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Facilitating Electric Vehicle Adoption with Vehicle Cost Calculators

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Summary

Consumer education regarding the costs of plug-in electric vehicles (PEV), particularly in comparison with similar gasoline vehicles, is important for adoption. However, the complexity of comparing gasoline and electricity prices, and balancing long-term return-on-investment from fuel and maintenance savings with purchase premiums for PEVs, makes it difficult for consumers to assess potential economic advantages of PEVs. Online vehicle cost calculators (VCCs) may help consumers navigate this complexity by providing tailored estimates of different types of vehicle costs for users and enabling comparisons across multiple vehicles. However, VCCs range widely and there has been virtually no behavioral research to identify functionalities and features that determine their usefulness in engaging and educating consumers and promoting PEV adoption. This research draws on a systematic review of available VCCs and findings from usability studies with three VCCs to articulate design specifications for effective VCCs.

Keywords: electric vehicle (EV), sales, consumers, cost, user behaviour

1 Introduction

Vehicle electrification is integral to a more sustainable transportation future. Replacing gasoline with electricity to power vehicles enables reduced dependence on fossil fuels and can dramatically reduce climate-altering greenhouse gas emissions, given a sufficient mix of clean energy sources providing the electricity [1-2]. There are two types of plug-in electric vehicles (PEVs—referred to also as EVs in this paper): (1) battery electric vehicles (BEVs), which are powered exclusively by electricity from rechargeable electric battery packs and have no direct (tailpipe) emissions, and (2) plug-in hybrid electric vehicles (PHEVs), which can run on gas and/or electricity via a rechargeable electric battery and an internal combustion (gas-powered) engine that is smaller relative to those in conventional gas vehicles.

Consumer benefits of EVs include lower fuel and maintenance costs compared to gas vehicles [3-4]. However, research suggests that consumers do not typically consider, let alone analyze, fuel costs when making a vehicle purchase [5-6]. Not only do consumers tend to not think about fuel costs, they are not very good at it. For example, Turrentine and Kurani [6] found that only 2 of 57 interviewed households were able to reasonably estimate potential cost savings associated with a higher fuel economy vehicle. In particular, consumers tend to underestimate relative savings potential when comparing lower MPG vehicles and overestimate differences between higher MPG vehicles (the "MPG illusion") [7]. Another bias called consumer myopia can cause consumers to focus on purchase price and ignore "shrouded" add-on costs, such as energy costs [5, 8].

Calculations can overcome the perceptual biases affecting our more "off-the-cuff" estimations. For example, Allcott [5] found a positive correlation between doing fuel cost calculations and choosing a higher fuel economy vehicle. However, calculating potential fuel savings with an EV compared to a gas vehicle is a complex endeavor, requiring a great deal of cognitive effort [9], e.g., taking into account current gas prices and electricity prices at each place the consumer may charge the EV (home, work and/or other public charging stations), fuel economy of the gas vehicle, and electricity consumption per mile of the EV [10].

VCCs have been recommended as a solution to help consumers navigate this complexity [11-12], e.g., "simple tools could query consumers about their typical daily VMT, percent of city driving, place of residence, and expected duration of ownership of their next vehicle... and then provide a range of expected lifetime vehicle fuel costs, using high and low governmental gas price projections, while accounting for regional differences in electricity and gasoline prices" [11, p. 3800]. However, even if consumers recognize the energy costs savings associated with EVs, they may not understand whether these savings will offset the higher vehicle purchase price of an EV compared to a gas vehicle. Thus, VCCs should support evaluations of total costs of ownership (TCO) which can account for the balance of acquisition and operating costs [12].

Many VCCs exist, but their designs are inconsistent, making it difficult to recognize best practices [12]. Furthermore, there has been almost no user research with VCCs. Thus, the goal of this research was to articulate design recommendations for VCCs that will educate consumers and nudge them toward EV adoption when suitable for their personal transportation needs and values.

2 Methodology

This research involved two general data collection strategies: an in-depth review of currently available VCCs and usability research. The goals of the VCC review were to operationalize the features of VCCs that could have implications for user experience and EV adoption intentions, identify VCCs to test in the user research that would represent the range of identified key features in existing tools, and inform recommendations for VCC design specifications. Available VCCs were identified via internet searches and consultation with experts. Extensive coding was conducted for each VCC to describe its objective features and functionalities. Table 1 presents the VCCs reviewed and simplified coding.

