The True Cost: An Aggregate Analysis of the Advanced Clean Cars II Policy

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Acknowledgements

Abstract

Global climate change, emphasis on the global, requires local solutions. Every entity plays a role, some more than others. Yet, when improvements in pollution or emissions in one region leads to more problems in another, how is the net cost or benefit to be deciphered for the environment, for the economy, and for humanity in general? Advanced Clean Cars II (ACC II), a proposed policy in California, United States, is a practical test of this question. For each model year beginning in 2026, the potential law gives a percentage of new vehicle sales that must be zero-emission vehicles (ZEVs) - cars that do not emit exhaust gas or other pollutants from the onboard source of power - or plug-in-hybrid electric vehicles (PHEVs). By 2035, ACC II would require all new vehicles purchased in California to be either a ZEV or a PHEV. With reduced tailpipe emissions, California expects to benefit from reduced smog, less carbon emissions, better air quality, a reduction in air-related health issues such as asthma, and increased sales from California-based electric vehicle companies such as Tesla and Rivian. Since air is a common resource, improving California's quality also betters air globally. Yet emissions and pollution produced during the mining, production, and scrappage phases work in opposition to the decreased tailpipe emissions. By converting each type of pollutant into a per vehicle dollar cost, I paint a better picture of the global cost-benefit. The per vehicle cost is scaled based on the expected number of electric and conventional vehicles in California which is predicted under two scenarios: ACC II passes with full enforcement and the law is not passed. I forecast the number of electric vehicles likely bought in both instances using the Bass Model for New Product Growth of Consumer Durables (Bass 1969). I determine that a maximum of eighteen states, including California, could successfully implement ACC II and lower emissions given their 2021 electricity grid's carbon intensity.

Introduction

Many of the resources affected by climate change are common goods, such as air and water. Positive or negative changes in these resources in one geographic location can have impacts reaching the opposite side of the globe. Therefore, the responsibility for protecting said resources falls on all people and governments and has led to many taking the approach of developing local solutions. Yet because of the globalization of trade and many of the relevant resources being common goods, regional solutions can have inverse effects outside of the target area. Advanced Clean Cars II (ACC II) is one of these.

This policy in California, US sets legal requirements for the percent of new light duty vehicle sales that must be zero emission vehicles or plug-in hybrid electric vehicles from model years 2026 to 2035. Light duty vehicles are those weighing less than 10,000 pounds, excluding trucks with two or more axles or six or more tires, and zero emission vehicles are those that are battery electric or powered by hydrogen fuel cells. By 2035, the state's goal is to have 100% of new vehicles purchased in the state be zero emission. Below, Figure 1 displays the targets for each year given by ACC II. This greater proportion of electric vehicles is inherently linked to decreased tailpipe emissions, lower air pollution, and less carbon dioxide produced during the use phase of a car. Yet it also means a greater quantity of raw materials is needed for production and the extraction and refinement of such minerals produces emissions. The scrappage portion of a vehicle also creates pollution either through leakage into soil and water, or through the carbon emissions created through the different recycling processes.

Figure 1: Advanced Clean Cars II Zero Emissions Vehicle Sales Targets
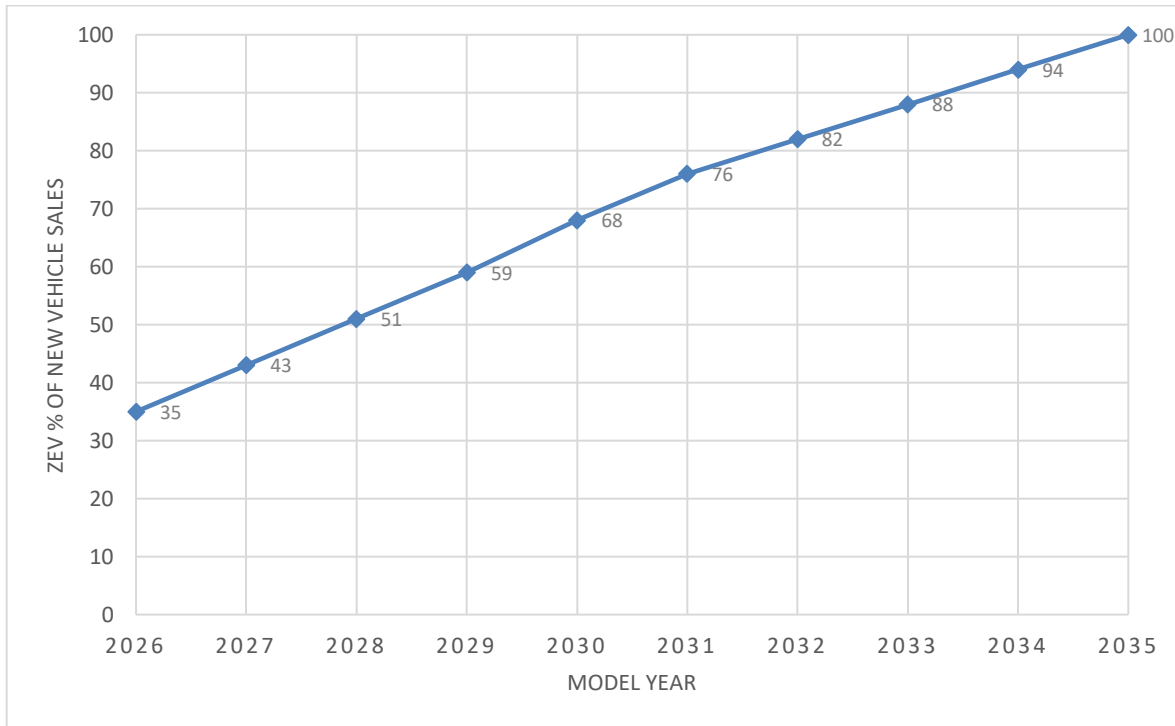
The main goal of ACC II is to reduce the amount of CO_2 being produced by the vehicle fleet in California in the use phase of the vehicles' lifecycle. Intuitively, having all new vehicles be zero and low emissions does just this. Yet there are several other repercussions of such a drastic change. Some of these include health impacts due to the reduced air pollution, employment differences from altering infrastructure, and many more. Some of these outcomes are likely not yet known. Going forward, I look at several of the consequences inherent to the increased electric vehicle production necessary to meet the target percentages of new light duty vehicle sales, including pollution, relative to the full lifecycle of a battery electric vehicle (BEV).

These overall implications are made through forecasts of growth under two chosen scenarios. Scenario A is that ACC II becoming law and strictly enforced, meeting every model year target, and under Scenario B, ACC II does not officially become law. A New Product Growth for Model Consumer Durables, also known as the Bass Model, by Frank M. Bass is used to estimate these cases. It is a

network externalities model further explained in the Methods section of this paper. Projected new car sales are used to predict the implied future impacts, specifically related to pollution and its costs. For local solutions to be their most effective, it requires isolation of the affected resources and in a globalized world that is nearly impossible. ACC II has its obvious benefits for California air quality and reducing tailpipe emissions, but the raw materials necessary for this drastic increase in electric car batteries will simultaneously create issues both in the state and outside of it.

