ELECTRIC VEHICLE
BENEFIT/COST ANALYSIS
METHODOLOGY BY
THE MARYLAND JOINT-UTILITIES
(FINAL DRAFT)

Prepared by Gabel Associates, Inc.

In Support Of The Electric Vehicle
Benefit Cost Analysis Working Group

November 30, 2021

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TABLE OF CONTENTS

SECTION 1: INTRODUCTION

As part of its Order 89678, the Maryland Public Service Commission (PSC) directed that the standing PC44 stakeholder process form a working group focused on defining a Benefit/Cost Analysis (BCA) methodology that can be used for the assessment of utility electric vehicle (EV) programs. The order directs that the EV-BCA working group make its methodology recommendation by December 1, 2021. That working group has met (virtually) each month since January 2021 for review of relevant background, discussion of stakeholder perspectives on methodology approach, and consensus building.

Consistent with their active participation in the new EV-BCA working group, the Maryland Joint Utilities (MD-JU), including BGE, PEPCO, DPL, Potomac Edison, and SMECO, engaged Gabel Associates to support them throughout this process. This Whitepaper has been developed by Gabel Associates in collaboration with, and the active involvement of, the full MD-JU.

The white paper has evolved through several additional iterations, based on discussion during the calls from June through November, including (on several occasions) written comments from the Maryland Office of People's Counsel (OPC), PSC-staff, and other stakeholders. Significant progress was made reconciling diverse stakeholder input over the last six months of the year, and this final version of the whitepaper is intended to capture that consensus on the overall methodology.

SECTION 2: DESIGN CONSIDERATIONS

As discussed during early working group calls, the methodology definition effort evolved through two phases: a) reaching consensus on an overall approach and assessment framework, including identification of the components to be included in that framework, and b) detailed definition of the computation methods for the methodology defined. Key concepts and terms are further defined in a Glossary at the end of the document.

This section summarizes key considerations distilled from working group discussions, and the principles upon which the recommended methodology is based:

1. The EV-BCA working group considered a wide range of input in developing the EV-BCA framework. Key sources included **methodology used previously by the utilities** as part of multi-year plan filings, examples of EV-BCA done in **other jurisdictions** (such as California and New York), the **National Service Practice Manual (NSPM)**, and methodology currently used by **Maryland's EmPOWER program**.

2. The EV-BCA framework has proceeded through multiple phases of iteration, in response to feedback from stakeholders and discussion within the working group.

3. The MD-JU acknowledges that the NSPM represents a valuable framework for structuring BCA methodologies for a variety of Distributed Energy Resources (DER) – including EVs. The EV-BCA

framework incorporates the NSPM principles while also striving to address the full spectrum of issues that have been raised within the working group, including the need for assessment ratepayer impact as emphasized by several stakeholders.

4. Consistent with NSPM principles, a primary focus for design of the EV-BCA framework was to make sure that Maryland Policy goals have been properly reflected. Many of the State's key goals – especially related to climate change mitigation and public health improvements (through air quality improvements) have been incorporated. Key policy drivers include[1]:
    a. Greenhouse Gas Reduction Act;
    b. Adoption of the California ZEV Framework for LDVs (2011)
    c. Multi-State Zero-Emission Vehicle Memorandum of Understanding;
    d. EV adoption goal-setting (for LDVs): 300K registered EVs in operation by YE 2025;
    e. Transportation Climate Initiative;
    f. ZEEVIC;
    g. Medium- and Heavy-Duty (MHD) ZEV MOU;
    h. Mid-Atlantic Electrification Partnership;
    i. Mid-Atlantic Electric School Bus Experience Project.

5. The MD-JU have developed this methodology specifically to reflect considerations associated with utility EV programs[2]. From the MD-JU perspective, there is no intention, or expectation, that this methodology is generic enough to be applicable to other DERs without further consideration and possible adjustment. That said, some concepts represented within this framework may be applicable to other DERs in the future, although case by case evaluation and fine-tuning will be needed to determine applicability. This working group was chartered by the Commission to focus on developing a methodology for EV-BCA only, and the MD-JU believe it is important to focus this stakeholder effort faithfully on that scope.

6. This recommended methodology is intended to fully address the scope directed by the Commission – specifically regarding utility EV program cost effectiveness and ratepayer impact. The MD-JU acknowledges that there are numerous other questions about EV market development that may be of interest, but which are outside the scope of this analysis.

7. Consistent with the principle of accounting for ALL costs and benefits, it is critical that the methodology allow for appropriate recognition of EV-specific impacts. At a macroscopic level, there are three impacts from widespread vehicle electrification that are intended to be captured within the EV-BCA methodology, as summarized below :

    a. **Changes in Emissions:** Conclusive analysis in multiple jurisdictions has confirmed that EV adoption reduces the absolute mass of key pollutant emissions (especially CO2), and also shifts *where* those emissions happen – from the roadway and nearby communities to less

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[1] This list of policy drivers was provided by PSC staff (Amanda Best)

[2] The language in this section represents the consensus of the MD-JU. Other stakeholders within the working group have a different view on this topic, including the expectation that the recommended framework could be more generally applicable to other DERs.

harmful regions. This improvement in air quality addresses both climate change mitigation and public health goals, with significant equity implications as well.

b. **Reduced Operating Costs:** EV drivers realize significant reductions in vehicle operating costs, both due to the displacement of fuel-purchases with electricity-purchases, and also reduced maintenance costs. This displacement not only reduces the absolute cost of vehicle operation, but also replaces expenditures that typically flow out of state (to petroleum extraction and processing centers) with more local cash flow.

c. **Increased Electricity Use:** Displacing petroleum use with electricity use means that more electricity will flow through the markets and the infrastructure. This increases asset utilization, and could potentially put downward pressure on rates – even for non-EV owners[3]. In particular, utility revenues from EV owners for vehicle charging can reduce revenue requirements from all other (non-participating) ratepayers associated with fixed cost recovery. This is a critical dynamic that provides policy context for consideration of utility EV program, since which non-participating ratepayers could benefit economically (and in other ways) from actions by EV owners.

8. There are several unique aspects about how EV adoption impacts markets, infrastructure, and specific populations. The EV-BCA methodology is intended to fairly account for these characteristics, including:

a. Vehicle electrification represents a fuel switching strategy that also increases the efficiency by which primary energy sources are used, while increasing electricity consumption, reducing net emissions, and shifting where emissions take place. This is a unique impact profile that should be fairly represented in the methodology.

b. The impact of charging investment varies based on how that equipment is used. For example, two physically identical chargers could be used in different ways – one of which increases coincident peak load, and one of which does not. EV assessment methodologies must account for this range of operating characteristics, which have a significant bearing on the resulting impact.

c. Although a primary focus has been on "how a given program promotes EV adoption", that is not the only impact. Some EV programs (like increasing public charging) can help increase EV adoption – in support of state adoption goals. Other programs – such as residential smart charging programs – likely have some impact on adoption, but also mitigate how vehicle charging impacts the grid (and associated ratepayer costs) – in

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[3] Vehicle electrification is not happening in a vacuum, and there are other changes (such as renewables, energy storage, more advanced demand response) that will impact what the net overall impact on rates will be. In addition, exactly HOW vehicle charging emerges – and whether managed charging strategies are used to mitigated impact - will influence the impact on rates as well. Despite those parallel influences, however, a key consequence of using more electricity in support of vehicle charging will be more volumetric flow through both the markets and the infrastructure, and increased utility revenues that could have a beneficial impact on recovery of fixed costs.

support of ratepayer cost containment goals.   The EV-BCA methodology is intended to account for these diverse market impact profiles in appropriate ways.

    d.   Most (if not all) conventional DERs are owned by a single customer, and generate impacts through changes in efficiency or operating profile of that one owner/user. In contrast, in some cases charging infrastructure can be a shared asset (multi-family, workplace, public charging), and impacts must be characterized based on consideration of how this shared asset is used by multiple EV owners.