The usability research aimed to reach multiple relevant stakeholder groups, including VCC users, EV consumers representing the range of adoption stages (e.g., considering, shopping for, or current owners of an EV), and EV salespersons). Goals included gaining an understanding of use cases for VCCs and user experience of several specific VCCs (representing the range of available tools) to inform recommendations.

To target VCC users, we deployed an online survey to an opt-in contact list from one VCC called EV Explorer. The survey was designed to gain better insights into who VCC users are, what they want to accomplish, and their experience and preferences with respect to three VCCs (EVExplorer, PlugStar, and BeFrugal) chosen based on the VCC review. The survey asked participants to explore each of the VCCs for at least five minutes prior to answering closed- and open-ended questions about their use and preferences for different features. Twenty-two participants completed the survey (22% response rate); 86% male, with median age 52, and median household income \$100,000-149,999, with 38% of respondents making over \$150,000. Most participants (67%) had used other VCCs in addition to EV Explorer.

Table 1: VCC Tools Reviewed

	Inputs										Outputs							
	Vehicle Selection and Specification		Driving		Fueling		Financing		Other		Financial Costs					Social and Environmental Costs		
Tool	Optional	Required	Optional	Required	Optional	Required	Optional	Required	Optional	Required	Energy Costs	Total Costs	Break-even	Incentives	Savings	Fuel Use	CO2	Air Pollution
Argonne Lab AFLEET	X	X	X		X		X		X								X	X
BeFrugal	X	X	X		X		X		X		X	X	X			X	X	X
Consumer's Energy Plug-in EV Calculator	X		X		X				X		X				X			
DOE Vehicle Cost Calculator	X	X	X	X	X	X			X		X	X				X	X	
PG&E EV Savings Calculator	X	X	X		X		X		X		X	X		X	X	X	X	X
UC Davis EV Explorer	X		X	X	X				X		X				X			
Fueleconomy.gov Fuel Savings Calculator	X		X	X	X		X		X						X	X		
Fueleconomy.gov My Plug-in Hybrid Calc.	X		X	X	X				X		X					X		
Fueleconomy.gov Trip Calculator		X		X					X						X	X		
Oncor Operating Savings Calculator	X		X		X				X		X				X			
PlugStar "Compare" and "Research a Car"	X	X	X	X			X		X									
SMUD	X	X	X		X				X		X				X	X	X	
WattPlan	X	X	X	X	X		X		X		X	X	X	X	X	X	X	X

We also conducted in-person usability tests of the three VCCs with 15 EV consumers (shoppers and owners) recruited from the Los Angeles International Auto Show's EV Lounge (*n* = 9), the SacEV Newsletter (*n* = 4), and University of California, Davis (*n* = 2). Participants were given 10-15 minutes to interact with each tool and encouraged to naturally explore the VCCs in a way that seemed interesting to them while describing their reactions and thought processes ("thinking aloud") to the researcher, who also asked questions about particular features (retrospective probing). Eye-tracking equipment was also used to analyze where participants were looking on the websites; paired with audio recording, these data yielded insights about usability issues.

Finally, in partnership with Plug In America, we conducted a focus group with EV salespersons at a dealership in Roseville, California, with sales staff experienced in EV sales. We assessed salespersons experiences and opinions regarding the PlugStar dealer app (unrelated to this study) and PlugStar's VCC.

3 Analysis

Findings from the VCC review and usability research are integrated and organized into the four sections that follow: use cases, outputs, general user experience design considerations, and inputs. VCC design recommendations based on this integrative analysis are presented in the Conclusion section.

3.1 Use Cases

User research revealed a variety of use cases for consumers with a range of knowledge of and experience with EVs, ranging from more general exploratory research to the pursuit of precise answers to specific questions. Most had goals involving cost comparisons, e.g., to support an upcoming purchase decision, including gas vehicle drivers trying to understand the cost implications of EVs vs. gas vehicles or deciding between multiple prospective EVs. Sometimes the focus was on energy or operational costs exclusively, and other times users wanted help understanding total costs, including acquisition and incentives (particularly important for those very close to a purchase decision). A minority seemed to be interested in just learning more about EVs, either generally (typically non-EV drivers) or in terms of a specific aspect like charging or range sufficiency.

