Final Step to Green *En Masse* Financially

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We make seven direct intra-brand comparisons between legacy carmakers' electric vehicle (EV) and gas-powered vehicle who achieved top ten most-efficient electric vehicles in America. We find six out of the seven EVs will be able to breakeven the higher price relative to their gas counterparts within reasonable gas price range, electricity charge range, and federal government tax credit for buying EVs. We further find that federal government tax credit is the most effective policy tool that will induce new car buyers to choose EVs over comparable same-brand gas vehicle though other green initiatives such as solar panels on owner's roof tops and below-market-interest-rate (BMIR) loans are effective as well.

Keywords: discounted payback period, incremental cash flow, below-market-interest-rate loans, tax credit, legacy carmakers

INTRODUCTION

Ozili (2022) documented that green finance has the potential to make a significant difference in the environment, society and for climate-change mitigation. Still, many challenges abound such as lack of awareness, inconsistent definitions, lack of policy coordination, inconsistent policies, lack of profitable incentives and insurmountable inertia by financial institutions to invest in the green initiatives. In this study, we conducted a simple experiment to discover how car buyers can switch from gas vehicle to electric vehicle, EV, of the same brand by overcoming the challenges Ozili spelled out. Henderson (2007) reported that USA and Canada are still caught in their wasteful transportation, inefficient suburban sprawl and petroleum addictions while Europe and Japan are rapidly building their green economy sectors. This study attempts to show how such wasteful transportation can be mitigated by switching from gas vehicles to EVs for the civilians *en masse*.

Wilmot (Mar 7, 2022, and Mar 12, 2022) reported the top ten electric vehicles (EVs) for efficiency in America. Tesla had won 3 models of the 10 top spots, while GM and Hyundai each won with 2 models. The remaining 3 winners of one model each were BMW, Kia and Nissan. Of the six makers, only Tesla produces exclusively EVs. The remaining five legacy carmakers each produce both EVs and gasoline cars simultaneously. The table presented by Wilmot, with last column added to more explicitly identify the carmakers, is shown in Figure 1.

FIGURE 1
TOP TEN ELECTRIC VEHICLES IN AMERICAN IN 2022

Model	kWh/100 miles	Maker
2020 Hyundai Ioniq Electric	20.8	Hyundai
2020 Mini Cooper SE	21.8	BMW
2019 Hyundai Kona Electric	22.3	Hyundai
2020 Tesla Model 3 Std Range Plus	23.0	Tesla
2020 Kia Niro EV	25.3	Kia
2022 Chevrolet Bolt	25.7	GMC
2020 Chevrolet Bolt	25.7	GMC
2021 Tesla Model 3 Long Range	25.9	Tesla
2021 Tesla Model Y Long Range	26.2	Tesla
2020 Nissan Leaf Plus SL	27.1	Nissan

From Figure 1, it is apparent that Wilmot ranked the top ten EVs based on their respective efficiency of energy consumption per 100 miles driven, data points which he attributed to Edmunds.com. Edmunds.com Inc. is an American online resource for automotive inventory and information, including expert car reviews based on testing at the firm's private facility. In 2021, Carmax purchased Edmunds.com at the enterprise value of $404 million.

Given Tesla's lack of mass production capacity impedes it from achieving the coveted economies of scale, Tesla models' prices remain beyond reach by the general American consumers[1]. Consequently, the viable path to transition *en masse* out of the internal combustion engines that consume gasoline and into the electric engines for propulsion lies now with the legacy carmakers who only need to reconfigure their production facilities instead of building them from scratch. However, these legacy carmakers will produce the electric vehicles only if the consumers are ready to buy them. In other words, the demands for EVs must exist before or at least must exist contemporaneously for the legacy carmakers to start producing electric vehicles.

The motivations to transition from gasoline to electric engines can be macro, micro, and pull (or carrot) or push (or stick). The four permutations can be the roadmap for either policy prescriptions or educating the general public on the advantages of EVs. An example of macro-pull is tax deduction for EV purchases; an example of macro-push is an increase in gasoline tax at the federal level. Examples of micro-pull are free or lower tolls for EVs on roadways or bridges, and more rapid-charging stations along major roadways. An example of micro-push is replacing more gas stations along the major roadways with rapid-charging stations.

While the above discussions are relevant and cogent, they lack implementation details. Often, it is the implementation details that can seal the deal for the general public. In this study, we zero in on the remaining 7 EV models listed by Wilmot in Fig. 1 that the five legacy carmakers produced. We lay out the detailed financial pathway in which an average car buyer can be motivated to favorably choose the EV model and not the gasoline counterpart model of the same carmaker. In matching the EV with each of its same-maker gasoline counterpart, we match the physical features of the two models to be as closely as possible to increase their comparability. Some of the salient physical features we consider are size, class, interior volume. Perhaps, the two physical features that we wish we could make them as close as possible but could not are mileage range and weight in which each EV has lower mileage range and heavier than its gasoline counterpart.

SAMPLE

We chose our sample for direct intra-brand comparison between EV and a gasoline car made by the same carmaker whose EV made it to America's top ten most efficient EVs. The seven EVs came from the

Wilmot (March 2022) articles while the seven corresponding gasoline counterparts are chosen based on size, class, interior volume that match as closely to the EV. The seven pairs of vehicles we study are shown in Fig. 2. As far as possible, we culled all other performance data, except the seven EVs' efficiency data which Wilmot attributed to Edmunds.com, from the federal government website at http://fueleconomy.gov[2] to maintain consistency of data source. The same-brand comparison conducted in this exercise obviates the phenomenon of green brand positioning by Ratna and Ojha (2022), arguing that customers sometimes intentionally buy green products of another brand just to show they are loyal to the green agendas despite higher prices. The same-brand comparison also obviates the need to use perceived value to justify paying higher prices for eco-friendly products than traditional non-eco-friendly ones, as Walia and Kumar asserted (2022).

For the MSRP (manufacturer suggested retail price), we chose the lower number reported in the government website for all models to remain consistent, and to avoid in our later analyses, been muddied by the unequal monetary values of the option features added. The numeral below the MSRP is the fully-charged or full-tank range in miles of the vehicle using the combined mpg as reported in the government website.The numeral to the right of the MSRP is the energy efficiency in kWh/100 miles for the EV as reported by Wilmot (2022), and in miles-per-gallon (mpg) for the gas vehicle as reported in the government website. The numeral in cubit feet, ft^3, is the passenger volume of the vehicle as reported by the respective manufacturers.