9. The EV-BCA framework is intended to define a methodology that can guide regulatory approval decisions at the beginning of program life, based on information currently available, with the assumption that more detailed assessment and analysis can be completed at program mid-life or end-point.

10. For all impacts noted in the assessment portfolio (costs, benefits, etc), it is necessary to identify the boundaries within which the analysis takes place. Based on extensive discussion within the working group, as well as consideration of approaches being adopted in other matters or jurisdictions, the working group settled on the following approach regarding analysis boundaries:

    a.   There are TWO sets of boundaries to consider for each impact factor: i) the boundary within which a physical change is computed (e.g. mass reduction in CO_2 emissions), and ii) the metric used to compute the economic value of that physical change (e.g. \$/ton of CO_2 generated or avoided). The following guiding principles are intended to address the need for both boundaries to be clearly and transparently defined for each impact factor.

    b.   Unless explicated defined otherwise below, the physical-change and economic-factor boundaries for all impact factors are the geographic boundaries of the state of Maryland, the population of Maryland, and the vehicles registered in Maryland (or the subset of those vehicles impacted by a utility program). This is appropriate since the intention is to inform Maryland policy-makers, about utility EV programs implemented within the state of Maryland, based on insight about impacts within the State of Maryland.

    c.   The one primary exception is in the area of air emissions and the electricity generation responsible for those emissions, which are a significant part of the analysis overall, but which are also more complicated than other impact factors. Discussion within the working group acknowledged that while there is a goal to be as consistent as possible and to ensure symmetric consideration of costs and benefits, those motivations need to be balanced with the intention to consider the full environmental impact of electricity consumption within MD - regardless of WHERE that consumption is served from across PJM (i.e. the induced generation impact). The boundary decisions must also consider difficult trade-offs that can emerge depending on boundary definitions, physical realities that apply when considering emissions, and the boundaries implicit in the data sources used (which are frequently not consistent or even explicit when considering boundaries).

d. In addition to those factors, there is a design intention to ensure that the framework is appropriate for use by MD policy-makers given overall goals in the state, especially regarding GHG and other emission reductions. For example, boundary decisions that result in a negligible quantification of environmental or public health impact from generation would be inconsistent with state goals to consider emission reductions as a primary motivation in clean energy investment (including EVs). The definition of boundaries should be consistent with what State policies identify as important.

e. The recommended approach to the boundaries for physical impact calculation is as follows:

    i. For all four emissions considered (CO_2, NO_x, SO_2, and PM2.5), the physical boundary of impact is established globally. In the case of CO_2 especially, this approach reflects the physical reality that CO_2 circulates globally and has impacts globally, but also that Maryland residents benefit even if those impacts are realized outside the state. This approach is also consistent with state policies that identify environmental and public health impacts as a primary factor in clean energy investments (including EVs).

    ii. Emission calculations should be based on marginal rates[4], where data is available to establish those metrics. These marginal rates should reflect how intensity is changing over time as a result of changes in the generation fleet. This was referred to within the working group as "long term marginal" rates.

    iii. Given the need to account for changing intensity over time, assumptions about the changing character of generation are necessary. The Maryland Department of Energy (MDE) "Policy Case" should be used as the basis for those assumptions.

    iv. At the current time, emission factors for the MDE "Policy Case" over time can be quantified using the federal AVERT tool. Other credible sources or tools that become available in the future, which are at least as credible and/or accepted as AVERT, may be considered as appropriate.

    v. In summary, the physical emissions boundary are considered to be global for all emissions, as defined by the combination of the MDE "policy case" and the emission intensity factors quantified by the AVERT tool.

f. The recommended approach to the boundaries for economic impact factors is as follows:

    i. The economic impact factors for all emissions (i.e. $/ton of impact) are global, for the same reasons defined above.

    ii. For CO_2 emissions in particular, the EPA's "Inter-Departmental Working Group on the Social Cost of Carbon" (SCOC) provides economic impact factors that are global. This is a frequently cited source for these parameters, and consensus of the working group was that the "2.5% numbers" within that resource would be reasonable, or potentially a lower discount factor if one becomes available from that source (as is currently expected). If the EmPower working group identifies a

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[4] Marginal rates should also be used in consideration of capacity and transmission calculations, to the extent data is available to do so.

specific source for SCOC, and the associated discount factor used, the EV-BCA methodology should track the EmPower methodology[5].

iii. For all other criteria pollutants, consensus was to use the federal COBRA tool for evaluating the economic factors. If feasible, these factors would account for not just gross emission-mass reductions, but also changes in WHERE the emissions take place[6].

g. Whatever discount rate is used to establish the SCOC should also be used to make the NPV calculations for both the societal-scope and ANRI calculations.

11. In some cases, the computational methodologies reflect the realities of what data is available. Where appropriate, this white paper distinguishes between an ideal methodology if sufficient data is available, and estimations or proxy's that may be required due to limitations in data availability. **In several cases, potential data sources are identified to support the intended computation, but specific mention of these sources is not intended to exclude the use of better, more recent, or more granular sources that may become available over time.**

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[5] There were references within the working group discussion about independent SCOC calculations that have been done in other states that might be relevant – those could be adopted for the EV-BCA if the EmPower program endorses those sources as preferred over the existing federal SCOC source.

[6] Existing EPA sources used in prior MD EV-BCA analysis can account for the different monetary impacts associated with mobile sources (typically in high population areas) compared with power plants (typically in lower population areas). Such changes in geography would ideally be accounted for in the criteria pollutant economic factors.

SECTION 3: METHODOLOGY FRAMEWORK

The recommended methodology is based on consideration of numerous guiding sources and collective feedback from stakeholders, and there is consensus within the working group on the framework outlined below.   The EV-BCA framework is based on multiple evaluations that provide a combination of perspectives expected to be useful to the utilities, regulators, and other stakeholders.   The EV-BCA framework includes:

1. **Primary Test - MD EV-JST:** Quantifies the cost effectiveness of utility EV programs resulting from impacts on the utility system, host customers (i.e., participants), and society, consistent with Maryland policy goals (i.e. a Jurisdiction Specific Test, or JST).

2. **Market-Wide Test - MW:** The same methodology as the MD EV-JST, but applied market-wide to quantify the net benefits of vehicle electrification overall when considered on a societal basis. Three sensitivities will be considered: all natural charging, all managed charging, and an intermediate "likely case" as expected result from approved utility filings.

3. **ANRI (all):**   aggregate non-participating-ratepayer impact (ANRI) as induced by the utility program, including both monetized impacts (on utility bills) and important externalities (such as avoided environmental harm and improved public health). This assessment is provided for both each utility EV-program individually, and for the entire portfolio of programs in combination.

4. **ANRI (bills only):** A sensitivity of the ANRI calculation that considers only monetized impact on utility bills (i.e. does not include environmental impact or public health). Both per-program and portfolio-level variations will be developed.