Findings across the user research were distilled into three general use cases: (1) **Exploratory-** may or may not have an EV, seeking to learn more about costs, range, and/or charging; (2) **Computational-** may or may not have an EV, seeking to quantify costs; may wish to compare across vehicles (same or different drivetrain, new or used) or different routes and; (3) **Confirmatory-** has or wants an EV, is seeking to validate adoption decision. EV shoppers who were very close to a purchase decision resembled EV drivers' confirmation use case (rather than an exploratory or strictly computational use case) seeing VCCs as helping them accomplish their "due diligence"— confirming the benefits of the EV they had already decided to acquire. For example, one female interviewee considering either a Chevy Bolt or Tesla Model Y, was clearly more attracted to the Tesla and upon seeing a $3 advantage in Tesla maintenance costs, exclaimed, "Score 1 for Tesla!"

3.2 Outputs

3.2.1. VCC review

The VCCs reviewed include different types of financial cost information displayed in different styles. Some tools include only energy costs, but most attempt to account for a broader picture of costs, including additional operating and acquisition costs. However, there is variability in terms of how costs are categorized and which are included in a "total costs" output. For example, some include insurance costs and others do not, some account for depreciation and others do not, and some provide tailored incentive information while others do not. WattPlan is unique in that it provides costs for solar PV installation as well as optimal electricity rate plan and expected energy bills based on solar installation and EV charging.

Many tools also include social and environmental costs (i.e., fuel used, trips to the gas station, carbon emissions and other air pollutants). BeFrugal is unique in breaking CO_2 down into tailpipe and upstream emissions. Some provide equivalencies for CO_2, e.g., number of trees required to offset carbon associated with compared vehicles or trees planted for carbon spared with an EV. AFLEET is unique in highlighting other air pollutants.

Another category of outputs pertains to range sufficiency of selected EV models, which is typically a tangential output not highly integrated with cost outputs. For example, WattPlan provides a map at the end of their output highlighting the one-way and roundtrip distances of the selected EV relative to user location (modifiable) as well as nearby charging stations. PlugStar and PG&E have another dedicated tool within their respective websites that helps the user find EV models suited to their needs including required range.

In addition to displaying the separate costs for multiple vehicles, some VCCs specifically call out the potential financial and environmental savings achievable with an EV compared to a gas car, while for others the user would need to independently calculate the difference between values for compared vehicles. Another way some VCCs frame costs is to show cumulative costs over time and/or highlight years to breakeven if considering an EV with higher acquisition costs but lower operating costs than a gas vehicle.

Cost outputs are displayed over various time periods (or over distance, e.g., per mile costs) and in various visualization styles. Cost (and savings) breakdowns over specific time periods and costs per mile are typically displayed in bar charts and/or tables with text. Cumulative costs are typically displayed with line graphs. Social and environmental costs are typically presented only as annual costs (with the exception of PlugStar's Compare Tool which gives grams per mile and SMUD which provides monthly CO_2 savings) and there is less consistency in the display style (e.g., text, table, bar chart, line graph, icons are all used).

3.2.2. User research

In the survey of VCC users, BeFrugal's output was rated highest on accuracy and relevance, presumably due to its higher degree of customization through inputs. Usability interviewees were not as positive about BeFrugal, perhaps because they were less prepared to take advantage of the many editable inputs due to relatively less motivation to use VCCs and/or less experience with them. PlugStar was rated highest in engagement in the survey, and usability testing was consistent, appreciated for its aesthetics and interactivity. While participants liked the simplicity of EV Explorer, they expressed a desire for information beyond energy costs in the output. They also wanted to see more on the map, such as charging stations, and did not notice the bar graph beneath the map displaying EV range in relation to commute.

A common criticism of both PlugStar and BeFrugal was inaccuracy of maintenance costs; in particular, EV maintenance costs seemed too high. For PlugStar, many participants had difficulty understanding the net depreciation cost category. A couple participants were curious about differences in insurance costs for comparable cars, but they did not scroll down to read the relevant assumptions about insurance costs. Some salespersons (who only provided feedback on PlugStar's VCC) suggested that depreciation and insurance costs be excluded from the tool because they are not good distinguishers of EVs versus gas cars. One remarked, "all cars are depreciating assets; nobody invests in a car," suggesting that car buyers do not usually think in terms of depreciation, although they noted that EVs do depreciate faster. Insurance is not something they focus on and also they noted that it would not be much different for comparable cars. In their conversations with customers, they focus on the benefits of incentives and operational cost savings (fuel and maintenance). These tend to be separate discussions: (a) net cost for buying or leasing, and (b) operational savings (and convenience).