Literature Review

The original Advanced Clean Cars (ACC) Program in California set regulations regarding the amount of allowable criteria pollutants and greenhouse gases (GHGs) emitted from vehicles (California Air Resources Board, n.d.). Criteria pollutants include carbon monoxide, ground-level ozone, lead, nitrogen dioxide, particulate matter, and sulfur dioxide, some of which are emitted by conventional vehicles. ACC also requires car manufacturers operating in California to have a certain percentage of sales of plug-in hybrid or zero emission vehicles (California Air Resources Board, n.d.). The average conventional vehicle lasts for about 12 years (Progressive) and the average person keeps their conventional vehicle for 8 years (Blackley). Electric vehicles, on the other hand, last from 10 to 20 years (Hawley, 2022). Here, it is assumed the average person is likely to hold their electric vehicle for 8 years as well. Originally developed in 1990, the policy has since been adopted by 17 other states: New York, Massachusetts, Vermont, Maine, Pennsylvania, Connecticut, Rhode Island, Washington, Oregon, New Jersey, Maryland, Delaware, Colorado, Minnesota, Nevada, Virginia, and New Mexico (California Air Resources Board, 2022). These 18 states make up 40.1% of US new light duty vehicle sales. Vermont, Washington, Oregon, and New York have already adopted ACC II with Massachusetts, Delaware, and Colorado indicating their intent to do the same (Gallo, 2023). California makes up 11% of US new light duty car sales on its own, so if Advanced Clean Cars II has the same adoption rate among other states, this will nearly quadruple its effects.

While not all of the remaining states are obligated to undertake this policy, it does seem likely the rest will follow. States must give manufacturers a two-year lead time before the regulation can go into effect, so any states announcing adoption of ACC II in 2023 will begin the program in model year 2027 (Gallo, 2023). According to Kelley Blue Book, there are 23 current electric vehicle manufacturers and several more companies with prototypes or plans to produce electric vehicles in the near future

(Morris, 2022). Two of the current producers are located in California, Tesla and Rivian, and seven others have plants in the United States outside of California. Tesla had 4 of the top 10 most popular electric cars of 2022, the Model Y, the Model 3, the Model S, and the Model X placing 1, 2, 4, and 6 respectively (Johnson, 2023). So, not only does a policy increasing the number of electric vehicles in the state benefit them environmentally, but the companies located in the state will likely grow immensely as well.

In order to increase production, a great amount of raw materials will be necessary. Electric vehicles require several minerals including copper, lithium, nickel, manganese, cobalt, graphite, zinc, and rare earth metals. This excludes aluminum and steel, however, as the amounts needed for electric and conventional vehicles are comparable (International Energy Agency, 2022). Most of the above minerals are used in the lithium-ion battery. Chile has the largest lithium reserves and most lithium comes from Chile and Australia. The Democratic Republic of the Congo has the most cobalt and also mines copper, while Indonesia, Australia, and Brazil have the largest nickel reserves. Therefore, most of the raw materials necessary for electric vehicles are not sourced in the United States. So, as much as ACC II is directed at California specifically, many other countries and people are affected.

California is mostly focused on the intrastate benefits it will reap from the policy and combating climate change. Climate change has been escalating both in real terms as well as in conversation and personal belief. As of 2021, almost three quarters of the US population acknowledged global warming is happening (*Yale Climate Opinion Maps 2021*, 2022). Even more, 77%, thought the government should provide tax rebates for energy efficient vehicles or solar panels (*Yale Climate Opinion Maps 2021*, 2022). So, as public demand for renewable energy sources is on the rise, policies are likely to follow. ACC II is just one example.

The Environmental Protection Agency (EPA) produces the Social Cost of Greenhouse Gases (SC-GHGs) which are estimates of social costs for emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). See Tables 1-3. These are monetary values of the net harm to society from emitting a metric ton of the given GHG into the atmosphere in a given year. These are derived from three different damage functions: a subnational, sectoral damage function, a country-scale sectoral damage function, and a meta-analysis based damage function (Environmental Protection Agency, 2022). Using discount rates of 1.5, 2,0, and 2.5 percent, nine cost estimates are produced for each gas, which are then averaged to produce the estimated social cost of greenhouse gases (Environmental Protection Agency, 2022). In Table 1, Table 2, and Table 3 the furthest left column denotes the year in which emissions occur. This cost grows over time even when discounted, because as the impacts of climate change accumulate, the physical and economic systems are increasingly burdened. These are generally used for policy application and to help estimate cost-benefit more thoroughly by incorporating a dollar-denominated environmental cost to society, which is extremely relevant to a policy like ACC II.

Table 1: The Estimated Social Cost of a Metric Ton of Carbon Dioxide in 2020 Dollars using Near-Term Ramsey Discount Rates[2]

Emission Year	2.50%	2.00%	1.50%
2020	$120	$190	$340
2030	$140	$230	$380
2040	$170	$270	$430
2050	$200	$310	$480
2060	$230	$350	$530
2070	$260	$380	$570
2080	$280	$410	$600

Table 2: The Estimated Social Cost of a Metric Ton of Methane in 2020 Dollars using Near-Term Ramsey Discount Rates[2]

Emission Year	2.50%	2.00%	1.50%
2020	$1,300	$1,600	$2,300
2030	$1,900	$2,400	$3,200
2040	$2,700	$3,300	$4,200
2050	$3,500	$4,200	$5,300
2060	$4,300	$5,100	$6,300
2070	$5,000	$5,900	$7,200
2080	$5,800	$6,800	$8,200

Table 3: The Estimated Social Cost of a Metric Ton of Nitrous Oxide in 2020 Dollars using Near-Term Ramsey Discount Rates[1]

Emission Year	2.50%	2.00%	1.50%
2020	$35,000	$54,000	$87,000
2030	$45,000	$66,000	$100,000
2040	$55,000	$79,000	$120,000
2050	$66,000	$93,000	$140,000
2060	$76,000	$110,000	$150,000
2070	$85,000	$120,000	$170,000
2080	$95,000	$130,000	$180,000

[2] Values of Social Cost of Carbon Dioxide, Methane, and Nitrous Oxide are rounded to two significant figures. Environmental Protection Agency. (2022, September). *Supplementary Material for the Regulatory Impact Analysis for the Supplemental Proposed Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review."* EPA. Retrieved from https://www.epa.gov/environmental-economics/scghg

Methods

Attempting to predict the time and rate of growth is difficult in new markets with rapidly developing technology, especially ones that require dominant infrastructure to change for mass use to even become feasible. Yet, this is where electric vehicles lie as a product. The US highway system and businesses around it are built for ICEVs, specifically gasoline powered for the light duty fleet, with fuel stations, mechanics, and auto repair stores functioning around the internal combustion engine. Yet in order to predict the impacts of Advanced Clean Cars II, first the level of adoption of electric vehicles in California must be estimated with and without the policy. To forecast new electric vehicle sales, I use the Bass Model for New Product Growth of Consumer Durables (Bass, 1969).[2]

When buying a car, one considers many factors including, but not limited to, price, quality, maintenance costs, and reliability. One also values a vehicle based upon network externalities, which are changes in benefit that a consumer derives from a good when others consume the same type of good changes (Liebowitz & Margolis, 1994). Because the current infrastructure is designed for gasoline-based cars rather than electric cars, the simplest choice to make is to continue purchasing gas powered cars. This is at least until the network of electric vehicles becomes large enough to lead to widespread introduction of infrastructure supporting electric cars. In order to switch from a historically dominant choice to a newer and more uncertain alternative, one generally would expect to have benefits following that purchase that outweigh any inconvenience, premium, or hardship that comes with the less prominent one. The Bass Model for New Product Growth of Consumer Durables is built upon these principles of an innovation requiring perceived benefit greater than the opportunity cost of foregoing the dominant technology. Bass (1969) develops a model for estimating the timing of initial purchases of

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[2] The Bass Model for New Product Growth of Consumer Durables has been cited approximately 10,933 times according to Google Scholar and was named by INFORM as one of the Ten Most Influential Papers published in the 50-year history of Management Science.

new products using the current adoption rate and maximum potential adoption rate as the main

indicators of growth. It has become a standard of growth and diffusion measurements ever since.