FIGURE 2
SEVEN EV MODELS JUXTAPOSED WITH THEIR COMPARABLE GASOLINE MODELS OF THE SAME CARMAKERS WITH PRICING, PERFORMANCE DATA AND PHYSICAL FEATURES

No.	**EV year and model**		**Gas car year and model**	
1	2020 Hyundai Ioniq Electric		2020 Hyundai Elantra SE	
	$33,045	20.8 kWh/100 mi.	$20,050	36 mpg
	170 mi.	96.2 ft^3	532 mi.	99.4 ft^3
2	2020 MINI Cooper SE		2020 MINI Cooper	
	$29,900	21.8 kWh/100 mi.	$28,400	29 mpg
	110 mi.	93 ft^3	467 mi.	93 ft^3
3	2019 Hyundai Kona Electric		2019 Hyundai Kona FWD	
	$36,950	22.3 kWh/100 mi.	$19,900	30 mpg
	258 mi.	92.4 ft^3	396 mi.	94.1 ft^3
4	2020 Kia Niro EV		2020 Kia Niro	
	$39,900	25.3 kWh/100 mi.	$24,590	49 mpg
	239 mi.	96.6 ft^3	583 mi.	100.9 ft^3
5	2022 Chevrolet Bolt		2022 Chevrolet Malibu	
	$31,000*	25.7 kWh/100 mi.	$23,400	32 mpg
	259 mi.	93.9 ft^3	506 mi.	102.9 ft^3
6	2020 Chevrolet Bolt		2020 Chevrolet Malibu	
	$36,620*	25.7 kWh/100 mi.	$22,095	32 mpg
	259 mi.	93.9 ft^3	506 mi.	102.9 ft^3

No.	EV year and model		Gas car year and model	
7	2020 Nissan Leaf Plus PL		2020 Nissan Sentra	
	\$31,600	27.1 kWh/100 mi.	\$19,310	33 mpg
	149 mi.	92.4 ft^3	409 mi.	96.0 ft^3

*We checked with Oak Ridge National Laboratory, who confirmed that the higher price of the older 2020 model at \$36,620 was the brand-new price in 2020. Apparently, the 2022 model brand-new price is \$5,620 cheaper two years later.

ANALYSIS

Huang et al. (2012), and Ng et al. (2015) showed how gasoline internal combustion engine vehicles can be replaced by hybrid propulsion numerically and later by electric vehicle under varying prices of gasoline, electric supply charges and tax credits. Their attempts made binary comparison between two vehicles of two <u>different</u> carmakers. This study, however, makes seven binary comparisons of the <u>same</u> carmakers all of whom are legacy carmakers with the production capacity that can be raised easily to meet national demands if needed, unlike Tesla who has been capacity-challenged all these years. This explains the *en masse* part of the title for this writing. Consistent with this intra-brand comparison is the evidence of brand loyalty in the automobile industry as documented by Chaudhuri and Holbrook (2001) and Correia-Loureiro et al. (2017).

We will begin our financial calculations by comparing the 2020 Hyundai Ioniq Electric and the Hyundai Elantra SE. We will repeat the same calculations for the remaining 6 pairs of comparisons using the pertinent price and performance data.

Irrelevance of Car-Note Payments

One may think we should begin our financial analysis by finding the two respective car-note payments. Ironically, that step is totally unnecessary or superfluous indeed. To whet the curiosity, here is the numerical proof that shows the car-note payments are indeed irrelevant.

Let’s assume a buyer takes a 5-year (or 60-month) car note to purchase either the Hyundai Ioniq EV or the Elantra SE. Let’s further assume the bank charges 3.6% interest rate per year (or .3% per month). Going inside the Excel spreadsheet, and type in Cell A1 the formula =PMT(3.6%/12, 60, 33045, 0, 0) and press Enter key will give us the monthly payment for the Hyundai Ioniq Electric as \$602.63. Go to Cell A2, now type in =PMT(3.6%/12, 60, 20050, 0, 0) and press Enter key will give us the monthly payment for the Hyundai Elantra as \$365.64. Now, find the difference between the two monthly payments, we will get \$236.98. This is the extra monthly payment the EV buyer has to make since the EV is priced at \$30,045 while the gas-powered Elantra is priced at \$20,050. We now need to find the total present value of the sixty payments of \$236.98. To do so, go to Cell A3 in Excel and type in =PV(3.6%/12, 60, 236.98, 0, 0) and press the Enter key, we will get \$12,994.77. However, if we use the calculator function in Excel and type in =A1 – A2 and press Enter in Cell A3, and not key in 236.98 manually, we’ll also see 236.98 appears in Cell A3. Now go to Cell A4 and type in =PV(3.6%/12, 60, A3, 0, 0), we will get \$12,995.00 which is exactly the MSRP difference between \$33,045 and \$20,050. Hence, we can conclude that we need not deal with the two car-note payments separately as long as we recognize the MSRP difference of \$12,995 in our analysis. In other words, the initial MSRP difference of \$12,995 has already captured all the sixty <u>*incremental*</u> monthly payments entailed by the pricier EV relative to the cheaper gasoline-powered Elantra.

There is a significant regulatory difference between the gas vehicle and EV in the State of New Jersey where both authors reside permanently. In a recent purchase experience of an EV, we learned that the EV was fully exempted from the 6.625% state consumption sales tax, but all gas vehicles remain fully subject to such sales tax. Hence, the actual price difference between the Ioniq and the Elantra is now not \$12,995, but \$11,666.69 (= 33045 – 20050*1.06625) instead. Such tax exemption is instituted to induce more buyers to consider the purchase of EV over any brand-new gas vehicle whose sale will be banned by state legislation in 2035. We also found similar sale tax exemptions and banning of brand-new gas vehicles sales by 2035 in other major populous states which include California and New York.

Relevance of Savings

The only relevant cash flows in our analysis are the savings realized in filling the more expensive gas tank than charging the EV. Such savings is then used to offset the higher initial price of the EV compared to the post-tax price of the gas vehicle. To make the calculations trackable, we assume the car buyer needs to drive on average 1,000 miles a month or 12,000 miles a year. The savings in driving the 1,000 miles a month is then used to offset the higher initial price of the EV. This is the underlying theoretical framework of this study. Of course, if gas price is so cheap that it costs less to drive in gas than in EV, then our proposal to transition from gas vehicles to EVs collapses as there is no viable pathway to do so.

Since the EV entails extra monthly payment amount (all of which is summarily captured by the higher initial EV price as we have proven in the Irrelevance of Car-note Payments section prior), we must derive some tangible benefits from owning the EV to breakeven or do better than owning the gasoline-powered Elantra. The main tangible financial benefit comes from the cheaper price of charging the EV battery compared to the price of filling the Elantra gas tank. At an efficiency of 20.8 kWh/100 miles or .208 kWh/mi, and let's say we pay $0.16 for every kWh of electricity[3] it will cost the EV owner 3.328 cents to drive one mile. At $4.50 per gallon, and an efficiency of 36 mpg, it will cost the Elantra owner 12.5 cents to drive one mile. To make the numbers more realistic and sensible, let's further assume that a typical US driver must drive an average of 1,000 miles per month. This means the EV will cost $33.28 to charge while the Elantra will cost $125.00 to top up its tank. This gives the EV owner a monthly savings of $91.72. A non-financial novice will now conveniently, but erroneously, take the $11,667 price difference, and divide it by $91.72 to arrive at 127.20 months or 10.6 years to breakeven for owning the EV. A financial-savvy individual will now go to Cell A5 in Excel and type in the formula =NPER(3.6%/12, 91.72, -11667, 0, 0) and press the Enter key to see 160.445 months or 13.37 years if one add /12 to the end part of the formula. This means at 3.6% per year interest rate, the EV owner will need 13.37 years to breakeven the extra $11,667 payment for the EV. At 1,000 miles driven per month, it also entails the EV to last 160,445 miles in engineering life. The 3.6% is also not a number pulled out of thin air; it could very well be the mortgage rate the EV buyer faces. It means the extra $11,667 could have been used to pay down extra principal for the mortgage, and it is being repurposed to pay for the EV now instead of buying the less-expensive gasoline-power Elantra. Even for those not cash-rich buyers to pay in cash, it also means the buyer has to take a bigger car note with interest to purchase the EV. Hence, it is imperative to take the 3.6% interest into consideration seriously instead of simply ignoring it for convenience. Moreover, 33 (=160 – 127) months or 33,000 miles difference is not a trivial amount that can be safely and reasonably ignored for serious analysis.