One survey respondent thought environmental costs should be featured more in PlugStar, with another noting, "Emissions are not as important as total life cycle CO_2. If manufacturing, etc. is taken into account, it isn't indicated." Other consumers throughout the usability testing expressed a desire to better understand the life cycle carbon emissions (particularly those associated with manufacturing) for EVs versus gas cars, indicating some concern that focusing only on emissions associated with operating costs paints an overly optimistic picture. Some participants also expressed a desire for more meaningful metrics, beyond grams, pounds or tons of carbon and equivalent trees, or contextual information to understand the emissions.

3.3 General User Experience Design Considerations

Available VCCs vary in terms of a variety of user experience design parameters, including linearity of the process. Some tools are highly structured such that the user is guided through considering all possible inputs before an output can be produced. In some cases, the user must begin the entire process again if they wish to explore other inputs (e.g., change a car being compared). Such tools can be considered linear, as opposed to more non-linear tools that may present an output earlier on in the process and allow the user to modify it further via optional inputs. Most VCCs use a combination of linear and non-linear processes, beginning with linear steps to produce an initial output and then allowing the user to modify original inputs and/or offering additional inputs. PG&E's is an example of more non-linear tools. whereas WattPlan and BeFrugal are more linear.

VCCs also vary in terms of the number of required and optional inputs and the number of different forms containing those inputs. The more inputs a VCC has, the more opportunities a user has to tailor cost outputs. Required inputs are those that the user must fill in order to generate vehicle cost outputs. Most VCCs have 2-6 required inputs; PG&E's has the fewest required inputs (0), WattPlan and BeFrugal have the most (over 20). Optional inputs are sometimes available before an initial cost output (just not required) and/or they are available after the initial output enabling further customization.

All inputs may be presented in a single form or organized into multiple forms, often by category (e.g., choosing a car, reporting driving habits, specifying fuel prices), and in either case they may be layered such that certain inputs appear conditionally based on other inputs. More linear tools may guide the user through a series of required and/or optional input forms which can only be accessed in a particular order and/or organize the inputs listwise and present the output beneath them after the user presses a button, typically labelled something like "Calculate". Others allow for easier exploration by displaying optional inputs on the same page as outputs and automatically updating results when inputs are changed. Some also provide interactive outputs, allowing the user to select or view different cost categories or change the interval over which costs are calculated.

In the usability interviews, participants generally engaged more with the optional inputs that were integrated in the linear process leading up to the initial cost comparison output, compared to optional inputs that were only available after the initial output. For example, most interviewees deliberated for at least a moment about each of the optional inputs and their default values in BeFrugal. However, this engagement was not necessarily positive. Some participants felt the process in BeFrugal was too long, and they were frustrated when they were unsure if the default values in the optional inputs were accurate or they could not easily estimate a more accurate value themselves. It was not always obvious to some participants what some of the inputs meant, particularly when inputs were not relevant (e.g., City and Highway MPG fields for electric vehicles).

On the other hand, with the less linear EV Explorer and PlugStar, users often did not notice optional inputs without prompting. For EV Explorer, participants typically noticed the optional inputs that appeared in the same form where they had entered required inputs, but often did not notice the input forms accessible only via the menu in the website header ("Car Manager" and fuel prices). For PlugStar, most participants noticed the optional inputs integrated in the output (financing type and term, annual mileage, and % electric driving), but they did not independently locate the additional optional financing inputs which are only accessible via the menu tabs above the output (i.e., "Build" and "Incentives").

3.4 User Inputs

VCCs organize and label inputs in different ways, but through our review we synthesized the range of inputs into four main categories: vehicle selection and specification, driving, fueling, and financing.