In the Bass Model (1969), the group of potential buyers of the given good are divided into one of

two categories: innovators or imitators - otherwise known as early adopters and late adopters. Innovators

are those that prefer to be the initial users (or even the inventors) of new trends and technology and

thereby make purchase decisions independently of others. Imitators, on the other hand, do quite the

opposite. Buying for them is heavily reliant on the number of previous adopters, as well as those

purchasers' reviews of the product. The Bass model (1969) specifically considers consumer durables

which are commodities purchased and used repeatedly or continuously over a prolonged period. The

model further assumes that buyers in this model are all purchasing on the primary market. This

assumption nicely parallels with the Advanced Clean Cars II policy as it is directed at only new vehicle

purchases.

In the Bass model, there are four important functions: f_T, F_T, S_T, and Y_T.

$$(1)\ f_T = \ (\frac{(p+q)^2}{p})[\frac{e^{-(p+q)T}}{\left(1+\frac{q}{p}e^{-(p+q)T}\right)^2}]$$

$$(2)\ F_T = \ (\frac{1-e^{-(p+q)T}}{1+\left(\frac{q}{p}\right)e^{-(p+q)T}})$$

$$(3)\ S_T = mf_T = \ m(\frac{(p+q)^2}{p})[\frac{e^{-(p+q)T}}{\left(1+\frac{q}{p}e^{-(p+q)T}\right)^2}]$$

$$(4)\ Y_T = mF_T = m(\frac{1-e^{-(p+q)T}}{1+\left(\frac{q}{p}\right)e^{-(p+q)T}})$$

The three defining variables of the Bass (1969) are m, p, and q. p is the coefficient of innovation while q

is the coefficient of imitation. Functionally, p and q indicate the fraction of early and late adopters at

time, t, with external and internal influence being the drivers respectively. m, on the other hand, is the

potential number of adopters of the new technology. Often, this is measured using survey data. These three estimated values, m, p, and q, are the most important factors in the Bass model. Even slight alterations in these estimates drastically changes predicted sales and peak sales timing. Equation 1 above is a probability distribution function and is the likelihood of purchase at time T. Equation 2 is the cumulative distribution function and is the cumulative probability that someone in the target market will adopt the product by time T. Since, S_T and Y_T are f_T and F_T scaled respectively by m, Equation 3 represents the sales in time T and Equation 4 is the total number purchasing in the $(0, T)$ interval.

The Bass Model indicates the probability that an initial purchase will be made at T given that no purchase has yet been made. Bass (1969) theorizes that this relationship is a linear function of the number of previous buyers, indicating the network effects. This relationship is defined as…

$$(5)\ P_T = p + \left(\frac{q}{m}\right) Y_T$$

where p and (q/m) are constants and Y_T is the number of previous buyers. Since $Y_0 = 0$, p is the probability of an initial purchase at $T=0$ and its magnitude reflects the importance of innovators. $(q/m)Y_T$ reflects the pressures operating on imitators as the number of previous buyers increases.

Bass (1969) assumes that there will be m initial purchases over the life of the product. Repurchasing or secondary sales occur in practice, but are not included in this model. Therefore, the sales curve, Equation 3, is S-shaped and indicates high growth and then a subsequent decline. This does not indicate a decrease in sales or popularity necessarily, but shows the path of the first m initial purchases. Peak sales, S_{T*}, occur at time $T*$ where

$$(6)\ T* = \frac{ln\ (q) - ln\ (p)}{p + q}$$

and are defined as

$$(7)\ S_{T*} = \frac{m(p + q)^2}{4q}$$

Because $q > p$ for most successful new products, sales attain maximum value around the time that cumulative sales are about one-half m.

In this paper, I estimate m to be 30 million, because data on light duty vehicle registrations in California range from about 29 million to 34 million with more examples on the lower end of this range. For the other parameters, I estimate p to be 0.000256 and q to be 0.26. These two estimates are on the lower end of normal ranges for average p and q, because electric vehicle adoption is slow due to high need for infrastructure change relative to other durable goods such as microwaves. A meta-analysis of the Bass model by Mahajan et. al. (1990) uses hundreds of real-world applications and made several generalizations surrounding p and q. In their analysis they also found p is usually 0.01 or less and the average q is 0.38. (Mahajan et. al., 1990). My estimates of p and q are in line with many of the real-world examples of consumer durables. From the year 2010 until 2021, there is sales data regarding electric vehicles in California which closely matches the Bass Model predictions using these $m, p,$ and q values with a low mean squared error of only 0.012 generally tending to slightly underpredict.

<center>**Data**</center>

Vehicle Forecasts

In my estimation, I assume that the light duty vehicle fleet in California will continue to grow with the size of the human population of the state. In 2022, the total number of registered light duty vehicles in California is 31,776,955. This number is a rough approximation as reports range from about 29 million to about 34 million.[3] In my forecasts, 30 million is used as the *m* value which serves as an approximation of the total California light-duty vehicle registrations. The number of new light duty vehicle purchases made in California each year is about 2 million.[4] I use this as a means for representing 100% of new car sales in a given year. First, I estimate the number of light duty electric vehicles under the "Full Pass" scenario where the Advanced Clean Cars II targets are percentages of 2 million new light duty vehicles each year. Then, using Bass (1969), I predict light duty electric vehicle sales in model years 2026 to 2040 under the "No Pass" scenario.