Another important factor that can significantly reduce the breakeven period in the above numerical example is tax credit given by the federal government to EV buyer. If, for example, the above buyer is given $7,500 tax credit in the year the EV is purchased, resulting in only $5,495 extra payment for the EV, then the breakeven formula becomes =NPER(3.6%/12, 91.72, –4167, 0, 0) in Excel, and we get 48.91 months or 4.08 years.

Thus far, All the calculations are point estimates for illustration purposes. It results in a specific number given the point inputs. For a more comprehensive analysis, one may need to perform sensitivity or scenario analysis to examine the outcomes when we change one or more variables simultaneously. In this study, we perform three 2-variable scenario analyses for each pair of EV-gas vehicles over reasonable ranges of 4 variables. The four variables are gasoline price, electricity price, interest rate, and tax credit.

Specifically, we generate three 2-variable tables for each pair of EV-gas vehicle comparison. They are labeled as Tables 1, 2 and 3 below. For each table, since gas is the only input to operate the gas vehicle, we use gas price as the variable for the gas vehicle. For the EV, we use the electricity charge rate, interest rate, and tax credit as the other variable. The output contents of these three tables are the number of years needed to operate the EV to breakeven the higher price of the EV by energy savings of the EV relative to the gas vehicle.

TABLE 1
BREAKEVEN, IN YEARS, OF AN EV OVER A GASOLINE CAR OF THE SAME MAKER AT VARIOUS GAS PRICES AND VARIOUS ELECTRICITY SUPPLY CHARGE RATES

		Gas price, $/gallon								
		3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50
Electricity rate, ¢/kWh	0									
	12									
	13									
	14									
	15									
	16									
	17									
	18									
	19									
	20									

TABLE 2
BREAKEVEN, IN YEARS, OF AN EV OVER A GASOLINE CAR OF THE SAME MAKER AT VARIOUS GAS PRICES AND VARIOUS INTEREST RATES FACED BY THE CAR BUYER

		Gas price, $/gallon								
		3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50
Interest rate, % p.a.	0									
	2.0									
	2.5									
	3.0									
	3.6									
	4.0									
	4.5									
	5.0									

TABLE 3
BREAKEVEN, IN YEARS, OF AN EV OVER A GASOLINE CAR OF THE SAME MAKER AT VARIOUS GAS PRICES AND VARIOUS TAX CREDITS GIVEN BY US FEDERAL GOVERNMENT TO EV BUYERS IN THE PURCHASE YEAR

		Gas price, $/gallon								
		3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50
Tax credit for electric car, $	0									
	1000									
	2000									
	3000									
	4000									
	5000									
	6000									
	7500									

To generate each of the above table, we use the Data → What-if Analysis → Data Table functions in Excel. The header rows description and range of gas prices are manually transcribed. So were the header columns description and range of electricity prices, interest rates and tax credit potential given by the federal government for purchasing the EV. The empty cells will contain numeric empirical results that show the number of years to breakeven the extra purchase price of the EV.

RESULTS

Our Excel spreadsheet used to generate the 3 tables for Ioniq vs. Elantra binary comparison is as follows. We manually entered data points in Cells B1 through B8, and annotate the formulas in other cells when it does not contain data manually entered. Cell B12 is the final output.

	A	B	C
1	$/gallon	$4.50	←The yellow data points are manually transcribed
2	$/kWh	$0.16	
3	mpg	36	
4	kWh/100 miles	20.8	
5	Annual miles driven	12,000	
6	Elantra MSRP	$=20050*1.06625	
7	Ioniq Electric MSRP	$ 33,045	
8	Interest cost per year	3.6%	
9	Savings/mile	$ 0.09172	=B1/B3 – B2*B4/100
10	Monthly savings	$ 91.72	=B9*B5/12
11	MSRP spread	$ 11,666.69	=B7 – B6
12	Breakeven years	13.37	=NPER(B8/12, B10,-B11,0,0)/12

The =NPER formula in Cell B12 calculates the discounted payback period which we commonly call the breakeven years. The negative sign that precedes B11 in the formula is consistent with the fact that the MSRP spread is a cash *outflow* initially while the monthly saving in B10 is cash *inflow* since Excel's algorithm is sign-sensitive. The penultimate 0, and the final 0 are respectively for the future value, and to designate the cash flow mode to occur at the end of each month instead of at the beginning of each period. The last division by 12 is to convert the breakeven period from months into years.

A word on the use of discounted payback method is in order here. In the teaching of project evaluation in Financial Management, discounted payback is one of the techniques used to evaluate, rank and compare multiple projects for their relative merits. Two other more economically prominent techniques are the net present value (NPV) and the internal rate of return (IRR) techniques. Osborne (2010, p. 243), however, documented the evidence that discounted payback criterion dominated NPV and IRR in all European countries, and he called such phenomenon a puzzle since NPV and IRR have been diligently taught in management schools as the superior techniques for decades. Hence, the choice of the discounted payback method in our study here is consistent with Osborne's observation in Europe.

To create Table 4, we manually enter the gas prices in the header row (E2 through M2), and the electricity prices in header column (D3 through D11). We go to the northwest corner of the intersection of the header row and header column, Cell D2, and key in =B12 to output the 15.40 breakeven years we found earlier. Then, we highlight the entire table from D2 through M12, click the Data function, select the What-if Analysis, and select the Data Table function further. Excel will then prompt us to enter Row input cell and Column input cell in which we enter B1 and B2 respectively. Click the Ok icon, and we'll get the output breakeven years as follows after we format all outputs to 2 decimal places.

TABLE 4
HYUNDAI IONIQ EV VS. HYUNDAI ELANTRA:
SENSITIVITY ANALYS OF ELECTRIC CHARGES AND GAS PRICE PER GALLON

	D	E	F	G	H	I	J	K	L	M
2	13.37	3.5	4	4.5	5	5.5	6	6.5	7	7.5
3	0.00	12.42	10.53	9.14	8.08	7.24	6.56	5.99	5.52	5.12
4	$0.12	18.43	14.50	11.98	10.21	8.90	7.89	7.09	6.43	5.89
5	$0.13	19.21	14.98	12.30	10.44	9.08	8.03	7.20	6.53	5.97
6	$0.14	20.07	15.49	12.64	10.68	9.26	8.17	7.31	6.62	6.04
7	$0.15	21.01	16.03	12.99	10.93	9.45	8.32	7.43	6.71	6.12
8	$0.16	22.05	16.62	13.37	11.20	9.64	8.47	7.55	6.81	6.21
9	$0.17	23.21	17.25	13.77	11.48	9.85	8.62	7.67	6.91	6.29
10	$0.18	24.50	17.93	14.20	11.77	10.06	8.79	7.80	7.02	6.38
11	$0.19	25.95	18.67	14.65	12.08	10.28	8.96	7.94	7.12	6.46
12	$0.20	27.60	19.48	15.14	12.40	10.52	9.13	8.07	7.23	6.55

Table 4: Breakeven years to buy Hyundai Ioniq EV over Hyundai Elantra for an initial MSRP spread of $11,667 for an individual who drives 1,000 miles per month and faces 3.6% interest rate per year. We use gas price range from $3.50 to $7.50 per gallon, and electricity price at 12 cents through 20 cents per kWh.