3.4.1 Vehicle selection and specification

All of the reviewed VCCs include opportunities to choose a specific vehicle make and model for which costs are calculated. Some tools require the user to specify one or more vehicles (make and model) before a cost output is generated, whereas others provide an output for default vehicles which can then be changed, or a combination (choose an EV and a default comparison car is also displayed). Sometimes vehicle selection is limited, e.g., only new models or particular drivetrain(s). Some VCCs also allow the user to specify a vehicle in terms of its efficiency and range (for EVs) or modify those fields for a selected model. Tools also vary in the number of vehicles for which costs can be calculated in a single output, from one (no comparison) to unlimited.

In the usability research, participants' level of engagement was drastically reduced if the specific vehicle they were interested in exploring was unavailable in a VCC. Interest in the initial output was greatest when tools required some vehicle specification input(s) upfront, rather than displaying cost calculations for default vehicles that could later be changed. Users also preferred to be able to compare as many vehicles side-by-side as they wished, without limit, although they most commonly chose to compare only two.

The option to modify default values for vehicle efficiency and range in EV Explorer and BeFrugal was not widely used by participants, except in one or two cases with Be Frugal when the user was essentially creating a custom vehicle because the tool did not include a vehicle they wanted to select. Some participants mentioned that they were not sure if the default values were best or if they should change them. One survey participant mentioned they would like to set efficiency estimates for highway and city (MPG or MPGe) as in BeFrugal instead of an average as in EV Explorer. One interviewee who was a long-time EV owner and advocate suggested that if a user is exploring a used EV there could be some qualifying information near the range and time to charge optional vehicle specification inputs to educate the user about potential battery degradation.

There are some limitations to vehicle selection by make and model. Some interviewees were not well-versed in EV makes and models. One interviewee expressed interest in being able to select more general categories of vehicles because he knew he wanted an EV, but was not set on a specific model; he was specifically interested in semi-automated technologies. Salespersons reported that they would be more likely to refer customers to a VCC if its vehicle selection was restricted to the EV(s) they sell. In particular, they suggested that the EV(s) that a user could select should be theirs, but a comparison ICE vehicle could be from a different manufacturer.

3.4.2 Driving

Most VCCs allow customization of cost calculations based on the user's driving patterns; these driving inputs may be required or optional. The most common driving inputs are annual and daily mileage. Daily mileage has implications for operating costs for PHEVs (% gas versus electric driving) and adequacy of a particular EV's range for the user's needs. Simpler formats for daily mileage often assume a consistent workday commute or are at least much easier to answer and more accurate if that is the case (e.g., daily mileage or origin-destination for one trip). The DOE's My Plug-in Hybrid Calculator offers allows the user to either enter driving patterns in a short form (daily and annual mileage) or a long form that accounts for different daily driving profiles (e.g., weekday and weekend), infrequent long distance trips, and percentage of stop-and-go traffic.

The usability research identified insufficiencies in each of the tested VCC's driving inputs. BeFrugal's calculator was criticized for having too many inputs upfront that were not easy to answer quickly (even though they were optional). In the other extreme, PlugStar only offers the ability to tailor annual mileage, which many users did not notice. Annual mileage was easier to estimate for some participants, compared to daily driving, with some citing familiarity with annual mileage in the context of auto insurance. In particular, participants with variable driving patterns, (e.g., retired persons), found daily mileage annoying to estimate. Participants liked the EV Explorer map, but only allowing one trip does not adequately reflect the driving patterns of many users. One interviewee noted, "Right up front my commute location was demanded, and I don't drive to work." Some participants suggested the ability to modify the route and add waypoints on the map would be useful, e.g., "I'd like to add waypoints along the map and re-route manually."

3.4.3 Fueling

Most VCCs allow the user to modify gas and electricity prices and charging opportunities. However, unlike vehicle selection and driving inputs, these inputs are always optional, never required. Default fuel prices are typically provided based on user location (auto-generated or user-supplied). About half the VCCs reviewed include the option to specify if there is a home charger and/or charging level, only a few ask about charging frequency, and WattPlan is unique in asking for time of charging. Many tools assume charging will be done exclusively at home and either assume off-peak charging only or use average electricity rates. Only a few tools allow the user to specify details about charging away from home, e.g., percent of charging at public stations and associated cost, or hours parked at destination, charging level, and cost. For PHEVs, most tools generate assumptions about distribution of electric v. gas driving by triangulating multiple driving and fueling inputs (e.g., charging at home and daily mileage), while a few ask directly for percent of driving in electric mode.