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[3] The California Energy Commission reported 29,942,517 registered light duty vehicles in 2021. The US Department of Transportation reported 30,398,249 in 2020 and the US Department of Energy reported 34,990,100 in 2021.
[4] California Auto Outlook

Table 4: Projected Sales from 2026 to 2040 in the Full Pass and No Pass ACC II Scenarios

T	Full Pass	No Pass
2026	700,000	437,836
2027	860,000	548,394
2028	1,020,000	680,350
2029	1,180,000	834,136
2030	1,360,000	1,007,973
2031	1,520,000	1,196,917
2032	1,640,000	1,392,081
2033	1,760,000	1,580,485
2034	1,880,000	1,745,954
2035	2,000,000	1,871,360
2036	2,000,000	1,941,911
2037	2,000,000	1,948,603
2038	2,000,000	1,890,557
2039	2,000,000	1,775,254
2040	2,000,000	1,616,571

I.   Scenario A: Full Pass

In Scenario A, all sales outcomes are legally enforced to match the specific targets in each year as seen in Figure 1 above. I assume that the total California light duty vehicle market remains around 30 million vehicles and the number of new light duty vehicles sold per year in the state is 2 million. From these, I generate ZEV sales per year beginning when ACC II would go into effect in 2026 through 2040, which is 5 years after the law determines 100% of new cars purchased in the state will be zero emission. After this 2035 target of 100% of new vehicles sold in the state being EVs, the parameter will remain 100% in every following year because of the law. This turnover is also likely, because the majority of the gasoline vehicle fleet will have to be replaced at some point during this 15-year span if the law passes. This is because most gas cars are held for about eight years, but can actually last for ten to fifteen.

II.   Scenario B: No Pass

$m = 30$ million, $p = 0.000256$, $q = 0.26$, Mean Squared Error (2010-2021) = 0.0127

In this scenario, Advanced Clean Cars II does not become law in California and there are no significant changes in policy or technology regarding zero-emission vehicles. The total light duty vehicle market in California is about 30 million cars. In 2022, it is plausible to assume that this is equivalent to the potential market for ZEVs since there is increasing concern over climate change, the cost of maintenance and fueling is lower than with gas cars, there is growing infrastructure around electric vehicles, and there will continue to be significant upgrades in electric car technology. With the total market held constant and the new vehicle sales in California remaining at about 2 million per year, I find p and q values that minimize the mean squared error given the available data, on new ZEV sales from 2010 to 2021 in the state. I estimate in Scenario B the probability of a purchase by early adopters is 0.000256 and the probability of a purchase by late adopters is 0.26, which are the p and q values respectively. Figure 2 and Figure 3 respectively display forecasted cumulative sales through year *T-1*, *Y(T)*, and sales in the year *T*, *S(T)*. The first depicts cumulative ZEV sales over and is indicated by a green line. The second shows ZEV sales per year in purple relative to the observed sales from 2010 to 2021 which are the points varying in color.

Figure 2: Forecasted Cumulative ZEV Sales over Time if ACC II Does not Pass

Number of ZEV Purchases (millions)

Time, where T = 0 is 2010 (years)
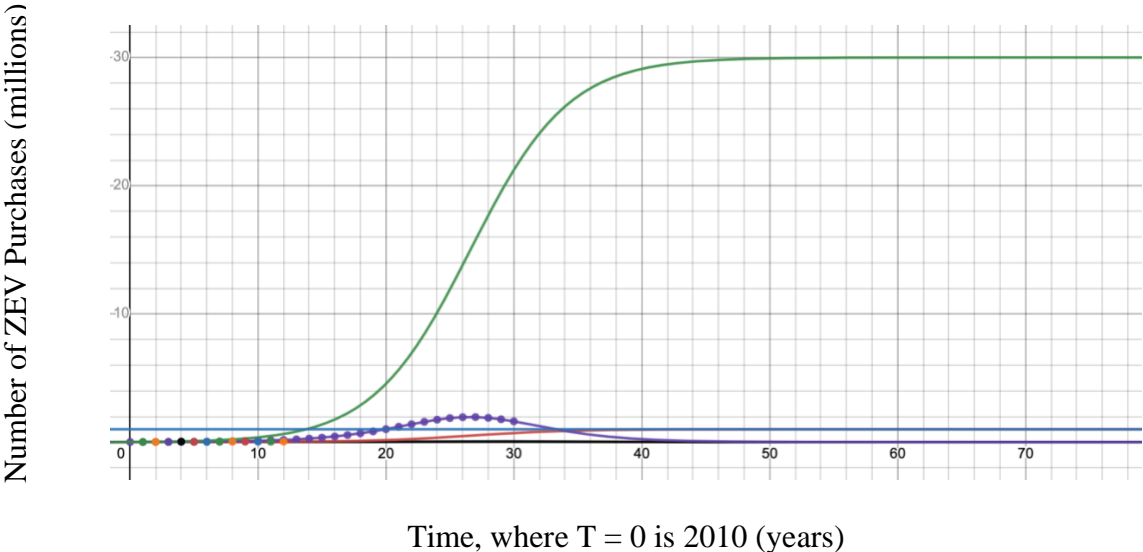
Figure 3: Forecasted ZEV Sales over Time Relative to Actual Sales Observed from 2010-2021

Number of ZEV Purchases per Year (millions)

Time, where T = 0 is 2010 (years)
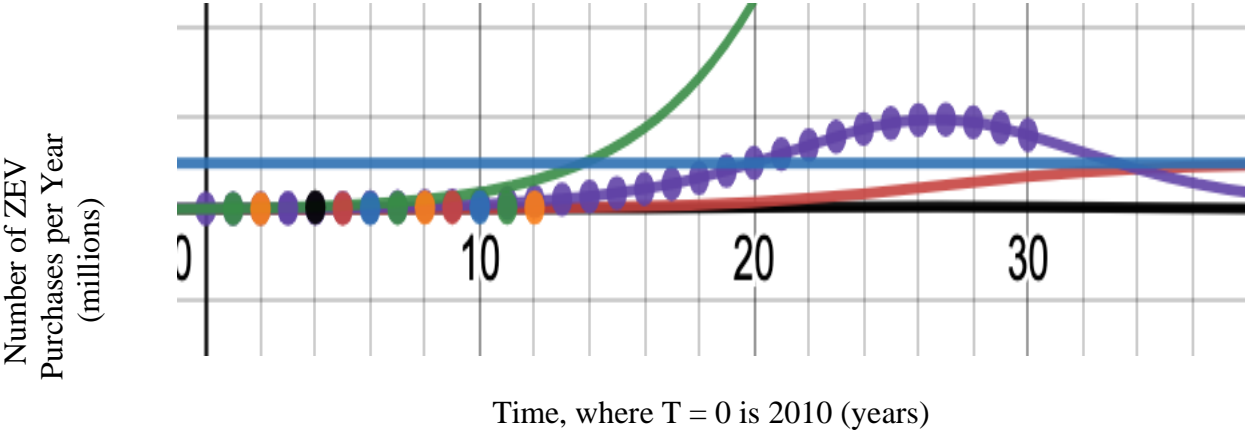
Pollution

I.   Mining and Production

Table 5: Average Amount of a Mineral in the Average Gas Vehicle and Electric Vehicle

Mineral Name	Amount Present in the Average Gas Vehicle (kg)	Amount Present in the Average Electric Vehicle (kg)
Copper	22.3	53.2
Lithium	0	8.9
Nickel	0	39.9
Manganese	11.2	24.5
Cobalt	0	13.3
Graphite	0	66.3
Zinc	0.1	0.1
Other	0	0.3

While carbon dioxide produced during extraction is considered in the manufacturing piece of a vehicle's lifecycle, mining has many negative effects beyond just the CO_2 produced from gathering minerals. This includes the most common forms of pollution from mining including water and soil pollution. Besides steel and aluminum use, which is comparable between conventional and electric vehicles, gas cars use three main sources of minerals whereas electric cars use over eight different mined materials. Conventional vehicles require copper, manganese, and zinc while electric vehicles need copper, lithium, nickel, manganese, cobalt, graphite, zinc, rare earth metals, and more. The difference between vehicle types is generally due to the electric car's battery, most commonly a lithium-ion battery.