We can similarly create Table 5 and Table 6 using the same gas price range as header row and interest rate and tax credit as header column respectively. Of course, we have to enter a different Column input cell reference when promoted by Excel. We obtain the two tables as:

TABLE 5
HYUNDAI IONIQ EV VS. HYUNDAI ELANTRA:
SENSITIVITY ANALYS OF LOAN INTEREST RATES AND GAS PRICE PER GALLON

	13.37	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
Interest rate in % per year	0.00%	15.20	12.49	10.60	9.21	8.14	7.29	6.60	6.03	5.55	This row of 0% for zero-interest policy
	2.00%	18.14	14.38	11.92	10.18	8.89	7.88	7.09	6.43	5.89	
	2.50%	19.15	14.99	12.33	10.47	9.11	8.05	7.22	6.55	5.99	
	3.00%	20.33	15.67	12.77	10.79	9.34	8.24	7.37	6.66	6.08	
	3.60%	22.05	16.62	13.37	11.20	9.64	8.47	7.55	6.81	6.21	
	4.00%	23.46	17.34	13.81	11.50	9.86	8.63	7.68	6.92	6.29	
	4.50%	25.66	18.39	14.43	11.91	10.15	8.85	7.85	7.05	6.40	
	5.00%	28.62	19.63	15.13	12.36	10.47	9.08	8.03	7.19	6.52	

Table 5: Breakeven years to buy Hyundai Ioniq EV over Hyundai Elantra for an initial MSRP spread of $11,667 for an individual who drives 1000 miles per month and faces electricity price of 16 cents per kWh. We use gas price range from $3.50 to $7.50 per gallon, and interest rate range from 0% through 5%.

TABLE 6
HYUNDAI IONIQ EV VS. HYUNDAI ELANTRA: SENSITIVITY ANALYS OF TAX CREDIT AND GAS PRICE PER GALLON

	4.08	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
Tax credit given by federal government in purchase year of EV	0.00	22.05	16.62	13.37	11.20	9.64	8.47	7.55	6.81	6.21	$7500 is the tax credit for EV given by the federal govt in recent years
	$ 1,000	19.31	14.73	11.94	10.04	8.67	7.63	6.82	6.16	5.62	
	$ 2,000	16.81	12.97	10.57	8.93	7.73	6.82	6.10	5.52	5.04	
	$ 3,000	14.52	11.31	9.27	7.86	6.83	6.03	5.40	4.89	4.47	
	$ 4,000	12.40	9.74	8.03	6.83	5.95	5.27	4.72	4.28	3.92	
	$ 5,000	10.44	8.26	6.84	5.84	5.10	4.52	4.06	3.69	3.38	
	$ 6,000	8.60	6.86	5.70	4.88	4.27	3.79	3.41	3.10	2.84	
	$ 7,500	6.05	4.87	4.08	3.50	3.07	2.74	2.47	2.25	2.06	

Table 6: Breakeven years to buy Hyundai Ioniq EV over Hyundai Elantra for an initial MSRP spread of $11,667 for an individual who drives 1,000 miles per month, faces electricity price of 16 cents per kWh, and interest rate of 3.6% per year. We use gas price range from $3.50 to $7.50 per gallon, and tax credit of $0 through $7,500 on the year the EV is purchased. The $7,500 tax credit was the number used in the many recent government incentive.

In each Tables 4, 5 and 6, the red numeral represents the point estimate of our base case. The other numbers in black are the spectrum of outcomes obtained by varying the other two inputs. The row of numerals in green are the respective pathways to green with renewable energy generation in Table 4, 0% green loan policy for Table 5, and the $7,500 tax rebate for Table 6. These are the respective three financial pathways to green in the gasoline-to-EV transition.

In Table 4, we see that increasing gasoline prices indeed shorten the breakeven period, *ceteris paribus*, but increasing electricity prices lengthen the breakeven period. The first row of $0.00 for electricity charge can be interpreted as the opportunity to charge the EV by renewable energy sources such as solar panels installed on the EV owner's rooftop.

In Table 5, increasing gasoline prices shorten the breakeven period, *ceteris paribus*, but increase electricity prices lengthen the breakeven period. The first row of 0% interest rate can be interpreted as a recommended policy inducement allowing EV buyers to qualify for 0% interest loans[4]. Comparing Tables 4 and 5, we see that decreasing the electricity charges is a more effective way to shorten the breakeven period than decreasing the interest rate on the EV auto loans. This seems to suggest convincing auto owners to install solar panels on rooftops is better than convincing banks to make interest-free loans in our attempt to accelerate the transition from gasoline cars to EV. Of course, the solar panel route may be less carbon-neutral than the interest-free route since the solar panels certainly entail energy and carbon emission to manufacture them while 0% interest car note rate is carbon-free.

In Table 6, we finally see that the most effective pathway to green is for the federal government to give tax credit (a green initiative started in 2010) for EV or hybrid-plug-in buyers. Tax credit means an EV buyer must have incurred $7,500 in tax liability to qualify for such tax credit. EV buyers who do not incur such high a tax liability will not be able to fully benefit from the tax credit. Again, increasing gasoline prices shorten the breakeven period, *ceteris paribus*, but increasing tax credit to $7,500 from $0 cut the initial breakeven period from 13.37 years to 4.08 years while holding gasoline price constant at $4.50 per gallon. Perhaps, policymakers should make the current tax *credit* into tax *rebate* so that EV buyers do not have to have any tax liability to qualify for the tax rebate. We posit that such a tax-friendly policy will make many new car buyers to financially favor EV over gas-powered car because the breakeven period is well within the engineering lifespan of the EV[5].

Since we have discussed the 3 scenario analyses of Ioniq vs. Elantra in details, we will be more succinct in our subsequent discussions for the remaining 6 intra-brand comparisons. We will highlight the more interesting empirical results for each of them. We combine the 3 scenario analyses into one table for each intra-brand comparison for ease of exposition.