5. **Other Strategic Considerations:** An inventory of other qualitative factors that provide important context for the quantified assessments.

As discussed extensively within the working group, these separate calculations serve different purposes. The Primary Test (MD EV-JST) addresses the question of cost effectiveness at societal scope, but looking only at the impacts directly induced by the utility EV programs.   The Market-Wide Test (MW) applies a similar societal-scope assessment to quantify the merit of vehicle electrification overall. Separately, ANRI assessments addresses the question of how the proposed utility EV programs impact ratepayers, considering either "all impacts" or just monetized impact "on bills only". While these ANRI assessments are not considered a "cost effectiveness test", they address a key policy question identified by PSC-staff (which is also of interest to the utilities)[7]: the **aggregate** impact on **non-participating** ratepayers. The ANRI (bills only) provides the traditional perspective based exclusively on how the utility EV program changes the utility bills of non-participating customers, while the ANRI (all) includes the broader impacts on ratepayers from externalities.   As noted in the NSPM, such additional analyses beyond cost-effectiveness assessments can be important to regulatory decisions on utility investments.

This framework provides a comprehensive approach to quantifying the many ways that EVs impact both society and ratepayers, and allows utility programs to be considered from multiple perspectives.

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[7] The ANRI assessment quantifies important equity considerations when considering ratepayer impacts, but may also help address other important considerations as well.

3.1 THE PRIMARY TEST – THE MD EV-JST

The Primary Test represents a quantification of benefits and costs, using the widely accepted structure in which the net-present-value (NPV) of benefits is divided by the NPV of costs. Any B/C-ratio greater than 1.0 is considered to be cost effective. **Given the policy goals for Maryland and the broad impacts resulting from vehicle electrification, a methodology similar to the traditional Societal Cost Test was used as the basis for defining the Primary Test**[8]. The proposed inventory of costs and benefits was tuned to include consideration of benefits and costs associated with Maryland policy goals, where feasible[9]. As a result, this Primary Test can be considered a Jurisdiction Specific Test (i.e. the MD EV-JST).

The Primary Test is organized according to the following principles:

1. The scope of the MD EV-JST is "societal impacts", specifically the population of the State of Maryland, except when considering emissions whose impacts are considered globally (see detailed discussion about calculation boundaries in Section 2 above). This societal scope therefore reflects impacts realized by customers participating in the various utility EV programs, impacts realized by the utility (which ultimately impact ratepayers), and impacts realized by society at large (within the State, or globally when considering emissions).

2. The MD EV-JST reflects impacts relative to a baseline (as defined further below), and the benefits and costs quantify changes relative to that baseline as induced by the proposed utility programs in question. The baseline should reflect changes in the generation fleet over time, consistent with the MDE "policy case".

3. There is a portfolio of benefits and costs associated with the MD EV-JST, and each are translated into an economic value over a fixed period of time. The time period is generally intended to cover the period over which utility program investments are made, and the "useful life" of the change induced by the utility EV programs.

4. Costs generally include "up-front" costs associated with delivery of the incentive to a participating customer, and recurring costs over the "useful life" assessed in the test. Benefits generally include the recurring stream of annual impacts over the "useful life" realized by impacted populations.

5. The MD EV-JST focuses on the impacts directly induced by the utility program, NOT the total number of EVs on the road.

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[8] In his comments to the working group (June 18, 2021), Chris Neme noted that "… from what we know about the state's broad energy policy goals and objectives, it is likely that a 'Maryland-specific' primary test would be close to a Societal Cost Test (SCT)".

[9] In their comments to the working group regarding the FIRST DRAFT proposal, staff noted that "Staff has no concern with the various cost and benefit inputs to the tests. This is an exhaustive list". Staff went on to note questions about assumptions associated with the proposed FIRST DRAFT tests, which are intended to be further addressed (in part) in this Second Draft proposal. Other details about those assumptions will be addressed as part of the second phase of methodology development, within the scope of BCA and ratepayer impact analysis.

6. The MD EV-JST will be performed for each proposed utility offer individually, then combined to represent a portfolio view of cost effectiveness. It should be noted that individual per-offer tests can be difficult, especially since some programs (like those that change charging behavior) reduce to a small subset of the full SCT benefit or cost portfolio. In addition, there are cross-offer costs that are difficult to separate, and these programs can have a synergistic impact in the market. For those reasons, the MD-JU considers the portfolio view of the Utility Offer (UO) test to be the most representative quantification of cost effectiveness.

3.2 THE MARKET-WIDE TEST

The Market-Wide (MW) test is nearly identical to the MD EV-JST, except that the scope is all vehicles on the road, rather than only those vehicles (or impacts) directly induced by a given utility program. Like the MD EV-JST, this test is based on a ratio of the NPV of benefits over the NPV of costs. The MW-Test quantifies the net benefit of vehicle electrification overall based on a given adoption forecast, not just the impact of the proposed utility programs. This test therefore provides important context for the MD EV-JST.

Because the scope of this test is much larger, important dynamics related to how consumers charge their vehicles can be quantified. The MW-test will be performed for three sensitivities: the case where all vehicles use natural charging, the case where all vehicles use managed charging, and the "likely reality" case between these two extremes expected to result from the current scale of managed charging programs approved for the utility. This approach provides strategic information about two questions: a) the difference in net-benefit that results from full deployment of managed charging, compared with the natural charging baseline, and b) the fraction of the managed charging opportunity represented by current managed charging program approvals.

3.3 AGGREGATE NON-PARTICPATING RATEPAYER IMPACT (ALL)

The Aggregate Non-Participating Ratepayer Impact (ANRI) assessment is not a traditional cost-effectiveness test, but it quantifies the aggregate net impact – either positive or negative – of the proposed utility programs on ratepayers. This is not an examination of specific rate changes or equity considerations, but represents quantification of the net overall impact on ratepayers (collectively) of the proposed utility investment[10]. This is a valuable perspective for policy consideration, and responds directly to staff interest in understanding ratepayer impacts[11].

The scope for this assessment is non-participating ratepayers – i.e. ratepayers that do not own an EV, but which potentially bear part of the cost of utility program investments, and the consequences of those investments in multiple ways. In addition, since this assessment is intended to provide a comprehensive view of ratepayer impact, both the monetized impact on utility bills as well as the net

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[10] This approach reflects the key distinction raised in the June working group between rate-impact and aggregate ratepayer impact.

[11] In their written comments to the working group, in response to the FIRST DRAFT of the MD-JU methodology proposal, Staff noted that "… staff would like to see a ratepayer cost test…. this is an important piece of information to determine if the program benefits ratepayers."

impact of externalities are accounted for. Given that the goal of State policy is to encourage EV adoption to reduced air emissions in response to climate change and public health risks, comprehensive consideration of these impacts is both appropriate and necessary.

The ANRI (All) assessment is based on the following principles:

- The scope of the ANRI (All) Assessment is the utility programs, and market impacts directly induced by those utility programs (i.e. ANRI not a "market-wide test").

- The ANRI (All) Assessment is measured as the NPV of all impact-factors taken together, resulting in a measure of whether aggregate ratepayer impact goes up (a positive number) or goes down (a negative number). The outcome is an NPV (measured in dollars), and is not a "benefits divided by costs" ratio.

- The ANRI (All) Assessment is computed per utility offer, and also combined into a portfolio result.