To approximate the costs of producing electric vehicles more fully, I estimate the cost of the water and ground pollution caused by mining these raw materials. First, I use the average amount of each mineral in a typical gas vehicle and electric vehicle (IEA). Then, I gather the potential for eutrophication and ecotoxicity per kg of the mineral (IEA). Eutrophication is a type of water pollution where the water is over-enriched by nutrients or minerals which causes algal blooms that are visually

and nasally unappealing, block sunlight which can lead to loss of plants and animals in the area, and can even release toxins in some cases. Ecotoxicity, on the other hand, is a measure of chemical or physical stressors that affect ecosystems enough to disrupt the natural biochemical and physiological behavior and interactions. Using a euro denominated eco-cost, the cost of a unit of pollution in 2022 euros is estimated for both eutrophication and ecotoxicity (Eco-costs emissions, 2023). These eco-costs are then converted into 2022 US dollars, using the average exchange rate from 2022 (*Euro to US dollar spot exchange rates for 2022*, 2022). Then, from 2022 US dollars the costs are put into 2020 US dollars using the Consumer Price Index to incorporate these environmental costs more easily with the Social Cost of Carbon, which is also in 2020 US dollars. Those figures are multiplied to gather the US dollar cost of environmental damage to water per average electric vehicle. This calculation multiplied by the number of electric vehicles I have forecasted for the years 2026-2040 gives the environmental cost per year of each type of water pollution: eutrophication and ecotoxicity. I am able to do this calculation for lithium, nickel, copper, rare earth metals, and cobalt.

Table 6: The Remediation Cost of Water Pollution per Light-Duty Electric Vehicle from Mining in 2020 US Dollars

Mineral	Amount of Mineral per Vehicle (kg/vehicle)	Eutrophication Potential (kg P-eq/kg)	Ecotoxicity Potential (CTU eco/kg)	Eutrophication Cost per Vehicle ($)	Ecotoxicity Cost per Vehicle ($)	Water Pollution Cost per Vehicle from Mining ($)
Lithium	8.9	0.0013	5310	0.15	143.26	143.41
Nickel	39.9	0.014	17.52	7.46	2.12	9.58
Cobalt	13.3	0.00003	0.52	0.01	0.02	0.03
Copper	53.2	0.01	9.25	7.10	1.49	8.60
REE	0.5	0.0213	538	0.14	0.82	0.96
Total				**14.87**	**147.70**	**162.57**

For a gas car, the remediation cost of water pollution would be about $3.50. Relative to $160, the gap is quite large. These costs are an underestimate, because they do not include all the mined materials in a battery, just the ones for which I have data. Some of the other mined materials are listed in Table 5 including manganese, graphite, and zinc. Although $160 per vehicle seems low, the difference in the cumulative cost of the Full Pass and No Pass scenarios, assuming all vehicles are either battery electric or gasoline powered, is about $50 million.

Table 7: The Social Cost of Production and Manufacturing per Vehicle in 2020 US Dollars

Vehicle Type	Production and Manufacturing Emissions (metric tons of CO_2)	Social Cost of Production and Manufacturing (US Dollar, $)
Battery Electric	8	1093.33
Battery Electric (High GHG)	9.4	1284.67
Conventional	6	820.00

Beyond the water pollution, the cost of carbon emissions during mining and production is also necessary to estimate. In Table 7, the emissions to mine materials and produce each type of vehicle is listed with battery electric split between the base case and the high greenhouse gas case. I then calculate the cost for each type of vehicle using the Social Cost of Carbon. Assuming all vehicles are either base-case battery electric or gasoline powered, the Full Pass scenario has environmental damage costs that are almost $940 million more than the No Pass scenario. Again, the electric cars have a higher cost for emissions per vehicle in this phase by about $270 in the base case and $460 in the high greenhouse gas case. The difference between the base case for electric vehicles and the high greenhouse gas case is in the method of extraction. One example of this discrepancy is in lithium mining where there are two main pathways of extraction: brine and hard rock. Brine generally has lower concentrations of lithium per pound, but also has lower production costs (Davies, 2022). But, the emissions for the two processes and

mineral yields, lithium carbonate versus lithium hydroxide, vary. The brine process emits 2.8 tons of

CO_2 for lithium carbonate and 5.7 tons of CO_2 for lithium hydroxide whereas hard rock emits 9.6 tons of

CO_2 for lithium carbonate and 17.1 tons of CO_2 for lithium hydroxide per ton of the mineral

(International Energy Agency, 2022). Depending on the mining method and form the given material

takes, the environmental cost expands or shrinks and future areas of growth in mining determine how

costly this range can become.

II. Use

Table 8: The Social Cost of Use per Vehicle in 2020 US Dollars

Vehicle Type	Use Emissions in Low Carbon Electricity Mix (metric tons of CO_2)	Social Cost of Use in Low Carbon Electricity Mix ($)	Use Emissions in High Carbon Electricity Mix (metric tons of CO_2)	Social Cost of Use in High Carbon Electricity Mix ($)
Battery Electric	11.7	1599.00	38.4	5248.00
Battery Electric (High GHG)	11.7	1599.00	39.8	5439.33
Conventional	35.9	4906.33	35.9	4906.33

When it comes to the actual driving portion of a car's lifecycle, conventional vehicles are generally

regarded as being significantly more pollutive. This is because when gasoline is burned carbon dioxide

is emitted along with other gases. For electric vehicles, the amount of carbon emissions that are

attributed to the use phase depend on the electricity grid mix in the charging area. There are some states

and countries that have high carbon electricity mixes such as Botswana who uses 99.54% fossil fuels to

power its grid with about 81.74% of its power coming from coal specifically (Ritchie, Roser, & Rosado,

2022). There are also varying electricity grids across US states. California has the eighth lowest carbon intensity of the fifty states (Tieso, 2023). West Virginia's electricity grid has the highest carbon intensity emitting at a rate of almost five times California (Tieso, 2023). Table 8 shows the discrepancy between high and low carbon electricity mixes through emissions during the usage phase of vehicles for conventional vehicles and battery electric vehicles. Gas car emissions and therefore environmental costs in this stage are the same regardless of the electricity grid, because the amount of gasoline needed for the average vehicle is constant.

The use phase is also where electric vehicles have significantly lower emissions in the low carbon electricity grid. Using my Bass Model forecasts, I estimate the environmental savings in the usage phase to be around $11 billion dollars by implementing Advanced Clean Cars II. Yet, in the high carbon electricity mix the Full Pass Scenario would cost over $1 billion more than the No Pass scenario. Both of these cumulative cost estimates again assume all light-duty vehicles are either powered by gasoline or are battery electric. The carbon intensity of the electricity grid causes quite the reversal of cost and emphasizes the importance of factoring in power sources when creating transportation policy. California does fall on the lower end of this spectrum and is therefore able to see positive benefits during the use phase from implementing ACC II.