TABLE 7
MINI COOPER SE VS. MINI COOPER

$/gallon	$ 4.50			Gas price in $ per US gallon									
$/kWh	$ 0.12		-0.25	3.5	4	4.5	5	5.5	6	6.5	7	7.5	
mpg	29		0.00	(0.26)	(0.23)	(0.20)	(0.18)	(0.17)	(0.15)	(0.14)	(0.13)	(0.12)	This row of $0.00 kWh is created for solar charging argument
kWh/100 miles	21.8	Price of electricity in $ per kWh	$ 0.12	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	
Annual miles driven	12,000		$ 0.13	-0.34	-0.29	-0.25	-0.22	-0.20	-0.18	-0.16	-0.15	-0.14	
MINI Cooper MSRP	$ 30,282		$ 0.14	-0.35	-0.29	-0.25	-0.22	-0.20	-0.18	-0.16	-0.15	-0.14	
MINI Cooper SE MSRP	$ 29,900		$ 0.15	-0.36	-0.30	-0.26	-0.23	-0.20	-0.18	-0.17	-0.15	-0.14	
Interest cost per year	3.6%		$ 0.16	-0.37	-0.31	-0.26	-0.23	-0.20	-0.18	-0.17	-0.15	-0.14	
Savings/mile	$ 0.12901		$ 0.17	-0.38	-0.31	-0.27	-0.23	-0.21	-0.19	-0.17	-0.16	-0.14	
Monthly savings	$ 129.01		$ 0.18	-0.39	-0.32	-0.27	-0.24	-0.21	-0.19	-0.17	-0.16	-0.14	
MSRP spread	$ (381)		$ 0.19	-0.40	-0.33	-0.28	-0.24	-0.21	-0.19	-0.17	-0.16	-0.15	
Breakeven years	-0.25		$ 0.20	-0.41	-0.34	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	
			Gas price in $ per US gallon										
			-0.25	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
		Interest rate in % per year	0.00%	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	This row of 0% for zero-interest policy
			2.00%	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	
			2.50%	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	
			3.00%	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	
			3.60%	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	
			4.00%	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	
			4.50%	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	
			5.00%	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	
Tax credit	$ 7,500			Gas price in $ per US gallon									
After-tax MSRP spread	$ (7,882)		(4.68)	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
Brkev yrs w/ tax credit	(4.68)	Tax credit given by federal government in purchase year of EV	0.00	-0.33	-0.28	-0.25	-0.22	-0.19	-0.18	-0.16	-0.15	-0.14	$7500 is the max tax credit given by fed govt so far
			$ 1,000	-1.19	-1.01	-0.88	-0.78	-0.70	-0.63	-0.58	-0.53	-0.49	
			$ 2,000	-2.03	-1.72	-1.50	-1.33	-1.19	-1.08	-0.99	-0.91	-0.84	
			$ 3,000	-2.84	-2.42	-2.11	-1.87	-1.67	-1.52	-1.39	-1.28	-1.19	
			$ 4,000	-3.62	-3.09	-2.70	-2.39	-2.15	-1.95	-1.79	-1.65	-1.53	
			$ 5,000	-4.39	-3.75	-3.28	-2.91	-2.62	-2.38	-2.18	-2.01	-1.87	
			$ 6,000	-5.13	-4.40	-3.85	-3.42	-3.08	-2.80	-2.57	-2.37	-2.20	
			$ 7,500	-6.21	-5.34	-4.68	-4.17	-3.76	-3.42	-3.14	-2.90	-2.69	

From Table 7, we see that the $1,500 pre-tax price spread (= $29,900 – $28,400) between the MINI Cooper SE (an EV) and the MINI Cooper (a gas-powered car) results in the EV been cheaper than the gas vehicle after we added the 6.625% sales tax to the gas vehicle while the EV enjoys sales tax exemption. So, it is a no brainer to buy the EV for buyers who are loyal to the MINI brand. The ubiquitous negative breakeven periods in all three panels can be interpreted as, it did not make any financial sense to purchase the gas-powered MINI at all. MINI brand loyalists should opt directly for the MINI Cooper SE, the EV, without even thinking about its gas counterpart. Of course, the major drawback of the MINI Cooper SE, the EV, is that it has the lowest mileage range among the top-ten EVs at 110 miles. This range is barely sufficient for a worry-free round-trip travel from Princeton University to New York City, especially with traffic congestions *en route*.

TABLE 8
KONA VS KONA ELETRIC

$/gallon	$ 4.50			Gas price in $ per US gallon									
$/kWh	$ 0.12		13.43	3.5	4	4.5	5	5.5	6	6.5	7	7.5	
mpg	30		0.00	14.42	12.15	10.51	9.26	8.28	7.49	6.83	6.29	5.82	This row of $0.00 kWh is created for solar charging argument
kWh/100 miles	22.3	Price of electricity in $ per kWh	$ 0.12	20.71	16.27	13.43	11.45	9.98	8.85	7.95	7.22	6.61	
Annual miles driven	12,000		$ 0.13	21.50	16.75	13.75	11.68	10.15	8.98	8.06	7.31	6.68	
Kona MSRP	$ 21,218		$ 0.14	22.36	17.25	14.09	11.92	10.33	9.12	8.17	7.40	6.76	
Kona Electric MSRP	$ 36,950		$ 0.15	23.29	17.79	14.44	12.17	10.52	9.27	8.29	7.49	6.84	
Interest cost per year	3.6%		$ 0.16	24.32	18.37	14.81	12.43	10.71	9.42	8.41	7.59	6.92	
Savings/mile	$ 0.12324		$ 0.17	25.44	18.98	15.20	12.70	10.92	9.57	8.53	7.69	7.00	
Monthly savings	$ 123.24		$ 0.18	26.68	19.64	15.62	12.99	11.12	9.73	8.65	7.79	7.09	
MSRP spread	$ 15,732		$ 0.19	28.05	20.35	16.06	13.29	11.34	9.90	8.78	7.90	7.17	
Breakeven years	13.43		$ 0.20	29.60	21.12	16.52	13.60	11.57	10.07	8.92	8.01	7.26	
				Gas price in $ per US gallon									
			13.43	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
		Interest rate in % per year	0.00%	14.58	12.30	10.64	9.37	8.37	7.57	6.90	6.35	5.87	This row of 0% for zero-interest policy
			2.00%	17.25	14.13	11.97	10.38	9.17	8.21	7.43	6.79	6.25	
			2.50%	18.15	14.71	12.38	10.69	9.40	8.40	7.59	6.92	6.36	
			3.00%	19.20	15.37	12.83	11.02	9.65	8.59	7.74	7.05	6.47	
			3.60%	20.71	16.27	13.43	11.45	9.98	8.85	7.95	7.22	6.61	
			4.00%	21.92	16.96	13.88	11.76	10.21	9.03	8.09	7.33	6.70	
			4.50%	23.77	17.95	14.50	12.19	10.53	9.27	8.28	7.49	6.83	
			5.00%	26.17	19.13	15.21	12.67	10.87	9.53	8.48	7.65	6.97	
Tax credit	$ 7,500			Gas price in $ per US gallon									
After-tax MSRP spread	$ 8,232		6.22	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
Brkev yrs w/ tax credit	6.22	Tax credit given by federal government in purchase year of EV	0.00	20.71	16.27	13.43	11.45	9.98	8.85	7.95	7.22	6.61	$7500 is the max tax credit given by fed govt so far
			$ 1,000	18.82	14.90	12.36	10.56	9.23	8.19	7.37	6.70	6.14	
			$ 2,000	17.05	13.59	11.32	9.70	8.49	7.55	6.80	6.19	5.67	
			$ 3,000	15.39	12.35	10.32	8.87	7.78	6.93	6.25	5.69	5.22	
			$ 4,000	13.82	11.15	9.36	8.06	7.08	6.32	5.70	5.20	4.77	
			$ 5,000	12.33	10.01	8.42	7.28	6.40	5.72	5.17	4.71	4.33	
			$ 6,000	10.92	8.91	7.52	6.51	5.74	5.13	4.64	4.24	3.90	
			$ 7,500	8.93	7.33	6.22	5.40	4.78	4.28	3.88	3.54	3.26	

From Table 8, we see that the 2019 Hyundai Kona Electric's $15,732 price disadvantage relative to its gas-powered counterpart entailed longer breakeven period than the Hyundai 2020 Ioniq's $11,667 price disadvantage relative to its same-year Hyundai presented in Tables 4 through 6. Within one model year, the SUV-class Ioniq had achieved shorter breakeven period than the sedan-class Kona. Nevertheless, the green numerals in each of the three panels all point to the feasibility of achieving breakeven in less than 10 years, especially within the higher-gas-price range, or higher tax credit bestowed by the federal government to the EV buyers.

