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Supplementary Information
The Wall Street Journal

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Purpose of this document: Provides details, assumptions and sources associated with the quantitative analysis of The Wall Street Journal article.

Acronyms used in this document: AEO=Annual Energy Outlook of the U.S. Energy Information Administration; CO_2 eq.=CO_2 equivalent; EV=Electric Vehicle; GHG=Greenhouse gas; ICEV-G=Internal Combustion Engine Vehicle using Gasoline; kWh=Kilowatt-hour; lb=Pound (mass); LDV=Light-duty vehicle; L=Liter; metric t=metric tonne; mpg=Miles per gallon.

Part 1: Greenhouse gas emissions of an electric and an internal combustion engine vehicle

We compare the greenhouse gas (GHG) emissions of an electric vehicle (EV) model with those of an internal combustion engine vehicle using gasoline (ICEV-G) model over their respective vehicle lifetimes. We include six (6) life cycle stages: 1) Vehicle component production without battery; 2) vehicle assembly, disposal, and recycling; 3) battery production and assembly; 4) fluids production; 5) fuel production; and 6) vehicle operation.

GHG emissions are derived from the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model [1] adjusted to match the vehicle characteristics of Table 1, except for GHG emissions of electricity production that are obtained from the Power Sector Carbon Index of the Carnegie Mellon University [5]. Table 2 presents the GHG emission factors.

Table 1: Vehicle characteristics used in the analysis.

Vehicle characteristics			Ref
ICEV-G	Model	2021 Toyota RAV4 2.5 L, 4 cyl, Automatic (S8)	
	Fuel economy	30 mpg	[2]
	Curb weight	3,405 lb	[3]
EV	Model	2021 Tesla Model 3 Performance AWD	
	Fuel economy	0.29 kWh/mile (equivalent to 113 mpg)	[2]
	Battery size	82 kWh ***or*** 1054 lb	[2]
	Battery type	Lithium Nickel Cobalt Aluminum Oxides (NCA)	[2]
	Curb weight	4,065 lb	[4]

Table 2: GHG emission factors used in the analysis.

GHG emission factors			Ref
ICEV-G	Vehicle component (without EV battery) production	5.3 metric t CO_2 eq. / vehicle	[1]
	Vehicle Assembly, Disposal, and Recycling	0.9 metric t CO_2 eq. / vehicle	[1]
	Fluids Production	1.2 metric t CO_2 eq. / vehicle	[1]
	Gasoline Production (well-to-tank, U.S. Average)	4.21 lb CO_2 eq. / gal	[1]
	Gasoline Combustion	19.2 lb CO_2 eq. / gal	[1]
EV	Vehicle component (without EV battery) production	4.5 metric t CO_2 eq. / vehicle	[1]
	NCA Battery production and Assembly	13.6 lb CO_2 eq. / lb battery	[1]
	Vehicle Assembly, Disposal, and Recycling	0.9 metric t CO_2 eq. / vehicle	[1]
	Fluids Production	0.4 metric t CO_2 eq. / vehicle	[1]
	Electricity Production (2019 U.S. average)	877 lb CO_2 eq. / MWh	[5]

Note: While we approximate the Tesla Model 3 and Toyota RAV4 life cycle GHG emissions from published information on their characteristics and relevant life cycle inventory data, the estimates are not specific to the production of those vehicles and their supply chains.

Part 2: Greenhouse gas emissions of the U.S. light-duty vehicle fleet

The simulations of the prospective U.S. light-duty vehicle (LDV) fleet GHG emissions are derived from the Fleet Life Cycle Assessment and Material-Flow Estimation (FLAME) model, first described in Milovanoff et al. [6] and available open-source in a Zenodo repository [7]. FLAME is a LDV fleet model that estimates the LDV fleet GHG emissions as a function of time and technological changes.

The cumulative GHG target of 39 metric gigatons of CO_2 between 2019 and 2050 for the U.S. LDV fleet to be consistent with the climate goal of the Paris Agreement is explained in detail in Milovanoff et al. [8].

Most of the inputs for the four (4) scenarios shown on the article are derived from the reference case of the Annual Energy Outlook (AEO) 2020 of the U.S. Energy Information Administration [9]. Key inputs from the AEO include prospective total LDV stocks and electricity GHG emission factors. For scenario 1, we use the prospective LDV technology market shares of the AEO reference case. Technology market shares of scenario 2 were provided by The Wall Street Journal team and reflect an increasing deployment of hybrid electric vehicles in the short term and of battery electric vehicles in the long term. For scenario 3, we assume that all new vehicle sales are battery electric vehicles by 2035. For scenario 4, we assume that electric vehicles are being deployed according to the EV30@30 scenario developed by the International Energy Agency [10]. Figure 1 shows the prospective technology market shares in new vehicle sales for all four scenarios. In addition, Scenario 4 assumes improvements in fuel economy of internal combustion engine vehicles following the old Corporate Average Fuel Economy (CAFE) standards [11]. For Scenario 4, we also assume that manufacturers invest rapidly in lightweight materials and vehicle weights are reduced in the next decade. Finally, this scenario assumes that average miles traveled per vehicle decrease, reversing historical trends. More details about scenario 4 are provided in Milovanoff et al. [8].

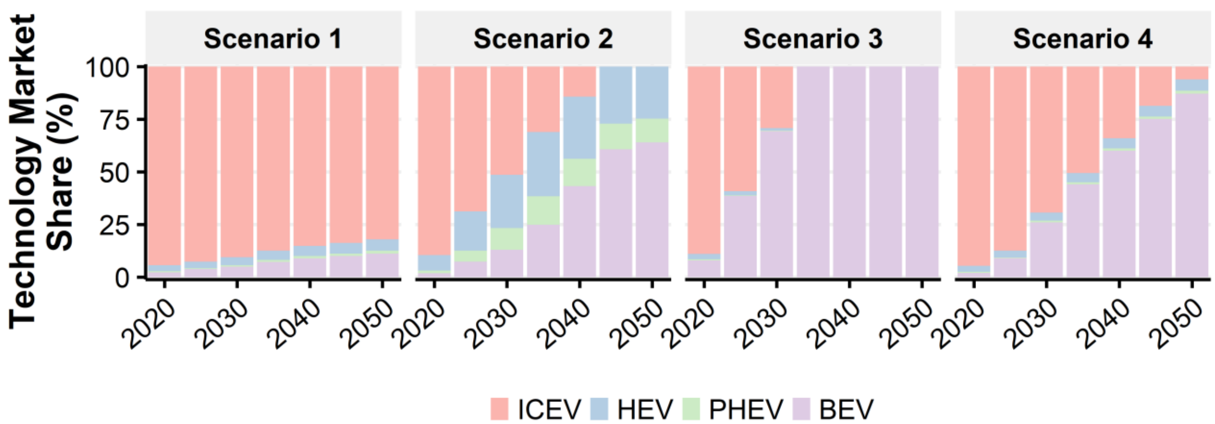

Figure 1: Prospective technology market share in the U.S. light-duty vehicle fleet. ICEV=Internal combustion engine vehicles, HEV=Hybrid electric vehicles, PHEV=Plug-in hybrid electric vehicles, and BEV=Battery electric vehicles.

References

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