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**Total Energy Cycle Assessment
Of Electric and Conventional Vehicles:
An Energy and Environmental Analysis**

**Volume IV:
Peer Review Comments on Technical Report**

Prepared by
Argonne National Laboratory (ANL)
National Renewable Energy Laboratory (NREL)
and
Pacific Northwest National Laboratory (PNNL)
for
U.S. Department of Energy
Office of Energy Efficiency
and Renewable Energy

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September 19, 1997.

Ms. Margaret Singh
Argonne National Laboratory
955 L'Enfant Plaza S.W.
Suite 6000
Washington, D.C. 20024

Subject: Comments on Draft Total Energy Cycle Assessment
 for Electric Vehicles ("EVTECA")

Dear Ms. Singh:

The American Petroleum Institute ("API") is pleased to offer these comments on the July 1997 draft total energy cycle assessment for electric vehicles ("EVTECA"). API is a trade association consisting of over 300 members involved in all aspects of petroleum exploration, production, product manufacturing and distribution.

The July 14, 1997 cover letter from Eric Peterson of the U.S. Department of Energy (DOE) that was used to distribute the draft EVTECA says the study has been underway for several years. Reports such as the EVTECA may be used by DOE and perhaps other federal and state agencies to justify policy decisions that could cost the U.S. economy many millions of dollars in increased vehicle and electricity infrastructure costs. For example, results from the final EVTECA may play a role in helping DOE determine any benefits of alternative fuels on a life cycle basis as required by the Energy Policy Act of 1992 (EPAAct). Therefore, this draft study deserves a proper and thorough peer review, including by impartial experts in the field of electric vehicle technology, before it is finalized.

As part of these comments, we have enclosed a copy of comments on the EVTECA prepared by Sierra Research. The Sierra Research comments are also included in comments on the draft EVTECA sent to you by the Western States Petroleum Association (dated September 15, 1997). API endorses the comments prepared by WSPA and Sierra Research on the draft EVTECA.

Below is an outline of some of our basic concerns with the study.

Ms. Margaret Singh
September 19, 1997
Page 2

The Study's Assumptions Are Overly Generous

Some of the study's assumptions about electric vehicles (EVs) lead to unrealistic conclusions about EV benefits:

EV Market Penetration. The study assumes electric vehicles (EVs) will replace conventional vehicles (CVs) on a one-for-one basis. This is an unrealistic base case. A more realistic base case is to assume EVs are purchased as a second or third car to supplement, rather than replace, existing CV use. The EV would most likely be used in limited applications for short trip, around town driving. In this case, EV use would only displace a portion of the mileage accumulated by older CVs.

Revising the base case in this way will affect the assumed emissions benefit for EVs. Under this revised base case, older, higher-emitting CVs will not be taken off the road and replaced on a one-for-one basis with new, lower-emitting CVs. Instead, any emission benefit assumed for EVs will be at least partially offset by emissions from older CVs that would remain in use. It is possible that any net emissions benefit calculated in this way for EVs could be less than the benefit that would be realized by simply replacing existing CVs with new, lower-emitting CVs.

Also, the high penetration scenario for Los Angeles is assumed to be 50% in the year 2010. This seems unrealistic, given this is only 13 years away.

Battery Replacement. The report summary indicates that EV batteries are expected to be replaced at least once in the life of the vehicle. The actual replacement frequency may be greater. Most studies today indicate that battery packs need to be replaced every 2 to 5 years. This would mean that for a 10 year vehicle life, an EV would have from 2 to 5 battery replacements. A more likely base case for the study would entail 2 to 3 battery changes.

Neither the draft report itself nor its appendices seem to provide data justifying an assumption for significantly longer battery life. No mention of replacement batteries could be found in the section on battery types and performance (Appendix B.2) or in the section on simulation of EV loads (Appendix C.3). Both of these areas have a significant bearing on the emissions attributed to EVs.

Ms. Margaret Singh

September 19, 1997

Page 3

Emissions. The emission estimates for conventional vehicles in the EVTECA report, which are based on MOBILE5a and Tier 1 vehicles, are much too high and do not represent the latest technology for gasoline vehicles. MOBILE5a does not include National Low Emission Vehicle (NLEV) or Tier 2 vehicles which could be introduced nationally after 2000. MOBILE5a also contains assumptions for California LEVs that are more pessimistic than the assumptions in the EMFAC model used by the California Air Resources Board (CARB). Additionally, recent in-use data presented by EPA to work groups of the Mobile Source Federal Advisory Committee indicate that MOBILE5a significantly overestimates emissions from vehicles built in the 1990s.