TABLE 9
KIA NIRO VS. KIA NIRO EV

$/gallon	$ 4.50			Gas price in $ per US gallon									
$/kWh	$ 0.12		30.64	3.5	4	4.5	5	5.5	6	6.5	7	7.5	
mpg	49		0.00	23.78	19.44	16.48	14.31	12.66	11.36	10.30	9.42	8.68	This row of $0.00 kWh is created for solar charging argument
kWh/100 miles	25.3	Price of electricity in $ per kWh	$ 0.12	205.07	44.84	30.64	23.65	19.35	16.41	14.27	12.63	11.33	
Annual miles driven	12,000		$ 0.13	#NUM!	51.34	33.15	25.04	20.26	17.05	14.74	13.00	11.62	
Kia Niro MSRP	$ 26,219		$ 0.14	#NUM!	60.94	36.17	26.63	21.26	17.75	15.26	13.39	11.94	
Kia Niro EV MSRP	$ 39,900		$ 0.15	#NUM!	78.07	39.89	28.45	22.36	18.50	15.80	13.81	12.27	
Interest cost per year	3.6%		$ 0.16	#NUM!	164.84	44.66	30.57	23.60	19.32	16.39	14.25	12.61	
Savings/mile	$ 0.06148		$ 0.17	#NUM!	#NUM!	51.08	33.06	24.99	20.23	17.03	14.73	12.98	
Monthly savings	$ 61.48		$ 0.18	#NUM!	#NUM!	60.54	36.06	26.57	21.22	17.72	15.24	13.38	
MSRP spread	$ 13,681		$ 0.19	#NUM!	#NUM!	77.25	39.76	28.39	22.33	18.47	15.78	13.79	
Breakeven years	30.64		$ 0.20	#NUM!	#NUM!	149.09	44.48	30.49	23.56	19.29	16.37	14.24	
				Gas price in $ per US gallon									
			30.64	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
		Interest rate in % per year	0.00%	27.76	22.24	18.54	15.90	13.92	12.38	11.15	10.13	9.29	This row of 0% for zero-interest policy
			2.00%	40.54	29.44	23.19	19.16	16.33	14.24	12.62	11.33	10.29	
			2.50%	47.42	32.50	24.94	20.30	17.13	14.83	13.08	11.70	10.58	
			3.00%	59.70	36.71	27.12	21.64	18.05	15.49	13.58	12.10	10.91	
			3.60%	205.07	44.84	30.64	23.65	19.35	16.41	14.27	12.63	11.33	
			4.00%	#NUM!	55.14	33.91	25.32	20.38	17.12	14.78	13.02	11.64	
			4.50%	#NUM!	#NUM!	40.05	28.00	21.93	18.13	15.50	13.56	12.06	
			5.00%	#NUM!	#NUM!	52.52	31.78	23.87	19.34	16.33	14.16	12.52	
Tax credit	$ 7,500			Gas price in $ per US gallon									
After-tax MSRP spread	$ 6,181		9.99	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
Brkev yrs w/ tax credit	9.99	Tax credit given by federal government in purchase year of EV	0.00	205.07	44.84	30.64	23.65	19.35	16.41	14.27	12.63	11.33	$7500 is the max tax credit given by fed govt so far
			$ 1,000	72.55	37.69	26.83	21.05	17.38	14.83	12.94	11.48	10.32	
			$ 2,000	53.39	32.00	23.48	18.67	15.54	13.32	11.67	10.38	9.36	
			$ 3,000	42.15	27.28	20.49	16.48	13.81	11.90	10.45	9.33	8.42	
			$ 4,000	34.17	23.25	17.79	14.45	12.19	10.54	9.29	8.31	7.51	
			$ 5,000	27.97	19.73	15.33	12.56	10.65	9.25	8.17	7.33	6.64	
			$ 6,000	22.91	16.60	13.07	10.79	9.19	8.01	7.10	6.38	5.79	
			$ 7,500	16.71	12.49	9.99	8.33	7.14	6.25	5.56	5.01	4.56	

The 2020 Kia Niro EV's $13,681 price disadvantage relative to its gas counterpart is the first time we encountered the #NUM! outputs in the scenario analysis. The #NUM! means there will never be able to breakeven. Let's take the first #NUM! in the first panel of Table 9. At $3.50/gallon, and $.12/kWh, the monthly savings in driving 1,000 miles equals ($3.50/49 - $.13/100*25.3)*1,000 = $38.54 per month. The present value of this perpetuity at 3.6% per year or .3% per month is $38.54/.003 = $12,846.16 which is still $834.81 less than the $13,681. This means even if the Kia Niro EV can last forever, an engineering impossibility, the savings of $38.54 it generates per month won't suffice to pay off the $13,681 because the present value of its perpetuity only sums to $12,846.16.

Looking at the green numerals, we see that even the green initiatives on free electricity, interest-free loans, and maximum tax credit are not that promising for the Kia Niro EV compared to the earlier Hyundai or MINI models. Too few of them are shorter than ten years in breakeven periods.

TABLE 10
CHEVY MALIBU 2022 VS CHEVY BOLT 2022

$/gallon	$ 4.50			Gas price in $ per US gallon									
$/kWh	$ 0.12		5.03	3.5	4	4.5	5	5.5	6	6.5	7	7.5	
mpg	32		0.00	5.05	4.36	3.84	3.43	3.10	2.83	2.60	2.41	2.24	This row of $0.00 kWh is created for solar charging argument
kWh/100 miles	25.7	Price of electricity in $ per kWh	$ 0.12	7.31	5.96	5.03	4.35	3.83	3.43	3.10	2.83	2.60	
Annual miles driven	12,000		$ 0.13	7.60	6.14	5.16	4.45	3.91	3.49	3.15	2.87	2.63	
Chevy Malibu MSRP	$ 24,950		$ 0.14	7.90	6.34	5.30	4.55	3.99	3.55	3.20	2.91	2.67	
Chevy Bolt 22 MSRP	$ 31,000		$ 0.15	8.24	6.56	5.45	4.66	4.07	3.61	3.25	2.95	2.71	
Interest cost per year	3.6%		$ 0.16	8.60	6.78	5.60	4.77	4.16	3.68	3.31	3.00	2.74	
Savings/mile	$ 0.10979		$ 0.17	9.00	7.03	5.77	4.89	4.25	3.75	3.36	3.04	2.78	
Monthly savings	$ 109.79		$ 0.18	9.43	7.29	5.94	5.02	4.34	3.83	3.42	3.09	2.82	
MSRP spread	$ 6,050		$ 0.19	9.91	7.57	6.13	5.15	4.44	3.90	3.48	3.14	2.86	
Breakeven years	5.03		$ 0.20	10.45	7.88	6.33	5.29	4.54	3.98	3.54	3.19	2.91	
				Gas price in $ per US gallon									
			5.03	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
		Interest rate in % per year	0.00%	6.42	5.35	4.59	4.02	3.57	3.22	2.93	2.68	2.48	This row of 0% for zero-interest policy
			2.00%	6.88	5.67	4.82	4.19	3.71	3.33	3.02	2.76	2.54	
			2.50%	7.00	5.75	4.88	4.24	3.75	3.36	3.04	2.78	2.56	
			3.00%	7.14	5.84	4.95	4.29	3.79	3.39	3.07	2.80	2.58	
			3.60%	7.31	5.96	5.03	4.35	3.83	3.43	3.10	2.83	2.60	
			4.00%	7.43	6.04	5.08	4.39	3.86	3.45	3.12	2.84	2.61	
			4.50%	7.59	6.14	5.15	4.44	3.90	3.48	3.14	2.86	2.63	
			5.00%	7.76	6.24	5.23	4.50	3.95	3.52	3.17	2.89	2.65	
Tax credit	$ 7,500			Gas price in $ per US gallon									
After-tax MSRP spread	$ (1,450)		(1.08)	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
Brkev yrs w/ tax credit	(1.08)	Tax credit given by federal government in purchase year of EV	0.00	7.31	5.96	5.03	4.35	3.83	3.43	3.10	2.83	2.60	$7500 is the max tax credit given by fed govt so far
			$ 1,000	5.96	4.88	4.13	3.58	3.16	2.83	2.56	2.34	2.15	
			$ 2,000	4.68	3.84	3.26	2.83	2.51	2.25	2.03	1.86	1.71	
			$ 3,000	3.45	2.84	2.42	2.11	1.87	1.67	1.52	1.39	1.28	
			$ 4,000	2.27	1.88	1.60	1.40	1.24	1.11	1.01	0.93	0.85	
			$ 5,000	1.14	0.95	0.81	0.71	0.63	0.56	0.51	0.47	0.43	
			$ 6,000	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	
			$ 7,500	-1.50	-1.26	-1.08	-0.95	-0.85	-0.76	-0.69	-0.64	-0.59	