- The ANRI (All) Assessment considers monetized impacts on non-participating customer utility bills, the value of avoided environmental harm and improved public health associated with reduced air emissions.

- The primary result of the ANRI (All) Assessment is an NPV (either positive or negative), but to provide context that result will be translated to a dollar-impact per residential customer ($/month) considering low, medium, and high examples of residential consumption.

3.4 AGGREGATE NON-PARTICPATING RATEPAYER IMPACT (BILLS ONLY)

The ANRI (Bills Only) Assessment is similar to a more traditional test regarding ratepayer impact, considering only those impacts that are monetized on utility bills. As a practical matter, the ANRI (Bills Only) Assessment is identical to the ANRI (ALL) methodology but excludes consideration of the environmental and public health impacts on ratepayers.

3.5 OTHER CONSIDERATIONS

An inventory of other strategic factors, including more qualitative considerations where appropriate, that provide context for the four quantified tests/assessments.

SECTION 4: IMPACT-FACTOR DEFINITIONS

The MD EV-JST, the MW-Test, and the two ANRI assessments consider a portfolio of factors that impact the sub-population within the scope of the test/assessment. For the MD EV-JST and the MW-Test, these factors quantify benefits or costs. For the ANRI assessments, these factors quantify either an increase or a reduction in ratepayer impact. The term "impact-factor" is used to generically refer to these quantified components.

As represented in the materials reviewed by the working group and outlined generically in the NSPM, these factors include impacts within the power sector (including the utility), those impacts borne by program participants, and impacts realized by society (within the population of Maryland). Note that this inventory represents a super-set of all possible impacts that might apply, and the inventory has been designed to represent Maryland's policy goals. For a given test/assessment and/or utility program, however, some of these components may not be applicable – see the offer-class mapping in Section 5.

These key impact-factors are defined below. For details on additional key terms or concepts, please see the glossary.

Utility (and other power sector) Impacts:

1. **Utility Program Administration:** All costs associated with administration, incentive delivery, marketing and customer outreach, compliance reporting, evaluation and BCA, and ongoing costs that may be applicable such as data collection or networking costs.

2. **Utility Program Implementation Costs:** One-time costs associated with creating programs, including changes in IT systems, billing system changes, etc.

3. **Impacts on Capacity Costs:** This factor represents changes in allocated capacity costs associated with coincident peak power levels, and it can be either a cost or a benefit. It is a cost if there is additional coincident peak load associated with vehicle charging. It is a benefit if there is avoided (or deferred) incremental coincident peak that would have otherwise been induced by vehicle charging.

4. **Impacts on Transmission Costs:** This factor represents changes in transmission costs associated with coincident peak power levels, and it can be either a cost or a benefit. It is a cost if there is additional coincident peak load associated with vehicle charging. It is a benefit if there is avoided (or deferred) incremental coincident peak that would have otherwise been induced by vehicle charging.

5. **Wholesale Energy Cost Impacts:** Based on changes in aggregate load associated with EV charging, there will be a change in the average cost of wholesale power applicable to all ratepayers. For example, if a program increases EV adoption and therefore induces charging-related load, the increase in consumption will cause market clearing prices for energy increase. In addition, a program designed to modify EV charging behavior will also change

the aggregate load-shape, thereby changing the average cost of wholesale power applicable to all ratepayers. Both of these changes are captured under this impact category.

6. **Increased Electricity (KWHr) Costs (for EV charging):**   Costs associated with the purchase of additional wholesale energy supply (kwhrs) associated with vehicle charging, including any PJM assessed fees or ancillary costs.

7. **Impacts on Grid Reinforcement:** This factor accounts for the impact on potential upgrades to the distribution system to support vehicle charging. If the aggregate impact of vehicle charging forces Grid Reinforcement investment, this factor is a cost. If Grid Reinforcement investment can be avoided (or deferred), this factor can be a benefit. The nature of the calculation for this factor depends on the test being done, its scope, and the time horizon over which the analysis is being done.

8. **Utility-Owned EV Charger – Costs:**   The cost of utility investment in public charging infrastructure (design, construction, operation).

9. **Utility-Owned EV Charger – Usage Revenues From EV Drivers:** Utility receipts associated with EV-driver usage of utility owned chargers. This factor is considered a transfer within societal-scale tests, and is therefore not included in the MD EV-JST or MW-Test. It is considered a decrease under the ANRI assessments.

10. **Increase RPS Compliance Costs:**   The costs associated with increased RPS compliance requirements associated with increased electricity generation to serve vehicle charging needs.

11. **T&D Losses:** In cases where electricity consumption increases due to vehicle charging, there will be additional Transmission and Distribution (T&D) losses.

12. **Utility Equipment Incentives:**   The full cost of incentives provided by the utility to a participating customer for purchase and/or installation of charging infrastructure. These investments are recovered from ratepayers. Example: a rebate paid for customer purchase of a smart charger. This factor is considered a transfer within societal-scale tests, and is therefore not included in the MD EV-JST or MW-Test. It is considered an increase under the ANRI assessments.

13. **Utility Rate Incentives:** Any incentive provided to a customer in the distribution component of the utility bill, in cases where EV-specific rates or programs are different than normal treatment under an established tariff. Example: discounts provided on demand charges normally included on a commercial tariff. This factor is considered a transfer within societal-scale tests, and is therefore not included in the MD EV-JST or MW-Test.

14. **Increased Utility Revenues:** Increased utility revenues (not including supply) associated with EV-owners charging their vehicles. This factor is considered a transfer within societal-scale tests, and is therefore not included in the MD EV-JST or MW-Test.

15. **Participant Impacts** (Participant = EV owner, customer of utility program)

16. **Incremental EV Purchase Cost:** The difference in price between an EV and a non-EV that would have otherwise been purchased by the vehicle owner.

17. **EV Charger Costs:** The full costs of buying, installing, and operating (i.e. data and network charges, maintenance) EV charging infrastructure. Any applicable utility charger incentives are not reflected in this factor (since that is a transfer). This factor is a cost under the MD EV-JST and MW tests, and is not applicable under the ANRI assessments.

18. **Avoided Vehicle Fuel Costs:** Savings that result from eliminating gasoline, diesel and/or other liquid fossil fuel purchases that are avoided by "fueling" an EV with electricity instead. This calculation is adjusted to reflect EV-owners paying "their fair share" toward Maryland state costs for infrastructure investment (i.e. Maryland fuel taxes).

19. **Savings From Decreased Vehicle Maintenance:** The value of reduced maintenance costs, which is recognized by the EV owner as a benefit.

20. **Federal Tax Incentive (EV purchase):** The value of any federal tax credit (or similar) incentive that may be due in support of an EV purchase, which is recognized by the EV owner as a benefit.

Societal Impacts:

21. **Benefits From Reduced GHG Emissions:** The economic value of reduced net GHG emissions, based on estimates for the "societal cost of carbon", represented as a societal benefit. The changes in emissions should reflect both absolute changes in emissions intensity (mobile sources vs generation sources), but also changes in emissions associated with differences in asset dispatch.

22. **Public Health Value Of Reduced/Shifted Emissions:** The economic value of improved public health associated with reduced net emission of criteria pollutants, combined with a shift in where those emissions take place (from the roadway to the power plant), represented as a societal benefit. The changes in emissions should reflect both absolute changes in emissions intensity (mobile sources vs generation sources), but also changes in emissions associated with differences in asset dispatch.