III.   Full Lifecycle

Table 9: Environmental Cost per Vehicle in the Low Carbon Electricity Mix in 2020 US Dollars[5]

Vehicle Type	Mining and Production ($)	Usage in Low Carbon Electricity Mix ($)	Battery Recycling ($)	Total Environmental Cost Low Carbon Electricity Mix ($)
Electric	1,255.90	1,599.00	2,828.29	5,683.19
Electric High GHG	1,447.24	1,599.00	2,828.29	5,874.53
Conventional	823.52	4,906.33	0	5,733.95

Table 10: Environmental Cost per Vehicle in the High Carbon Electricity Mix in 2020 US Dollars[5]

Vehicle Type	Mining and Production ($)	Usage in High Carbon Electricity Mix ($)	Battery Recycling ($)	Total Environmental Cost High Carbon Electricity Mix ($)
Electric	1,255.90	5,248.00	2,828.29	9,332.19
Electric High GHG	1,447.24	5,439.33	2,828.29	9,714.86
Conventional	823.52	4,906.33	0	5,733.95

Table 9 and Table 10 both indicate the environmental cost of electric and gas cars. From these calculations, there is one scenario where electric vehicles are less environmentally costly than gas cars over their entire lifecycle. This is when the battery electric car falls in the base case for greenhouse gas emissions during production and is used in a low carbon electricity grid. This is less environmentally costly by about $50 per vehicle than a gas car. On the other hand, the other electric vehicle cases are more costly by $140, $3,600, and $4,000 when the vehicle is produced in the high greenhouse gas

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[5] These environmental costs in Table 9 and Table 10 do not include figures for mining or recycling iron or aluminum. This is because these figures are comparable across both gas and electric vehicles. Therefore, these environmental costs are underestimates of the actual total.

scenario but used in the low carbon electricity grid, the base case for production and high carbon intensity power, and the high greenhouse gas and high carbon electricity mix combination respectively. This points to the use phase again being the most environmentally costly phase of a vehicle, which can partially be attributed to the sheer time difference between production, use, and recycling. It also indicates that the largest driver of environmental cost for electric vehicles is the electricity grid and therefore should be considered along with any potential electric vehicle policy. Additionally, the battery recycling portion of environmental cost is larger than mining and production. Recycling batteries is intended to offset front end emissions as well as reduce supply issues and decrease the cost of production. Yet, the cumulative difference in environmental damage cost at the end of model year 2040 between the Full Pass scenario and the No Pass scenario is $7.8 billion for recycling these batteries. The two most common methods for recovering these minerals include: pyrometallurgy and hydrometallurgy. The former is essentially burning the entire battery and is highly energy intensive, while the latter melts down the remainder of the battery in acid to separate metals. Hydrometallurgy is less energy intensive and has lower emissions, but does create toxic waste.

Findings

Over this paper, I assess the environmental costs and benefits to the Advanced Clean Cars II policy in California. The policy's environmental cost is mostly determined by California's electricity grid considering the usage phase will take place in this state. In California, this policy would be successful in lowering carbon emissions, because of the low carbon intensity electricity grid. Yet, as mentioned earlier, seventeen other states adopted the original Advanced Clean Cars policy and several states are already planning to adopt ACC II shortly after California. Yet, the differing carbon intensities of these grids limit how beneficial the policy would be, if at all.

As the length of an average electric vehicle's battery life increases, the amount of emissions produced during the use phase is higher because there is more time spent using electricity for charging. According to my analysis, about 12.0 metric tons of CO_2 can be released during the use phase of a vehicle before the environmental cost is higher than conventional vehicles assuming base case production emissions. This essentially means that if the state in question's electricity grid would allow an electric vehicle to cause over 12.0 metric tons of CO_2 over its entire use phase, then it is not environmentally beneficial to switch from gas to electric cars. Therefore, depending on the actual length of the battery life between seven (when the battery lasts 20 years) and eighteen (when the battery lasts 10 years) states could implement the same Advanced Clean Cars II policy and have it reduce environmental costs. This does not include how the battery degrades over time and becomes less efficient at taking in and using energy. In the former case, not even California's electricity grid would be satisfactory for environmental benefit. In the latter instance, Maryland is the final state able to successfully implement ACC II with Nevada lying just on the other side of the line. Table 11 highlights the last state for battery lengths of 10, 12, 15, 17.5, and 20 years that could implement Advanced Clean Cars II and successfully lower total emissions and therefore environmental cost.

Table 11: Carbon Emissions in the Use Phase of Battery-Electric Vehicles in Metric Tons of CO$_2$[6]

State	Usage Emissions with a 10 Year Battery Life (metric tons of CO$_2$)	Usage Emissions with a 12 Year Battery Life (metric tons of CO$_2$)	Usage Emissions with a 15 Year Battery Life (metric tons of CO$_2$)	Usage Emissions with a 17.5 Year Battery Life (metric tons of CO$_2$)	Usage Emissions with a 20 Year Battery Life (metric tons of CO$_2$)
Nevada	12.13	14.56	18.20	21.23	24.26
Maryland	11.62	13.94	17.42	20.33	23.23
Arizona	11.58	13.90	17.37	20.27	23.16
Illinois	11.55	13.86	17.32	20.21	23.09
North Carolina	11.43	13.71	17.14	20.00	22.85
Tennessee	11.32	13.59	16.98	19.81	22.64
Virginia	10.34	12.41	15.51	18.10	20.68
South Carolina	9.13	10.96	13.70	15.98	18.27
Connecticut	8.94	10.73	13.42	15.65	17.89
New Jersey	7.98	9.57	11.97	13.96	15.96
New York	7.79	9.35	11.68	13.63	15.58
California	6.74	8.09	10.11	11.79	13.48
South Dakota	4.91	5.89	7.37	8.60	9.82
Oregon	4.86	5.83	7.29	8.50	9.72
New Hampshire	4.79	5.75	7.19	8.38	9.58
Maine	4.50	5.40	6.75	7.87	9.00
Idaho	4.10	4.92	6.15	7.18	8.20
Washington	3.43	4.12	5.14	6.00	6.86
Vermont	0.02	0.02	0.03	0.03	0.03

The remaining thirty-one US states are not included in this chart since they would not pass the threshold for lowering emissions and therefore environmental cost by switching from gas cars to electric ones. Seven states have announced commitments to adopt Advanced Clean Cars II after California. At least as of 2021, three of these seven, Massachusetts, Delaware, and Colorado are too carbon intensive for this to create environmental benefit. Similarly, of the eighteen states that adopted the original Advanced Clean

[6] Tiseo, I. (2023, February 6). *U.S. Power Sector Carbon Index by State 2021*. Statista. Retrieved from
https://www.statista.com/statistics/1133295/electric-sector-carbon-dioxide-emission-rate-by-state-united-states/
These figures are calculated using 3.8 megawatt hours per year as the average for battery electric vehicles (United States Department of Energy, 2019).