In the user research, the default (national average) fuel prices in BeFrugal were a turn-off for participants who noticed they were very inaccurate. Participants rarely noticed the optional fuel price inputs in EV Explorer, and when directed to them interviewees rarely modified the defaults (state averages). PlugStar does not allow modification of fuel prices, but it offers more specific electricity price estimates than the other two tested tools (though it assumes only off-peak home charging) and provides a link to local utility rate schedules. However, not all utilities are represented. For example, one interviewee (EV owner) noted that the default electricity rate was for a neighboring large utility and was much higher than his small local utility's rate. A few other EV owners mentioned the need to take time-of-use pricing into account.

On the other hand, many first-time EV shoppers said they did not know their electricity rate. Some appreciated links provided to research fuel prices, while others just wanted accurate defaults and did not want to leave the VCC to research fuel prices. Similarly, many participants (particularly first-time EV shoppers) did not know how much public charging would cost or the charger level (for EV Explorer destination charging inputs). One survey participant suggested that those costs would auto-populate based on user-selected charger location. Finally, the percent electric driving input in PlugStar was not often used and several participants (particularly those without EVs) wondered what it meant.

3.4.4 Financing

VCCs that present TCO include inputs to specify vehicle acquisition costs, including financing type (cash purchase, loan, or lease), price, financing terms, taxes and fees, and incentives. Like fueling inputs, financing inputs are always optional. The comprehensiveness and level of detail of these inputs varies, from a single field for purchase price to multiple differentiated fields, e.g., price and incentives. Default values for incentives are not always up-to-date in terms of manufacturer-specific federal incentive, and only sometimes include available state and local incentives in addition to federal. PG&E includes inputs for income tax information to determine eligibility for available incentives. Only BeFrugal allows direct modification of incentive value. WattPlan is unique in allowing users to factor in home charger installation costs and rebates.

Usability participants typically used the cash/loan/lease inputs in PlugStar with no issue, but two participants remarked that the lease length options needed to include terms longer than 48 months. Additional financing inputs in PlugStar (under the "Incentives" tab) were not intuitive to find, and one participant wanted to change a car purchase price directly, which is not possible, rather than modify the additional fees and discounts toggles. On the other hand, several survey respondents criticized the absence of inputs for interest rate, taxes, and/or registration fees in BeFrugal, although purchase price or down payment amount was directly modifiable and could be adjusted up to account for these additional costs. Although participants appreciated personalized incentive information in PlugStar, some wanted to be able to modify it. On the other hand, participants were able to edit incentives total in BeFrugal but most needed more guidance to be able to do so.

Interviewees at the auto show in particular recognized that the default vehicle prices in BeFrugal and PlugStar did not reflect the marked-up prices they had been seeing for the EV model they wanted. Salespersons also expressed concerns about purchase price assumptions. They noted that advertised MSRP and lease prices may not reflect the actual price dealers are asking, which varies greatly by location due to different taxes and mark-ups based on demand. They reported some negative experiences with customers coming in with "unrealistic" expectations because of specific prices seen in advertisements or on websites. One interviewee said it should be made clear whether the default was the base trim level or be able to select a trim level; this is actually possible in the "Build" tab in PlugStar, but the participant did not notice it. Finally, several participants were dissatisfied because they could not describe used vehicles they were considering purchasing or their current vehicles that were already paid off in order to calculate the cost differences for keeping a current vehicle versus trading it in or selling and replacing with an EV.

3.4.5 Other inputs

Other inputs that do not fit squarely in one of the four categories above include user location, which is typically requested as zip code or state and used to determine default fuel prices and identify relevant incentives. The only usability issue with these was when one interviewee wanted to check electricity price defaults in different cities on PlugStar, and had to spend considerable time figuring out the zip code he wanted to compare. As described in the outputs section, a major point of confusion in the user research was the portrayal of EV maintenance cost in

BeFrugal and PlugStar (not a factor in EV Explorer). In BeFrugal but not PlugStar, users were able to modify the default annual maintenance cost as they wished, and some did (particularly for an EV they owned already). This maintenance cost input is located with the vehicle selection and specification inputs.