There are a variety of impact-factors that are sometimes included in SCT-style tests, and/or which are related to Maryland objectives, that were not included. These factors were considered as part of the methodology design, but in the case of EV programs were determined to be either negligible or impossible to calculate with credibility. However, the Commission may elect to qualitatively consider them together with the quantified benefit cost analyses and non-participant impact assessments previously described.

These excluded factors are summarized below for completeness, including the reason they aren't currently proposed to be included in monetized calculations of cost-effectiveness. If new information

enabling them to be quantified and monetized becomes available, they could be included in future benefit-cost analysis frameworks.

1. **Strategic Value Of Reduced Petroleum Use:** No quantifiable metrics for this objective in Maryland, and/or no established impact computation methods.

2. **Changes in Risk:** No quantifiable metrics for this objective in Maryland, and/or no established impact computation methods.

3. **Changes in Resilience:** No quantifiable metrics for this objective in Maryland, and/or no established impact computation methods. It should be noted that vehicle-to-home (V2H) capabilities – once enabled through future vehicle and charger innovations – could provide significant resiliency value to the home. That technology is still in early stages and not universally available, in addition to there being limited methodology for valuing this resiliency value. For those reasons, a resiliency impact-factor is not included at this time, but could be added to the portfolio when that changes.

4. **Changes in Security:** No quantifiable metrics for this objective in Maryland, and/or no established impact computation methods.

5. **Impacts on Water Use:** No quantifiable metrics for this objective in Maryland, and/or no established impact computation methods.

6. **Impacts on Attainment Of MD EV-Adoption Goals:** Maryland has clear targets for EV adoption, but no established impact computation methods.

SECTION 5: MAPPING IMPACT-FACTORS TO OFFER-CLASSES

The inventory of impact-factors summarized in Section 4 represents the super-set of components that could be included in a particular test or assessment. This section outlines how these impact-factors are used by the MD EV-JST, and MW-Test, and the ANRI assessments when applied to real-world utility EV programs and the associated market impacts.

5.1 INTRODUCTION TO IMPACT-FACTOR MAPPING

As summarized in Section 3, the various tests and assessments differ in the scope of impact considered. As a result of those differences, and in consideration of principles related to the avoidance of double-counting and ensuring complete and symmetric inclusion of both costs and benefits, the portfolio of impact-factors considered in each calculation varies. The following chart provides a high-level summary of how the impact-factors are included in each protocol.

Figure 5.1 – 1: Impact-Factors for Different Tests and Assessments

Impact-Factor	MD EV-JST	MW-Test	ANRI (All)	ANRI (Bills Only)
Utility (and Power Sector) Impacts				
Utility Program Administration Costs	Cost	Cost	Increase	Increase
Utility Program Implementation Costs	Cost	Cost	Increase	Increase
Impacts On Capacity Costs	Cost or Benefit	Cost or Benefit	Increase or Decrease	Increase or Decrease
Impacts On Transmission Costs	Cost or Benefit	Cost or Benefit	Increase or Decrease	Increase or Decrease
Wholesale Energy Cost Impacts	Cost or Benefit	Cost or Benefit	Increase or Decrease	Increase or Decrease
Increased Electricity (KWHr) Costs (for EV charging)	Cost	Cost	Increase	Increase
Impacts on Grid Reinforcement	Cost or Benefit	Cost or Benefit	Increase or Decrease	Increase or Decrease
Utility-Owned EV Chargers - Costs	Cost	Cost	Increase	Increase
Utility-Owned EV Chargers - Usage $ From EV Drivers	Transfer	Transfer	Decrease	Decrease
Increased RPS Compliance Costs	Cost	Cost	Increase	Increase
T&D Losses	Cost or Benefit	Cost or Benefit	Increase or Decrease	Increase or Decrease
Utility Equipment Incentives	Transfer	Transfer	Increase	Increase
Utility Rate Incentives	Transfer	Transfer	Increase	Increase
Increased Utility Revenues	Transfer	Transfer	Decrease	Decrease
Participant Impacts(from EV Driver Perspective)				
Incremental EV Purchase Costs	Cost	Cost	N/A	N/A
EV Charger Costs (equipment and installation)	Cost	Cost	N/A	N/A
Avoided Vehicle Fuel Costs	Benefit	Benefit	N/A	N/A
Savings From Decreased Vehicle Maintenance	Benefit	Benefit	N/A	N/A
Federal Tax Incentive (EV purchase)	Benefit	Benefit	N/A	N/A
Societal Costs or Benefits (from Society's Perspective)				
Value Of Reduced GHG Emissions	Benefit	Benefit	Decrease	N/A
Public Health Value Of Reduced/Shifted Emissions	Benefit	Benefit	Decrease	N/A

5.2 OFFER CLASSES

The impact-factors outlined above represent a super-set of components that might be applicable to a particular utility EV program. As noted in Section 2 and 3, however, each of these programs impacts the market in a different way – for example, some have little impact on adoption but change customer charging behavior, while others more directly induce EV adoption (and trigger the costs and benefits associated with that adoption). While the broad inventory of benefit/cost elements considered for each utility EV program is consistent, some of those elements may not be applicable depending on the offer. This section defines how the impact-factors map to generic classes of utility EV programs, within the context of the two societal scope tests (the MD EV-JST and the MW-Test) and the two ANRI assessments. Note that in some cases a given impact factor could have a positive or negative impact, depending on the details.

Given the current spectrum of utility EV programs in Maryland, the utility-off mapping is based on three types of utility offers:

- **Managed Residential Charging Programs (UO – 1):** programs which combine the charging infrastructure with economic incentives to encourage residential customers to charge their vehicles at preferred off-peak times.

- **Multi-Family Charging Programs (UO – 2):** Programs intended to provide level-2 charging for residents of multi-family properties, thereby ensuring that those residents are not blocked from EV adoption based on charging access limitations.

- **Public Charging Programs (UO – 3):** Programs for utility-owned level-2 and DCFC chargers that are available for public use, and which are intended to stimulate adoption by addressing consumer concerns about the shortage of public charging capacity (and the geographic distribution of that capacity).

If new utility EV programs are introduced that don't map cleanly into one of these three offer-classes, a customized mapping would need to be created for that new class. In this way, this proposed methodology can be adapted to an evolving portfolio of programs over time.

5.3 SOCIETAL SCOPE TESTS – IMPACT-FACTOR MAPPING

The MD EV-JST and the MW-Test are each an SCT-style assessment, and the rules generally applicable to SCT tests serve to guide the impact-factor mapping. In particular, several impact-factors are typically considered "transfers" within societal-scope. The following chart summarizes how the impact-factors are combined for the three offer-classes under the MD EV-JST and for the MW-Test. As summarized in Section 3, the Market-Wide test will be performed for three variations (natural charging, managed charging, most-likely charging profiles), but the structure of costs and benefits are consistent in all three cases.