Table 10 shows that the 2022 Chevy Bolt's $6,050 price disadvantage only entails 5.03 years or 60.36 months or 60,360 extra driven miles to breakeven its 2022 gas counterpart, the 2022 Chevy Malibu. Glancing over the green numerals with the proposed or already-implemented green initiatives, the breakeven periods needed by the 2022 Bolt are very promising indeed, especially those with $7,500 tax credit all of which are negative values meaning the EV is the optimum choice right off the bat.

TABLE 11
CHEVY MALIBU 2020 VS. CHEVY BOLT 2020

$/gallon	$ 4.50			Gas price in $ per US gallon									
$/kWh	$ 0.12		12.28	3.5	4	4.5	5	5.5	6	6.5	7	7.5	
mpg	32		0.00	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	This row of $0.00 kWh is created for solar charging argument
kWh/100 miles	25.7	Price of electricity in $ per kWh	$ 0.12	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
Annual miles driven	12,000		$ 0.13	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
Chevy Malibu MSRP	$ 23,559		$ 0.14	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
Chevy Bolt 20 MSRP	$ 36,620		$ 0.15	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
Interest cost per year	3.6%		$ 0.16	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
Savings/mile	$ 0.10979		$ 0.17	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
Monthly savings	$ 109.79		$ 0.18	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
MSRP spread	$ 13,061		$ 0.19	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
Breakeven years	12.28		$ 0.20	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	12.28	
				Gas price in $ per US gallon									
			12.28	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
		Interest rate in % per year	0.00%	13.86	11.56	9.91	8.68	7.72	6.95	6.32	5.79	5.35	This row of 0% for zero-interest policy
			2.00%	16.24	13.16	11.06	9.54	8.39	7.49	6.76	6.16	5.66	
			2.50%	17.03	13.66	11.40	9.79	8.58	7.64	6.88	6.26	5.75	
			3.00%	17.94	14.21	11.78	10.07	8.79	7.80	7.01	6.37	5.84	
			3.60%	19.22	14.97	12.28	10.42	9.06	8.01	7.18	6.51	5.95	
			4.00%	20.24	15.54	12.65	10.68	9.24	8.15	7.29	6.60	6.03	
			4.50%	21.76	16.35	13.15	11.03	9.50	8.35	7.45	6.72	6.13	
			5.00%	23.66	17.29	13.72	11.41	9.77	8.55	7.61	6.85	6.24	
Tax credit	$ 7,500			Gas price in $ per US gallon									
After-tax MSRP spread	$ 5,561		4.59	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
Brkev yrs w/ tax credit	4.59	Tax credit given by federal government in purchase year of EV	0.00	19.22	14.97	12.28	10.42	9.06	8.01	7.18	6.51	5.95	$7500 is the max tax credit given by fed govt so far
			$ 1,000	17.18	13.49	11.12	9.47	8.25	7.31	6.56	5.95	5.45	
			$ 2,000	15.28	12.09	10.01	8.55	7.46	6.62	5.95	5.41	4.95	
			$ 3,000	13.49	10.75	8.94	7.66	6.70	5.95	5.36	4.87	4.47	
			$ 4,000	11.82	9.48	7.91	6.80	5.96	5.30	4.78	4.35	3.99	
			$ 5,000	10.24	8.26	6.92	5.96	5.23	4.66	4.21	3.83	3.52	
			$ 6,000	8.74	7.09	5.96	5.15	4.53	4.04	3.65	3.33	3.06	
			$ 7,500	6.64	5.43	4.59	3.97	3.50	3.13	2.83	2.59	2.38	

Table 11 shows that the 2020 Chevy Bolt's $13,061 price disadvantage relative to its 2020 Malibu provides us with the golden opportunity to make an *intertemporal* comparison with their respective 2022 counterparts (see Table 10 earlier) whose price spread had shrunk by nearly 50% to $6,050. Such comparison leads us to aspire for something that parallels the Moore's law in the electronics industry. The breakeven period has shortened from 12.28 years to 5.03 years in just 2 model years, and the maximum-tax-credit breakeven period has also shortened from 4.59 years to -1.08 years, meaning the EV is the optimum choice. This near-Moore's law price decline is a significant step in the transitioning out of gas-powered vehicles into the EVs.