Cars policy, nine would be unable to do the same with ACC II and have a positive environmental impact using their 2021 electricity grids. These states include New Mexico, Nevada, Minnesota, Colorado, Delaware, Maryland, Rhode Island, Pennsylvania, and Massachusetts. Table 11 also implies that as battery technology improves and the average electric vehicle's battery lasts longer, carbon intensity of electricity grids must improve with it, so that the emissions from gas cars continues to be offset.

Overall, the difference in environmental cost in a Full Pass scenario and a No Pass scenario is large. Using my Bass Model forecasts for the state of California, the difference in the mining phase would cost slightly more than $50 million, the difference in the production phase would cost around $940 million, and the difference in recycling batteries would cost over $7.8 billion in environmental damage from model years 2026 to 2040. Alternatively, the use phase would have environmental savings of over $11 billion in the Full Pass scenario over the No Pass scenario. Therefore, I estimate California's Advanced Clean Cars II saves over $2.6 billion in environmental damage costs from model years 2026 to 2040. If California had the high carbon electricity grid, the same policy would increase environmental costs by almost $10 billion by the end of model year 2040. These are both assuming that there are only two vehicle types: battery electric with base case production emissions and gasoline.

There are many costs and benefits to implementing the Advanced Clean Cars II policy. Using my Bass Model forecasts, I estimate California could prevent over $2.6 billion of environmental damage by the end of model year 2040 by implementing ACC II. More mining for raw materials increases air, ground, and water pollution and simultaneously faces supply issues. By some estimates, demand will outpace supply for several of these minerals including lithium (Etechbrew, 2023). Battery recycling is another major contributor to the lifecycle emissions of a battery electric vehicle. This is both from burning the battery, otherwise known as pyrometallurgy, and then melting the remainder in acid, or hydrometallurgy. While this may lower the front-end emissions and reduce supply chain issues, the

recycling process is more environmentally costly than the entirety of mining and production. The most significant and usually most discussed portion of the vehicle lifecycle though is the use phase. This is because the electricity grid's makeup drastically changes the level and cost of emissions and it often has the most visible effects, some of which include smog, asthma, and other lung-related health issues. Altogether, California is likely able to reduce their emissions and therefore environmental damage costs by passing Advanced Clean Cars II. Future expansions for lowering environmental costs in relation to battery electric vehicles include choosing the lowest emissions producing mining methods, improving battery recycling by decreasing energy consumption and increasing the amount of minerals recovered, and reducing the carbon intensity of electricity grids. As vehicle technologies develop and the related processes (hopefully) become increasingly environmentally friendly, there is a future where more than eighteen states could make the switch towards zero-emission vehicles and do more good than harm.

Works Cited

Advanced clean cars II. Department of Environmental Quality : Advanced Clean Cars II : Rulemaking at

    DEQ : State of Oregon. (n.d.). Retrieved from

    https://www.oregon.gov/deq/rulemaking/Pages/CleanCarsII.aspx

Appendix F: Updated Costs and Benefits Analysis. (n.d.). Retrieved November 8, 2022, from

    https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/fsorappf.pdf

Backman, I. (2021, June 8). *Professors explain the social cost of carbon*. Stanford News. Retrieved from

    https://news.stanford.edu/2021/06/07/professors-explain-social-cost-

    carbon/#:~:text=The%20short%20answer%3A%20The%20social,causes%20warming%2C%20aff

    ecting%20human%20outcomes.

Bass, F. M. (1970, January 1). *A New Product Growth for Model Consumer Durables*. undefined.

    Retrieved November 7, 2022, from https://www.semanticscholar.org/paper/A-New-Product-

    Growth-for-Model-Consumer-Durables-Bass/6da5d24defba21364de4842d65666118e46edf12

Battery cases for electric vehicles. Battery Cases for Electric Vehicles | SGL Carbon. (n.d.). Retrieved

    from https://www.sglcarbon.com/en/markets-solutions/applications/battery-cases/#

Becker, T. A. (n.d.). *Electric Vehicles in the United States* . Retrieved November 8, 2022, from

    https://odpowiedzialnybiznes.pl/wp-

    content/uploads/attachments/news/cet_technical%20brief_economicmodel2030.pdf

Bhutada, G. (2022, July 21). *The key minerals in an EV Battery*. Elements by Visual Capitalist. Retrieved

    from https://elements.visualcapitalist.com/the-key-minerals-in-an-ev-battery/

Blackley, J. (n.d.). *How long do people keep their cars?* How Long Do People Keep Their Cars? -

    iSeeCars.com. Retrieved from https://www.iseecars.com/how-long-people-keep-cars-study

Brinn, J. (2022, July 7). *Electric Vehicle Battery Supply Chains: The basics*. Be a Force for the Future.

    Retrieved from https://www.nrdc.org/bio/jordan-brinn/electric-vehicle-battery-supply-chains-

    basics

California Air Resources Board. (n.d.). *Low Emission Vehicle Program*. Low-Emission Vehicle Program |

    California Air Resources Board. Retrieved from https://ww2.arb.ca.gov/our-work/programs/low-

    emission-vehicle-program/about

California Air Resources Board. (n.d.). *Zero-Emission Vehicle Program*. Zero-Emission Vehicle Program

    | California Air Resources Board. Retrieved from https://ww2.arb.ca.gov/our-work/programs/zero-

    emission-vehicle-program/about

California Air Resources Board. (2022). *States that have Adopted California's Vehicle Standards under*

    Section 177 of the Federal Clean Air Act. States that have Adopted California's Vehicle Standards

    under Section 177 of the Federal Clean Air Act | California Air Resources Board. (n.d.). Retrieved

    from https://ww2.arb.ca.gov/resources/documents/states-have-adopted-californias-vehicle-

    standards-under-section-177-federal

California Auto Outlook TM publication sponsored by - cncda.org. (n.d.). Retrieved from

    https://www.cncda.org/wp-content/uploads/Cal-Covering-1Q-22-002.pdf

Carey, N., Lienert, P., & Mcfarlane, S. (2023, March 20). *Scratched EV battery? your insurer may have to*

    junk the whole car. Reuters. Retrieved from https://www.reuters.com/business/autos-

    transportation/scratched-ev-battery-your-insurer-may-have-junk-whole-car-2023-03-20/

Cho, R. (2021, April 2). *Social Cost of carbon: What is it, and why do we need to calculate it?* State of the

    Planet. Retrieved from https://news.climate.columbia.edu/2021/04/01/social-cost-of-carbon/

Davies, E. (2022, July 22). *In bed with lithium: How to choose between hard rock or brines and where the*

    strongest ASX prospects abide. Stockhead. Retrieved from https://stockhead.com.au/resources/in-

bed-with-lithium-how-to-choose-between-hard-rock-or-brines-and-where-the-strong-asx-

prospects-

abide/#:~:text=While%20brines%20have%20lower%20concentrations,generally%20have%20low

er%20production%20costs.