Figure 5.3 – 1: Mapping of "Impact Factors" To Societal-Scale Tests

Impact-Factor	MD EV-JST (UO-1): Residential Managed Charging	MD EV-JST (UO-2): Multi-Family Charging	MD EV-JST (UO-3): Utility Owned Public Chargers	Market-Wide Test
Computation Scope:	Induced Charging Behavior	Induced Adoption	Induced Adoption	All EVs On The Road
Baseline:	EV Owner, Nat-Chrging	No EV Adoption	Pull-Through Adoption	Depends on Scenario
Utility (and Power Sector) Impacts				
Utility Program Administration Costs	Cost	Cost	Cost	Cost
Utility Program Implementation Costs	Cost	Cost	Cost	Cost
Impacts On Capacity Costs	Benefit	Cost	Cost	Cost or Benefit
Impacts On Transmission Costs	Benefit	Cost	Cost	Cost or Benefit
Wholesale Energy Cost Impacts	Benefit	Cost or Benefit	Cost or Benefit	Cost or Benefit
Increased Electricity (KWHr) Costs (for EV charging)	N/A	Cost	Cost	Cost
Impacts on Grid Reinforcement	Benefit	Cost	Cost	Cost
Utility-Owned EV Chargers - Costs	N/A	N/A	Cost	Cost
Utility-Owned EV Chargers - Usage $ From EV Drivers	N/A	N/A	Transfer	Transfer
Increased RPS Compliance Costs	N/A	Cost	Cost	Cost
T&D Losses	Benefit	Cost	Cost	Cost
Utility Equipment Incentives	Transfer	Transfer	Transfer	Transfer
Utility Rate Incentives	Transfer	Transfer	Transfer	Transfer
Increased Utility Revenues	Transfer	Transfer	Transfer	Transfer
Participant Impacts(from EV Driver Perspective)				
Incremental EV Purchase Costs	N/A	Cost	Cost	Cost
EV Charger Costs (equipment and installation)	N/A	Cost	Cost	Cost
Avoided Vehicle Fuel Costs	N/A	Benefit	Benefit	Benefit
Savings From Decreased Vehicle Maintenance	N/A	Benefit	Benefit	Benefit
Federal Tax Incentive (EV purchase)	N/A	Benefit	Benefit	Benefit
Societal Costs or Benefits (from Society's Perspective)				
Value Of Reduced GHG Emissions	N/A	Benefit	Benefit	Benefit
Public Health Value Of Reduced/Shifted Emissions	N/A	Benefit	Benefit	Benefit

5.4 ANRI ASSESSMENTS – IMPACT-FACTOR MAPPING

As summarized in Section 3, the two ANRI Assessments are not a test of cost effectiveness (as defined by the NSPM), but it is intended to respond to PSC staff (and utility) needs for understanding aggregate ratepayer impacts. Rather than looking at "costs" and "benefits", impact-factors for this assessment reflect either an increase or decrease in costs to ratepayers. The net impact of those factors – in aggregate – will be quantified as a NPV of all factors. The ANRE (All) considers at ALL impacts on non-participating ratepayer (both impacts monetized on a utility bill, and externalities), and the ANRI (bills only) is a more narrow protocol that considers monetized impacts on utility bills only. The following chart summarizes how the impact-factors are combined for the ANRI assessments across the three offer-classes. Note: the ANRE assessments are defined only for specific utility programs (separately, and in combination), and so a market-wide variation is not relevant.

The impact-factors for the ANRI calculations for each offer-class are summarized in the chart below.

Figure 5.4 – 1: Mapping of "Impact Factors" To Utility Offers For ANRI Calculations

Impact-Factor	UO-1: Residential Managed Charging	UO-2: Multi-Family Charging	UO-3: Utility Owned Public Chargers
Computation Scope:	Induced Charging Behavior	Induced Adoption	Induced Adoption
Baseline:	EV Owner, Nat-Chrging	No EV Adoption	Pull-Through Adoption
Utility (and Power Sector) Impacts			
Utility Program Administration Costs	Increase	Increase	Increase
Utility Program Implementation Costs	Increase	Increase	Increase
Impacts On Capacity Costs	Decrease	Increase	Increase
Impacts On Transmission Costs	Decrease	Increase	Increase
Wholesale Energy Cost Impacts	Decrease	Increase or Decrease	Increase or Decrease
Increased Electricity (KWHr) Costs (for EV charging)	Increase	Increase	Increase
Impacts on Grid Reinforcement	Decrease	Increase	Increase
Utility-Owned EV Chargers - Costs	N/A	N/A	Increase
Utility-Owned EV Chargers - Usage $ From EV Drivers	N/A	N/A	Decrease
Increased RPS Compliance Costs	Increase	Increase	Increase
T&D Losses	Decrease	Increase	Increase
Utility Equipment Incentives	Increase	Increase	Increase
Utility Rate Incentives	Increase	Increase	Increase
Increased Utility Revenues	Decrease	Decrease	Decrease
Participant Impacts(from EV Driver Perspective)			
Incremental EV Purchase Costs	N/A	N/A	N/A
EV Charger Costs (equipment and installation)	N/A	N/A	N/A
Avoided Vehicle Fuel Costs	N/A	N/A	N/A
Savings From Decreased Vehicle Maintenance	N/A	N/A	N/A
Federal Tax Incentive (EV purchase)	N/A	N/A	N/A
Societal Costs or Benefits (from Society's Perspective)			
Value Of Reduced GHG Emissions	N/A	"All" Case Only	"All" Case Only
Public Health Value Of Reduced/Shifted Emissions	N/A	"All" Case Only	"All" Case Only

SECTION 6: COMPUTATION OF IMPACT FACTORS

This section summarizes the computational approach associated with each impact factor. The computation method must include consideration of the scope (number of EVs used as the basis for quantifying induced impact), baseline (calculation of a change relative to *what?),* and the protocol associated with each factor (i.e. the arithmetic to be used, including identification of the key variables involved), and data sources (i.e. where key assumptions and or inputs for the identified variables).

In some cases, the computational method is constrained by the data available for the calculation. In those cases, an "ideal" computation method is identified, along with the "best available" methodology accepted at the current time.

Utility (and other power sector) Impacts:

1. **Utility Program Administration Costs:** Taken from utility program budgets, in nominal dollars each year.

2. **Utility Program Implementation Costs:** Taken from utility program budgets, in nominal dollars each year.

3. **Impacts on Capacity Costs:** Based on projections of allocated PJM capacity costs for the relevant utility zone, measured in $/MW-day (nominal $ for each year over the period), multiplied by the expected change in aggregate EV-charging induced load (in MW) during the typical PJM coincident peak hour for the relevant utility zone. Changes in capacity can be either positive or negative depending on the utility offer – for UO1 (residential smart charging), peak MW declines due to the impact of the managed charging program, but for UO2 (multi-family) and UO3 (public charging) peak MW increases. For the UO1 calculation, it is necessary to have a detailed time-of-day distribution for both managed and natural charging scenarios. For the UO2 and UO3 calculations, it is necessary to have a projected time-of-day distribution for the charging induced by the utility offer. The PJM designed capacity "reserve factor" is used to inflate the amount of capacity required, but T&D losses are not represented to avoid double counting with a separate line for that purpose.

4. **Impacts on Transmission Costs:** Based on projections of allocated PJM transmission costs for the relevant utility zone, measured in $/peak-MW (nominal $ for each year over the period), multiplied by the expected change in aggregate EV-charging induced load (in MW) during the typical PJM coincident peak hour for the relevant utility zone[12]. Changes in transmission can be either positive or negative depending on the utility offer – for UO1 (residential smart charging), peak MW declines due to the impact of the managed charging program, but for UO2 (multi-family) and UO3 (public charging) peak MW increases. For the UO1 calculation, it is necessary to have a detailed time-of-day distribution for both managed and natural

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[12] There may be a "time lag" between when EV charging changes peak load and when PJM authorizes incremental transmission construction and the associated changes in transmission costs. These delays are difficult to model, and to be conservative, are assumed to arise at the time peak loading changes – although in reality those cost impacts are probably deferred in time.

charging scenarios[13]. For the UO2 and UO3 calculations, it is necessary to have a projected time-of-day distribution for the charging induced by the utility offer. T&D losses are not represented to avoid double counting with a separate line for that purpose.