TABLE 12
NISSAN SENTRA VS. NISSAN LEAF

$/gallon	$ 4.50			Gas price in $ per US gallon									
$/kWh	$ 0.12		10.65	3.5	4	4.5	5	5.5	6	6.5	7	7.5	
mpg	33		0.00	10.38	8.85	7.72	6.84	6.14	5.58	5.11	4.71	4.37	This row of $0.00 kWh is created for solar charging argument
kWh/100 miles	27.1	Price of electricity in $ per kWh	$ 0.12	16.59	12.96	10.65	9.05	7.86	6.96	6.24	5.65	5.17	
Annual miles driven	12,000		$ 0.13	17.47	13.49	11.00	9.30	8.05	7.10	6.36	5.75	5.25	
Sentra MSRP	$ 20,589		$ 0.14	18.46	14.06	11.38	9.56	8.25	7.26	6.48	5.85	5.33	
Leaf MSRP	$ 31,600		$ 0.15	19.56	14.68	11.78	9.84	8.46	7.42	6.60	5.95	5.42	
Interest cost per year	3.6%		$ 0.16	20.82	15.36	12.21	10.14	8.67	7.58	6.74	6.06	5.51	
Savings/mile	$ 0.10384		$ 0.17	22.25	16.11	12.67	10.45	8.90	7.76	6.87	6.17	5.60	
Monthly savings	$ 103.84		$ 0.18	23.91	16.94	13.17	10.79	9.15	7.94	7.02	6.29	5.69	
MSRP spread	$ 11,011		$ 0.19	25.86	17.86	13.71	11.15	9.40	8.13	7.16	6.40	5.79	
Breakeven years	10.65		$ 0.20	28.19	18.89	14.31	11.54	9.67	8.33	7.32	6.53	5.89	
				Gas price in $ per US gallon									
			10.65	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
		Interest rate in % per year	0.00%	12.48	10.35	8.84	7.71	6.84	6.15	5.58	5.11	4.71	This row of 0% for zero-interest policy
			2.00%	14.37	11.60	9.73	8.38	7.36	6.56	5.92	5.39	4.95	
			2.50%	14.97	11.98	9.99	8.57	7.51	6.68	6.02	5.47	5.02	
			3.00%	15.65	12.40	10.28	8.78	7.67	6.80	6.11	5.55	5.09	
			3.60%	16.59	12.96	10.65	9.05	7.86	6.96	6.24	5.65	5.17	
			4.00%	17.31	13.38	10.92	9.24	8.00	7.07	6.32	5.72	5.23	
			4.50%	18.35	13.95	11.28	9.49	8.19	7.21	6.44	5.82	5.30	
			5.00%	19.60	14.60	11.68	9.76	8.39	7.36	6.56	5.91	5.38	
Tax credit	$ 7,500			Gas price in $ per US gallon									
After-tax MSRP spread	$ 3,511		2.98	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00	$ 6.50	$ 7.00	$ 7.50	
Brkev yrs w/ tax credit	2.98	Tax credit given by federal government in purchase year of EV	0.00	16.59	12.96	10.65	9.05	7.86	6.96	6.24	5.65	5.17	$7500 is the max tax credit given by fed govt so far
			$ 1,000	14.60	11.50	9.50	8.09	7.05	6.25	5.61	5.09	4.66	
			$ 2,000	12.75	10.11	8.39	7.17	6.26	5.56	5.00	4.54	4.16	
			$ 3,000	11.01	8.79	7.32	6.28	5.49	4.88	4.40	4.00	3.66	
			$ 4,000	9.37	7.53	6.30	5.41	4.74	4.22	3.81	3.46	3.18	
			$ 5,000	7.83	6.32	5.31	4.57	4.02	3.58	3.23	2.94	2.70	
			$ 6,000	6.36	5.17	4.35	3.76	3.31	2.95	2.67	2.43	2.23	
			$ 7,500	4.30	3.52	2.98	2.58	2.27	2.04	1.84	1.68	1.55	

Table 12 shows that the 2020 Nissan Leaf's $11,011 price disadvantage relative to its 2020 gas-powered Sentra yields the similar qualitative and quantitative pattern of breakeven periods compared to those given by the 2020 Chevy Bolt over the same year Chevy Malibu (see Table 11 earlier).

Challenges Ahead

The Ukraine war seems to revive the drive by more countries to green energy, but addiction to old habit is certainly tenacious to reform at the consumer level as Strasburg and Dvorak (Apr 5, 2022) reported. The disconnect between policy implementation and consumer preference is further manifest when consumers have to pay more for gasoline with restricted supplies. The reluctance of consumers to pay more for the EVs should be topics for rife public discourse, and the best way to wage a successful persuasion campaign is to educate new car buyers of the feasible financial paths made available by the several legacy carmakers, obviating the more-expensive Tesla path which is beyond the financial reach for many car buyers.

Nickel is an essential element in the manufacturing of the batteries for EVs. Wallace (2022) documents the nickel market breakdown in the London Metal Exchange on Mar 8, 2022. Until new technological breakthrough reduces or eliminates the dependence on nickel in the manufacturing of EV batteries, nickel will continue to be the binding constraint or the bottleneck in our pathway to green via the gas-to-EV transition.

McLain and Patterson (2022) reported that recent market prices of materials for the battery cathode, such as lithium, cobalt and nickel, have collectively gained about 150% in the past year, including 25% to 30% in the past one month. They further document that parts suppliers tend to prefer large, more established car companies that place large bulk orders and have a record of meeting their own targets on factory output. In view of these potential bottlenecks, both Puko and Parti (2002) and McLain and Patterson (2022) both reported that the Biden administration has pledged to invoke the Korean-war era's *Defense Production Act*

(1950) to boost U.S. production of materials used in rechargeable batteries to curb American reliance on China or other unfriendly nations for such key ingredients.

Colias (2022) documents that EVs made up only 8.3% of all vehicle sales in 2021 in USA. The average transaction price for EVs in the USA was $60,000 while the industry average (EV and gasoline vehicles) was $45,000. This implies the average gas-powered cars were selling at $43,642 each. With a price gap of $16,358, and with gas price at $4.50 per gallon, electricity charge at $.16/kWh, monthly driving distance of 1,000 miles, it will still take the most-efficient Hyundai Ioniq EV 21.30 years to breakeven its purchase over its gas-powered Elantra. Fortunately, collaborative efforts among legacy carmakers are beginning to emerge. GM and Honda declared a partnership to produce EVs that will sell below $30,000 per vehicle in America, but such production won't be ready until 2027.

CONCLUSION

Intra-brand breakeven-period analyses of the seven most-efficient EVs in America of legacy carmakers who also manufacture gas-powered vehicles show that the pathway to green via EV adoption is well within reach now with almost all EVs breakeven within their engineering lifespans. With conducive policies that will either lower the electricity charges or zero-interest loans, the breakeven period of the extra price on the EV is further shortened. The most effective policy that will make the conversion from gas-powered cars to EVs is unambiguously the extant tax credit or proposed tax rebate policy. We also observed some price decline that parallels the Moore's law observed in the electronics industry between the 2020 Chevy Bolt and the 2022 Chevy Bolt relative to their respective gas-powered Malibu. The unfinished job now is for us to educate the car buyers on the viability with the certitude of this financial pathway to green whenever their opportunity to buy a new car arises.

ENDNOTES

1. Bobrowsky (Apr 4, 2022) reported that Tesla produced 310,000 vehicles in the first quarter of 2022 globally, and its biggest production site is in China. Elliot (Oct 19, 2023) reported Tesla's projection to deliver 1.8m EVs in 2023, up from its 1.3m EVs sold in 2022 globally. Meanwhile, GMC, Toyota, Ford, Honda, and Nissan sold 2.0m, 1.9m, 1.8m, 1.3m, and 1.0m vehicles respectively in 2021 in America. In short, Tesla won't be able to meet America's appetite for vehicle demand without the help of the legacy carmakers.
2. This website is maintained by Oak Ridge National Laboratory for the U.S. Dept. of Energy and the U.S. Environmental Protection Agency.
3. This $0.16 per kWh is the rate a resident in a mid-Atlantic state resident pays, including delivery charges, to PSE&G Company for the electricity supply. With other renewable sources, e.g., solar panels on residential roof tops, this rate can be significantly reduced. Of course, we have to factor in the cost of acquiring and installing the solar panels to make the comparison fair and meaningful.
4. Below-market-interest-rate (BMIR) loans abound in other areas such as the BMIR loans for veterans' mortgages. BMIR can be of 0% in interest too. This remains a very viable policy implementation in the pathway to green.
5. BBC News, Jun 8, 2020, reported that the most expensive part of an EV built in the 2020s is the battery, and its lifetime is expected to be about 16 years, or about 1.2million miles if the car is driven a lot. Dexter Ford, Mar 18, 2012, reported in *The New York Times* that due to manufacturing improvements in the 2000s, such as tighter tolerances and better anti-corrosion coatings, the typical gasoline car lasts closer to 200,000 miles.

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