Currently, both CARB and U.S. EPA assume that either LEV or NLEV with enhanced I&M will have in-use emissions that are roughly equivalent to vehicle certification standards. However, the projected emissions for conventional vehicles used in EVTECA (listed in Table B.7.1) are several times LEV/NLEV certification standards for NMHC, CO and NO_x. The analysis also assumes that emissions on the LA-92 cycle will be higher than those on the standard federal urban cycle. However both EPA and CARB have adopted regulations to limit emissions on the aggressive driving contained in the LA-92 cycle. These regulations will phase-in beginning with the 2000 model year; therefore, the assumption of increased emissions on the LA-92 cycle for new conventional vehicles is incorrect.

Energy Efficiency. The energy efficiency of EVs is somewhat optimistic. Some of this may be attributable to the fact that the study does not include the energy transmission losses that occur in normal electrical distribution. Also, on page S-4, it is stated that the efficiency of the base CV is assumed to be 21 mpg, while the EV is 100 mpg. But the greatest part of this difference is because conversion of the fuel to energy (which is the least efficient of all of the production chain processes) occurs onboard the CV; whereas for the EV, it occurs at the power plant. Further, while the assumptions predict tremendous improvements in EV efficiency over the study period (about 25%), CVs are shown to have little improvement in efficiency (about 7%). This is despite the fact that CVs with mpg ratings of 45-50 mpg or more already exist, and that new internal combustion engine technology (such as fuel-efficient direct injection gasoline engines and clean-burning diesel engines) are currently being introduced into the market place.

Ms. Margaret Singh
September 19, 1997
Page 4

Also, because the assumptions do not address the energy required to produce the gasoline or electricity, the results mislead the reader regarding the "assumed" efficiency of EVs. Gasoline production from crude is highly efficient (roughly 85%), while electricity generation from coal or natural gas is relatively inefficient (roughly 30%). Even if production and distribution inefficiencies are omitted, EVs are still only about 3 times as efficient as CVs—not the reported 5 times as efficient (21 mpg vs. 100 mpg).

Vehicle Performance. EVs must be compared with CVs of similar performance characteristics to make the analysis credible. Despite the discussion on efficiency in the Appendices (and commented on above), it remains unclear if the study compares a 2 passenger EV with a payload of around 225 pounds with a 4-door conventional sedan with at least 3 times the payload. In the Summary, at page S-4, it indicates that a CV with 21 mpg is used as the base case. If this 21 mpg CV is not compared to a similar EV with nearly identical payload and range, the analysis will unfairly advantage EVs. Even Appendix B (page B-49) of the report does not give proper credit to existing highly efficient CVs with mpg ratings of around 45-50 (i.e. Geo Metro or Ford Fiesta).

The Summary of Emissions Data is Skewed

As discussed above, in some cases the draft assessment gives overly generous emissions benefits to EVs. In addition, those reductions are reported in a way that further biases the emission reduction estimates in favor of EVs. For example, the claimed EV emission benefits are reported as a percentage reduction, while emission increases attributable to EVs are reported as whole number multipliers. Thus, a 97% reduction in CO from EVs appears as a highly significant number. But if the reader knows that CO emissions from a new vehicle running on reformulated gasoline approach zero, the reader could conclude that a 97% reduction from that baseline produces little additional benefit.

On the other hand, in discussing an increase in SO_x emissions, the report says that EV emissions could be 8 to 11 times as high. To be consistent with the approach discussed above, this should be reported as an 800% to 1100% increase caused by EVs.

Ms. Margaret Singh
September 19, 1997
Page 5

The report indicates that battery recycling was assumed to occur "out-of-basin" and that while recycling could occur in-basin, that scenario was not addressed. Battery recycling could very well occur in basin. If not, there could still be a significant in-basin emission contribution associated with the transport of the batteries to the out-of-basin recycling/disposal site that must be taken into account. Therefore, if the assumption remains that recycling occurs out-of-basin, at a minimum, the emissions of transporting recycled or disposed batteries must be accounted for in the data as additional emissions attributable to EV use.