5. **Wholesale Energy Cost Impacts:** Use PJM asset-dispatch simulation to compute the gross average cost of wholesale electricity for the modified load (resulting from vehicle charging) compared with the baseline load. Consistent with the definition in Section 4, this impact factor is intended to quantify all the consequences of a changes in induced load (and timing thereof), including impacts on clearing prices. This impact is modeled hourly over the multi-year period under investigation. The resulting $/kwhr rate is then applied to the kwhrs consumed by non-participating ratepayers.

6. **Increased Electricity (KWHr) Costs (for EV charging):** The wholesale costs of electricity associated with vehicle charging, based on marginal costs, and including any associated PJM supply charges (ancillary, etc), but not capacity or transmission costs.

7. **Impacts on Grid Reinforcement [14]:** This factor is specifically focused on widespread reinforcement required in the distribution system (transmission or generation is addressed separately through the transmission, capacity, and wholesale cost factors). This factor could be a cost (for offers that encourage EV adoption) or a benefit (for offers that avoid peak-coincident peak load additions through managed charging). Grid reinforcement impacts will be quantified using the same methodology recommended for use in the EmPower program BCA analysis (i.e. the opposite of "avoided distribution investment" associated with load reductions).

8. **Utility-Owned EV Charger – Costs:** Taken from utility program budgets, in nominal dollars each year, for design, construction, operation. Don't include electricity supply costs, since those are already reflected in the wholesale supply costs line.

9. **Utility-Owned EV Charger – Usage Revenues From EV Drivers:** Based on estimated utilization (from real-world usage statistics), projected over time, and assumed pricing.

10. **Increased RPS Compliance Costs:** The marginal RPS costs ($/MWHR) applied against all vehicle charging volume.

11. **T&D Losses:** A two part calculation, based on a marginal T&D loss factor for the utility zone (supplied by the utility): a) for the kwhr-volume of vehicle charging multiplied by the loss

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[13] It is not necessary to account for "free ridership" under this UO1 methodology, since the natural TOD distribution is a *measured* curve that implicitly includes the fraction of users that would naturally charge at off-peak times even though not motivated economically (via the utility offer) to do so.

[14] The consensus of the MD-JU is that in reality Grid reinforcement costs are not infinitely granular – i.e. reinforcement costs are not automatically triggered when a single EV is added. It is also not perfectly linear – i.e. the impacts of two EVs may not be twice the cost of adding one EV. The preferred methodology would therefore be to apply a threshold (based on EV penetration) below which costs are not considered applicable (i.e. those loads are absorbed by existing headroom within the distribution system. However, given the current lack of an accepted method for determining this threshold, the extremely unrealistic but common approach used in other BCA methodologies is recommended.

factor multiplied by the average wholesale cost of electricity, and b) for any change (positive or negative) in aggregate charging-induced load at the typical PJM coincident peak for the utility zone multiplied by the loss factor multiplied by projected capacity and transmission unit-cost factors.

12. **Utility Equipment Incentives:** Taken from utility program budgets, in nominal dollars each year ($/customer), applied against projected adoption levels for the program (customer/year).

13. **Utility Rate Incentives:** Taken from utility program budgets, in nominal dollars each year ($/customer), applied against projected adoption levels for the program (customer/year).

14. **Increased Utility Revenues:** An estimate of total incremental utility revenues (distribution component only), built up from billing determinants for both per-kwhr and per-kw rates, times incremental loads induced by vehicle charging. This calculation requires an estimate of the distribution of charging across residential and non-residential tariffs.

Participant Impacts (Participant = EV owner, customer of utility program)

15. **Incremental EV Purchase Costs:** In the ideal case, these costs would be based on a comprehensive projection of EV costs vs comparable ICE costs on a per-vehicle or market-segment basis. Such granular data is not currently available on a representative basis, and the computation method for this impact factor will need to reflect the data source used. One known source for this information – which provides these estimates on an "average vehicle" basis: an NREL study on projected base MRSPs for various vehicles, which can be tuned to the vehicle mix associate with a given market. Other sources may become available over time, if they are at least as granular and rigorous as the existing NREL source.

16. **EV Charger Costs (equipment and installation):** Project the average costs for EV charger costs (equipment, installation, make-ready, operating costs if any), by charging segment, multiplied by the number of chargers required over the period.

17. **Avoided Vehicle Fuel Costs:** Drivers that adopt EVs eliminate (or reduce) expenditures related to fuel consumption. Use NREL projections of vehicle efficiencies (for ICE vehicles), VMT data, and vehicle fuel costs (gasoline, diesel, etc) to compute EV owner fuel expenditure reductions. Adjust these savings to account for EV owners paying the per-mile equivalent of the current state gasoline tax.

18. **Savings From Decreased Vehicle Maintenance:** Compute the difference in maintenance (typically on a per-mile basis) between an average EV and an average ICE vehicle using third party data. Recommend source: annual AAA estimates on vehicle maintenance costs.

19. **Federal Tax Incentive (EV purchase):** Based on existing federal purchase incentives (currently a maximum $7,500 tax credit), compute the average incentive based on historical sales distribution, multiplied by the relevant forecast of vehicle sales.

Societal Impacts:

20. **Value of Reduced GHG Emissions:** Based on average EV (miles/kwhr) and traditional ICE vehicle (mpg) efficiencies, and mobile source emission factors (from EPA) and generation emission factors (from PJM), compute the absolute change in gross CO2 emissions resulting from the EV adoption scenario under consideration. Multiply this by the federal inter-departmental determination of the "social cost of carbon" (for the mid-range, 2.5% discount factor) [15]. This analysis primarily quantifies the "social cost" of climate change impacts resulting from CO2 emissions.

21. **Public Health Value Of Reduced/Shifted Emissions:** Based on average EV (miles/kwhr) and traditional ICE vehicle (mpg) efficiencies, and mobile source emission factors (from EPA) and generation emission factors (from eGrid and EPA), compute the absolute change in gross emissions resulting from the EV adoption scenario under consideration. Multiply this by LBL factors for mobile and stationary sources. Focus on NOx, SO2, and PM2.5.

SECTION 7: COMMON PARAMETERS

Section 6 summarizes the computation methodologies (and in some cases, provides information on sources) associated with the distinct impact parameters included in the EV-BCA framework. In addition, there are a variety of other "Common Parameters" that will be used in key calculations.

Key common parameters include:

1. **NPV Discount Factor:** the percentage used in all net present value calculations. As noted in Section 2, the discount factor used to select a particular set of "Social Cost of Carbon" parameters should also be used in the NPV calculations for both societal-scope and ANRI calculations.

2. **Electricity Cost Inflation:** the Y/Y inflation in electricity costs overall, including aggregate impact of supply, transmission, and utility costs.

3. **Other Cost Inflation:** the y/y inflation for all other costs besides electricity.

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[15] The EPA "Social Cost of Carbon" reference uses 5%, 3%, and 2.5% datasets.

