's reliance on coal-fired power generation. A study of the Mongolian electricity grid's NO_x and SO_2 emissions would yield more specific details about the emissions tradeoffs for those two pollutants. More comprehensive Mongolia-specific emissions factor data would enable a fine-tuned analysis, but such data are not likely to change the main conclusion of this study. It would also be worthwhile to compare the emissions tradeoffs of policies discussed here with those of various forms of mass transit system development.

Policymakers in Mongolia should acknowledge that due to the circumstances of the country's electricity generation, the increased smokestack emissions associated with EV charging could offset any environmental or health benefits from the reduction in tailpipe emissions. In this context, any regulatory stimulation of the EV market is misguided if it is not paired with temporally-aligned grid decarbonization efforts, either at the centralized scale (i.e., commercial-scale renewable energy generation development to replace a significant portion of CHP generation) or at the distributed scale (i.e., dedicated on-site renewable energy infrastructure at EV charging stations). Alternative policies such as a CARS implementation should replace EV uptake-oriented regulation to accelerate progress toward reducing vehicle emissions.

Figure 1 - Evaluation of vehicle exhaust emission levels by vehicle type (grams per km)[17]



References

[1] Source: "Electric Cars Exempted from License Plate Limitation and Road Charges." GoGo News, 22 Aug. 2017, mongolia.gogo.mn/r/160176.

[2] Note: PM2.5 refers to particulate matter that is 2.5 micrometers or less in diameter.

[3] Source: "Project Appraisal Document on a Proposed Credit in the Amount of SDR9.7 million (US$15 million equivalent) to Mongolia for a Ulaanbaatar Clear Air Project." World Bank, China & Mongolia Sustainable Development Unit, 29 Feb. 2012, pp.2, http://documents.worldbank.org/curated/en/676411468060542805/pdf/660810PAD0P12200fficial0use0only090.pdf. Accessed Nov. 2017.

[4] Source: Public lecture (Air Pollution Reduction Measurements in Ulaanbaatar City) delivered by Dorjgotov Tsendsuren of the World Bank Ulaanbaatar Clean Air Project in March, 2015. Note: Approximately 75% of all vehicles registered in Mongolia are passenger vehicles.

[5] Note: 13 of Ulaanbaatar's approximately 365,000 passenger vehicles are electric vehicles. Source: "Electric Cars Exempted from License Plate Limitation and Road Charges." GoGo News, 22. Aug. 2017., mongolia.gogo.mn/r/160176.

[6] Source: Energy Regulatory Commission 2016 Statistics on Energy Performance booklet, p.16

[7] Note: The specific number for Mongolia is 920 grams of CO_2 emitted per kilowatt hour. For comparison, the level for the European Union is 417 grams per kilowatt hour (source: "Technical Annex to the SEAP instructions document: The emissions factors." EU Covenant of Mayors, n.d., http://www.eumayors.eu/IMG/pdf/technical_annex_en.pdf . Accessed Nov. 2017). Here, Mongolia's CO_2 emissions factor is derived from central energy system plant-specific emissions factors (source: "Additional information on calculating the conservative emission factor of Mongolia" Joint Crediting Mechanism (JCM) GHG Emission Reduction Methodology MN_AM003, n.d., p.4, https://www.jcm.go.jp/mn-jp/methodologies/44/attached_document1), weighted by plant-specific generation shares (source: Energy Regulatory Commission 2016 Statistics on Energy Performance booklet, p.16).

[8] Source: Energy Regulatory Commission 2016 Statistics on Energy Performance booklet. Note: due to their high contribution to electricity production, these three plants (CHPP-2, CHPP-3, and CHPP-4) strongly drive the emissions factors used in this study. These plants' vicinity to the city is a consequence of their role in the city's district heating system, whereby waste heat emitted from power generation heats water which is then circulated via pipes to provide heating to apartment and office buildings. The geographic proximity minimizes heat loss.