DEC announces adoption of Advanced Clean Cars II rule for new passenger cars and light-duty truck

sales. DEC Announces Adoption of Advanced Clean Cars II Rule for New Passenger Cars and

Light-Duty Truck Sales - NYS Dept. of Environmental Conservation. (n.d.). Retrieved from

https://www.dec.ny.gov/press/126879.html

Eco-costs emissions. Sustainability Impact Metrics. (2023, February 8). Retrieved from

https://www.ecocostsvalue.com/eco-costs/eco-costs-emissions/

Environmental Protection Agency. (2022, June 30). *Greenhouse Gas Emissions from a Typical Passenger*

Vehicle. EPA. Retrieved from https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-

typical-passenger-vehicle

Environmental Protection Agency. (2022, September). *Supplementary Material for the Regulatory Impact*

Analysis for the Supplemental Proposed Rulemaking, "Standards of Performance for New,

Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and

Natural Gas Sector Climate Review." Politico Pro. Retrieved from

https://subscriber.politicopro.com/eenews/f/eenews/?id=00000184-77c6-d07e-a5fd-f7df41f80000

Etechbrew. (2023, February 17). *A by-the-numbers look at lithium, a key commodity for automakers*.

Emerging Tech Brew. Retrieved from https://www.emergingtechbrew.com/stories/2023/02/16/a-

by-the-numbers-look-at-lithium-a-key-commodity-for-

automakers?cid=30587404.146359&mid=dbd7e304020cb7897eedb888e20bb2fe&utm_campaign

=etb&utm_medium=newsletter&utm_source=morning_brew

Euro to US dollar spot exchange rates for 2022. Exchange Rates. (n.d.). Retrieved from

     https://www.exchangerates.org.uk/EUR-USD-spot-exchange-rates-history-2022.html

Fact sheet SCC - US EPA. (n.d.). Retrieved from https://www.epa.gov/sites/default/files/2016-

     12/documents/social_cost_of_carbon_fact_sheet.pdf

Gallo, A. (2023, January 10). *What California's new advanced clean car rule means for other states*.

     National Caucus of Environmental Legislators. Retrieved from

     http://www.ncelenviro.org/articles/what-californias-new-advanced-clean-car-rule-means-for-other-

     states/#:~:text=Six%20states%20(Massachusetts%2C%20New%20Jersey,in%20adopting%20the

     %20ACT%20rule.

Hawley, D. (2022, September 21). *How long do electric car batteries last?* J.D. Power. Retrieved from

     https://www.jdpower.com/cars/shopping-guides/how-long-do-electric-car-batteries-last

Igleheart, A. (2022, April 26). *State Policies Promoting Hybrid and Electric Vehicles*. State policies

     promoting hybrid and electric vehicles. Retrieved from

     https://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx

International Energy Agency. (2022). *The role of critical minerals in Clean Energy Transitions –

     analysis*. IEA. Retrieved from https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-

     energy-transitions

International Energy Agency. (2022, October 26). *Minerals used in electric cars compared to

     conventional cars – charts – Data & Statistics*. IEA. Retrieved from https://www.iea.org/data-and-

     statistics/charts/minerals-used-in-electric-cars-compared-to-conventional-cars

Johnson, P. (2023, January 10). *2022's top 10 best-selling electric vehicles in the US: Find out why they

     made the cut*. Electrek. Retrieved from https://electrek.co/2023/01/09/the-top-10-best-selling-

Johnson, P. (2022, November 14). *Here's how US electric vehicle sales by maker and EV model through Q3 2022 compare*. Electrek. Retrieved December 7, 2022, from https://electrek.co/2022/10/18/us-electric-vehicle-sales-by-maker-and-ev-model-through-q3-2022/#:~:text=The%20United%20States%20has%20now,a%2050%25%20share%20by%202030 electric-vehicles-in-the-us-of-2022/

Kilgore, G. (2023, January 20). *2023 plastic carbon footprint: Official Emissions Numbers + calculator*. 8 Billion Trees: Carbon Offset Projects & Ecological Footprint Calculators. Retrieved from https://8billiontrees.com/carbon-offsets-credits/carbon-ecological-footprint-calculators/plastic-carbon-footprint/#:~:text=Every%20ton%20of%20plastic%20waste,that%20contribute%20to%20climate%20change.

Kinder, P. D. (n.d.). *Not in my backyard phenomenon*. Encyclopædia Britannica. Retrieved from https://www.britannica.com/topic/Not-in-My-Backyard-Phenomenon

Liebowitz, S. J., & Margolis, S. E. (1994). *Network Externalities: An Uncommon Tragedy*. Retrieved from https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.8.2.133

Lindsey, R. (2022, June 17). *Climate change: Annual Greenhouse Gas Index*. NOAA Climate.gov. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-annual-greenhouse-gas-index

Mahajan, V., Muller, E., & Bass, F. M. (1990). New Product Diffusion Models in Marketing: A Review and Directions for Research. *Journal of Marketing*, *54*(1), 1–26. https://doi.org/10.2307/1252170

Morris, A. (2022, November 9). *Electric Car Companies Guide - Kelley Blue Book*. Kelley Blue Book. Retrieved from https://www.kbb.com/car-advice/ev-car-companies-guide/

Plastic and climate: The hidden costs of a plastic planet. Center for International Environmental Law. (2022, February 1). Retrieved from https://www.ciel.org/plasticandclimate/

Plastic waste and climate change - what's the connection? WWF. (n.d.). Retrieved from https://www.wwf.org.au/news/blogs/plastic-waste-and-climate-change-whats-the-connection

Progressive. (n.d.). *How many miles can a car last?* Progressive. Retrieved from https://www.progressive.com/answers/how-many-miles-does-a-car-last/#:~:text=A%20conventional%20car%20can%20last,help%20extend%20your%20car's%20longevity.

Ritchie, H., Roser, M., & Rosado, P. (2022, October 27). *Electricity mix*. Our World in Data. Retrieved from https://ourworldindata.org/electricity-mix

Rocchetti, L., Vegliò, F., Kopacek, B., & Beolchini, F. (2013, January 16). *Environmental impact assessment of hydrometallurgical processes for metal recovery from WEEE residues using a portable prototype plant*. Environmental science & technology. Retrieved from https://pubmed.ncbi.nlm.nih.gov/23323842/

The role of critical minerals in Clean Energy Transitions – analysis. IEA. (2021, May). Retrieved from https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

Tiseo, I. (2023, February 6). *U.S. Power Sector Carbon Index by State 2021*. Statista. Retrieved from https://www.statista.com/statistics/1133295/electric-sector-carbon-dioxide-emission-rate-by-state-united-states/

United States Department of Energy. (2019, November). *Summary report on EVS at scale and the U.S. Electric Power System*. Retrieved from https://www.energy.gov/eere/vehicles/articles/summary-report-evs-scale-and-us-electric-power-system-2019

United States Geological Survey. (2022, January). *Mineral Commodity Summaries 2022 - Lithium -*

USGS. Retrieved from https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-lithium.pdf

What California's new advanced clean car rule means for other states. National Caucus of Environmental

Legislators. (2023, April 10). Retrieved from http://www.ncelenviro.org/articles/what-californias-

new-advanced-clean-car-rule-means-for-other-

states/#:~:text=Six%20states%20(Massachusetts%2C%20New%20Jersey,in%20adopting%20the

%20ACT%20rule.

Yale climate opinion maps 2021. Yale Program on Climate Change Communication. (2022, February 23).

Retrieved September 20, 2022, from https://climatecommunication.yale.edu/visualizations-

data/ycom-us/