4 Recommendations

Based on the findings from the VCC review and user research detailed above, we outline the following best practices and recommendations for VCC user interface design.

4.1 Outputs

- Focus on comparing operational cost savings of an EV v. a similar ICEV, e.g., in an initial output
- Compare acquisition costs in a separate output for selected vehicles, highlighting impact of incentives
- Compare cumulative total costs in a separate output, highlighting breakeven time for EV v. ICEV TCO
- Present more realistic maintenance cost estimates for EVs, particularly in the short term (first 5 years)
- Exclude ongoing costs that are not significant differentiators of EVs v. ICEVs from default outputs
- Define depreciation costs in layman's terms and include as optional in the TCO output, not by default
- Integrate salient, emotionally-evocative information about social and environmental benefits of EVs
- Include and define life-cycle emissions estimates (as opposed to only tailpipe and/or well-to-wheels)
- If including maps in output, use them to visualize electric range and charging station locations

4.2 User Experience

- Required inputs should be relatively minimal and high leverage in terms of personalizing the output
- Inputs, required ones especially, should have flexible response formats to minimize cognitive demand
- Maximize optional inputs to maximize ability to tailor results
- Optional inputs should be separate from required inputs to lessen perceived demand
- Optional inputs should be salient when the output is displayed so the user is aware of them
- Optional inputs that are irrelevant based on other user inputs should not be displayed
- Default optional input values should be as tailored and accurate as possible and explicitly labelled
- Annotate input defaults with sources and tips to help users decide whether/how to modify them

4.3 Inputs

4.3.1 Vehicle selection and specification

- Require some vehicle selection inputs (e.g., one make-model-year, body style, price range, etc.)
- Provide comprehensive selection of vehicle makes, models and years (inclusive of all drivetrains)
- Provide link alongside vehicle selection inputs to tool dedicated to EV shopping
- Enable comparison of at least four vehicles (more is better, but default at two for initial output)
- Allow users to modify efficiency-related specs for chosen vehicles

4.3.2 Driving

- Require some driving inputs, designed to estimate total annual mileage accurately or generously
- Communicate the implications of daily driving (between charges) for PHEV fuel costs
- Use flexible formats so users can easily estimate their mileage in a way that makes sense to them
    - For mileage inputs, let the user specify the denominator (e.g., miles per day/week/month/year)
    - For mileage inputs, allow multiple daily profiles (e.g., weekdays and weekend days)
    - For trip inputs, allow more than one trip, as well as route specification and waypoints
    - Supplement trip inputs with "other driving" and/or annual mileage input

4.3.3 Fueling

- Include optional inputs for fuel prices with default values as specific to user location as possible

- Only display optional inputs for prices of fuel types used by the vehicles being compared
- Label default prices so the data source is clear (e.g., PG&E off-peak rate, average CA gas price)
- Use an off-peak rate as a default for home charging price (with link to more information on rates)
- Allow users to easily indicate exclusively home charging or exclusively public charging
- Provide advanced charging inputs where users can factor in time-of-use and multiple public chargers
- Partner with charging data companies to estimate charger level and cost for user-selected stations

4.3.4 Financing

- Include optional inputs for new and used vehicle acquisition costs
- Include different sets of inputs based on acquisition type (cash purchase, loan, lease, and rent)
- In default estimates of vehicle price, specify or note implications of different trim levels
- Estimate used car resale value based on Kelley Blue Book or Consumer Reports
- Include optional inputs for all relevant financing terms and state-specific taxes and fees
- Provide up-to-date federal, state and local incentive estimates
- Include household income tax information inputs to determine incentive eligibility
- Allow direct modification of vehicle price and incentives in addition to inputs specified above

4.3.5 Other

- Include zip code input for tailoring fuel price and incentives estimates
- Allow modification of maintenance costs estimates

5 Conclusion

This research articulated best practices and recommendations for VCC design. We focused on the user interface, or front-end, of VCCs. Further research is needed to develop recommendations for back-end development, including integrations with multiple data sources and cost calculations. Our future research plans include more consultation with EV experts to help develop specifications for back-end programming solutions. A variety of stakeholders, including government agencies, energy utilities, and EV advocacy groups, can use these recommendations to create VCCs that promote EV adoption by providing consumers with accurate and relevant information that highlights the economic, social, and environmental benefits of EVs.

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