[9] Source: Jadambaa, Amarzaya, et. al. *The Impact of the Environment on Health in Mongolia*. Asia Pacific Journal of Public Health 27.1 (2014): 45-75. Table 3.

[10] Source: VanderKlippe, Nathan. "Why the Toyota Prius Is Conquering the Land of Genghis Khan." The Globe and Mail, 9 June 2016.

[11] Note: 82% of 37,738 vehicles imported in 2016 were classified as hybrid vehicles, compared to 71% in of 37,086 vehicles in 2015. Source: Discussions with the National Auto Transportation Center of Mongolia, Vehicle Registration Department

[12] Source: "Electric Cars Exempted from License Plate Limitation and Road Charges." GoGo News, 22. Aug. 2017., mongolia.gogo.mn/r/160176.

[13] Source: Bento, A., Roth, K., Zuo, Y. *Vehicle Lifetime Trends and Scrappage Behavior in the U.S. Used Car Market.* May 20, 2013. Available at SSRN: https://ssrn.com/abstract=2262593

[14] Source: Brook R.D., Rajagopalan S. *Particulate matter, air pollution, and blood pressur*e. J. Am. Soc. Hypertens, 2009, 3(5):332–350

[15] Source: "Green Development Overview" Ministry of Environment and Tourism of Mongolia, 2012, pp.38,

[16] Note: The average monthly salary is 966,000 Mongolian Tugrik, approximately $390 USD. Source: Mongolian National Statistical Office

[17] Note: Emissions factors for vehicle pollutants were approximated for this analysis as follows: for ICE and hybrid vehicles, CO_2 per-mile emissions is estimated using standard tons-per-MWh emission values from the literature (source: "Technical Annex to the SEAP instructions document: The emissions factors." EU Covenant of Mayors, n.d., http://www.eumayors.eu/IMG/pdf/technical_annex_en.pdf. Accessed Nov. 2017) with standard fuel volume, joule, and kWh ratios of conversion applied to reach a per-kilometer (km) emissions equivalent. For EVs, Mongolia's grid CO_2 emissions

factor (calculated as noted in footnote 8) is applied to an assumed watt-hours per km to arrive at a per-km emissions equivalent. For ICE and hybrid vehicles, emission of NO_x, SO_2, and PM2.5 was derived from the EPA's values of grams-per-mile emissions for a 2005 passenger vehicle (source: Cai, Hao, Burnham, Andrew, and Wong, Michael. "Updated Emission Factors of Air Pollutants from Vehicle Operations in GREET™ Using MOVES." *Argonne National Laboratory*, 2013. pp. 15, https://greet.es.anl.gov/files/vehicles-13. Accessed Nov. 2017). For EVs, the Mongolian grid's emission factor of NO_x and SO_2 is approximated using EPA CHP emission and power generation data from 2015 (source: Air Markets Program query of Cross-State Air Pollution NO_x Annual Program); the PM2.5 emission factor is derived using the system-wide PM2.5 emissions (source: Hill L.D., Edwards R., Turner J.R., Argo Y.D., Olkhanud P.B., Odsuren M., Guttikunda S., Ochir C., Smith KR. "Health assessment of future PM2.5 exposures from indoor, outdoor, and secondhand tobacco smoke concentrations under alternative policy pathways in Ulaanbaatar, Mongolia", *PLoS One,* 2017, Table 4, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5663421/. Accessed Nov. 2017) in tons/year under the International Energy Agency's measure for total power generation in Mongolia (source: "Mongolia: Electricity and Heat for 2015." International Energy Agency Statistics, n.d., https://www.iea.org/statistics/statisticssearch/report/?country=Mongolia&product=electricityandheat. Accessed Nov. 2017), once again converted to a grams-per-km measure. This analysis assumes 20 miles per gallon (MPG) and 48 MPG for ICE and hybrid vehicles, respectively. EV fuel economy is assumed to be approximately 201 watt-hours per kilometer.

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