SECTION 8: IMPORTANT CHARGING DATA REQUIREMENTS

As noted in Section 6, several of the EV-BCA computations depend on real-world data about how, when, and where EV drivers charge their vehicles. There isn't a "single charger" associated with each vehicle – instead, each EV is supported by a full ecosystem of chargers that include private residential chargers, shared-use chargers in multi-family settings, workplace and fleet chargers, and public chargers. There is a growing need for the utilities to collect representative information from customer chargers so that the charging behavior (across the ecosystem) can be quantified in a consistent and granular way. The better this "charging behavior" data set, the better the BCA computations can be in both accuracy and confidence. This same "charging data" will be needed for a variety of other purposes, including program evaluation, program design and optimization, overall market development planning, infrastructure capacity planning, and distribution system impact assessments (among others).

The following details focus only on important data coming from EV chargers – there are a variety of other data elements and sources that will be needed to inform the EV-BCA calculations. Particular attention is needed on EV charging data since this is a relatively new and evolving market, whereas other important factors can be based on experience with other BCA methodologies where there is significant precedent.

Based on the protocols defined in Section 6, the following inventory of data represents a set of "minimum common requirements" for charging data collection across different technologies and charger settings. Two groups of data are needed, with each reported periodically (~monthly): transaction data which characterizes each charging session, and data about the data sources that provide the data. Note that "data source" is a genericized concept that includes physical chargers, but may also include the vehicles themselves and/or specialized metrology.

For each charging transaction, reporting at least monthly, the following information is required:

1. A unique "reporting entity" identifier, usually the network operator through which transaction data is reported
2. A unique data source identifier (typically a "charger ID")
3. A unique charging transaction (or "session") ID
4. Which port was used to deliver the transaction (applicable for multi-port chargers)
5. Four timestamps that characterize each transaction: plug_in, plug_out, charging_start, and charging_end.
6. Charging duration (which may be different than the difference between charging_end and charging_start).
7. The quantify of kwhrs delivered with each charging transaction
8. A 15-min load profile (i.e. interval data) for each charging transaction
9. The amount charged (to the EV driver) for the charging transaction (where applicable)
10. The above information is required for each transaction. There are a variety of additional fields desired for each transaction, but which are optional: vehicle ID, vehicle start and end State-Of-Charge, vehicle mileage, charging duration (may be different than the difference between charging_start and charging_end), peak KW, payment method, transaction_end_event_type, etc.
11. The "scope" of each transaction is everything that happens between the "plug-in" and "plug-out" events for a given charger/vehicle interaction. Any interrupted charging sessions should be

consolidated into a single transaction data set that covers the total kwhr-energy delivered and period of vehicle connection.

Separately, it is important to have accurate information about each charger (or other data source, such as a vehicle or telematics device). For each unique "data source ID" referenced in the monthly transaction data, information about the data source (i.e. charger in most cases) is necessary. Key fields include:

1. A unique "reporting entity" identifier, usually the network operator through which transaction data is reported
2. Unique data source identifier (allows for cross-referencing with transaction data)
3. Type of data source (charger make and model, or other data source identifier, etc)
4. Number of ports
5. Rated power (per port when operated simultaneously)
6. Location Address, including Host Site name (where applicable)
7. Owner/operator name
8. Service Type Code (dedicated service, behind the meter)
9. Utility providing service
10. Utility account number
11. Charge Setting (private home, retail, etc)
12. When commissioned
13. Operating status at time of report (active, inactive, etc)
14. Outage count (for the reporting period)
15. Outage duration (in minutes, total of all outages)

SECTION 9: GLOSSARY OF ADDITIONAL TERMS

The Section on Impact-Factors included definitions of the portfolio of elements that are to be included in the overall assessment framework. This Glossary provides a definition of other important terms or concepts. The goal in this case is to provide definitions for use within the scope of this whitepaper only.

1. **Baseline**: All Benefit/Cost or ratepayer assessments are based on the INCREMENTAL impact of a proposed utility investment compared with the baseline. The baseline represents the conditions for the impacted population (i.e. analysis scope) had the proposed investment not been made. The method by which a baseline is established can have a large impact on Benefit/Cost results.

2. **Benefit/Cost:** A quantified assessment of whether a particular population that is impacted by a proposed utility investment is beneficial, meaning that the "benefits exceed the costs". A Benefit/Cost Analysis (BCA) typically quantifies all costs and benefits economically, represents those impacts through a Net Present Value (NPV) calculation, and determines the NPV for all individual impacts when grouped together into Benefits and Costs categories. The Benefit/Cost ratio reflects the NPV of Benefits divided by the NPV of Costs, such that a ratio greater than one indicates that benefits exceed costs. BCA is typically synonymous with "cost effectiveness".

3. **Charger**: As used within this whitepaper, a charger is the equipment used to deliver charging services to an EV. It typically includes a physical "box" that contains power electronics and user interfaces, controlling the delivery of power (either AC or DC) through a plug to a vehicle. There are different kinds of chargers, and a variety of standards apply.

4. **Charging Infrastructure:** The electrical equipment needed to provide power to a physical charger. That typically includes conductors, trenching, conduit, safety equipment, switchgear, metering, etc. Chargers can be implemented behind new service dedicated to the chargers, or behind existing meters. This infrastructure is often referred to as the charging "make-ready", which could potentially have both utility-side and customer-side components.

5. **Cost Effectiveness:** See "Benefit/Cost".

6. **DC Fast Charger (DCFC):** A charger that requires high-power AC supply, and which typically delivers DC power to the vehicle at high power levels (at least 50KW, up to 350KW, in some cases higher). There are three different types of DCFC plugs in the US: CCS, CHAdeMO, and a proprietary solution exclusive to Tesla vehicles.

7. **Electric Vehicle:** A vehicle that uses an electric motor to turn the wheels, and for purposes of this whitepaper, is supplied by an on-board battery that has been charged predominantly from a source external to the vehicle. There are two types of EVs: Battery Electric Vehicles (BEVs) that operate exclusively from battery power, and Plug-in Hybrid Electric Vehicles that can run from either battery power (charged from an external source) or an on-board fueled engine used to create electricity. BEVs and PHEVs are referred to collectively as Plug-In Electric Vehicles (PEVs),

meaning any vehicle with a plug. Traditional "hybrids", without a plug, are not considered PEVs. "EV" and "PEV" are synonymous and used inter-changeably.

8. **Impact-Factor:** For purposes of this whitepaper, an "impact-factor" is any parameter that quantifies an impact on an identified population, and which generically include parameters that define benefits, costs, or increases/decreases in costs. Impact-factor is a generic collective noun for the portfolio of components used in an assessment of cost effectiveness or ratepayer impact.

9. **Level 2 Charger:** A Charger that requires 240V AC power, and which typically delivers AC charging power to the vehicle between 3.3 and ~20KW. There is a single standard (J1772) which is used by most EVs for Level2 charging, sometimes known as "L2 charging".

10. **Ratepayers**: for purposes of this whitepaper and the proposed methodology framework, "ratepayers" refers collectively to all utility customers that pay utility bills, as an aggregate group. It explicitly does not mean specific or individual ratepayers.

11. **Rates**: the prices, typically associated with specific tariffs, and often structured on a flat fees, per-kwhr, or per-KW basis, used to calculate a customer's bill. Different rates are defined (through tariff) for different rate-classes.