In the beginning of the Executive Summary at page S-1, the report identifies that the emissions associated with EVs are compared to CVs operating on RFG. However, this is misleading unless the reader looks into the details of the report. Table S-3 reports the tons and percentage of VOC reductions anticipated with increased EV use. These data are measured against a baseline that does not include RFG. Therefore, the benefits of EV usage are overstated. Later, the report correctly points out that using a 1990 emission inventory does not account for the use of RFG. This appears to contradict the statement made earlier at page S-1 (stating EVs are compared to CVs operating on RFG) and may confuse the reader.

Finally, the report notes that increased production of heavy metals associated with battery production is not comprehensively addressed. This point needs to be highlighted.

Economics Were Omitted

Despite the fact that the study does not address economics, it should be pointed out that an economic analysis would show EVs are not a cost effective way to reduce emissions.

Ms. Margaret Singh
September 19, 1997
Page 6

Some Tables and Charts Are Unclear and May Not Match the Text

In discussing power plant emissions page S-3 states: "Table S-1 presents total, not in basin, emissions." It is unclear what this statement means; i.e., whether in basin emissions are included in the "total." Also, Table S-1 shows negative emissions for Houston (using Combined Cycle Units or UCCs). It is unclear how total emissions can ever be negative.

Additional lack of clarity on power plant emissions is on page S-5. In discussing SOx emissions in Washington and Houston, the text of the report indicates that there are SOx decreases (in basin) with unconstrained charging and the addition of UCCs. We do not necessarily agree with this conclusion, but at least it is consistent with the tables for Houston (assuming the erroneous assumptions identified above are made). However, despite the dialogue at page S-5, Table S-1 shows no such SOx decrease for Washington. In fact, Washington shows increases across the board for SOx. This inconsistency needs to be resolved.

API appreciates the opportunity to comment on the draft EVTECA. We would like to be included on the list of reviewers for future drafts of this study or related materials.

Please call me if you have any questions.

Sincerely,

Jeff Trask

Comments on:

Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Analysis

prepared by:
Sierra Research, Inc.
September 11, 1997

1. The energy and emissions benefits assigned to EVs inappropriately result from the use of new powerplants to satisfy existing electricity demand.

The analysis of recharging emissions from powerplants and the fuel used for that recharging is done in three different ways in the report. Each method compares emissions and energy use with and without electric vehicles.

1. *Incremental emissions* are defined as the difference between the total system emissions (or energy use) with electric vehicles in place minus the total system emissions without electric vehicles in place. If electric vehicles required new powerplants, new powerplants that were very efficient (50% efficiency for combined cycle plants) were assumed. Thus, the incremental emissions were the difference between two different utility systems: (1) a currently planned system to meet the utility generation needs for the target year, and (2) an expanded system to meet the planned needs plus the extra generation requirements for electric vehicles.

In the expanded system, the newly added, very efficient units would be used almost continuously because, being the most economical to run, they would be dispatched first. As a result, almost all of the electricity produced by the new powerplants would be used to satisfy base-load demand, which is unrelated to EV recharging. In the analysis based on incremental emissions, electric vehicles were credited with 100% of the reduction in emissions (and energy use) resulting from the use of these new powerplants instead of older powerplants.

2. *Marginal emissions* are defined as the difference between the emissions from the same utility system with and without electric vehicles. In this case, the utility system is expanded to meet the future needs, including electric vehicles. Then the energy use and emissions are compared, for the same utility system, examining only the electricity generation used for electric vehicles.
3. *Average emissions* are simply the average emissions from all units in the utility system. The system considered in this case is the expanded system that meets the planned future needs, including electric vehicles.

The incremental emission and energy results are the only ones presented in the report synopsis and summary chapter. The report authors state their preference for incremental system emissions (ISE) in the utility analysis chapter:

... we believe the focus of the assessment should be placed on the ISE emissions because they most appropriately capture the overall effect of EVs on the emissions of the affected utility systems.

Although this rationale may superficially appear to be appropriate, it is based on the implicit assumption that new, more efficient powerplants will not be available in the absence of increases in peak demand. This assumption is inappropriate, especially given the deregulation and restructuring now occurring in the electric utility industry. Using this same rationale, energy and emissions benefits would be assigned to other strategies resulting in the construction of new, more efficient power generation plants such as encouraging people to *lower* their thermostats during hot weather so that air conditioning systems would run more and *increase* the peak electricity demand. Thus, energy conservation measures would be counterproductive since they would have energy and emissions disbenefits. This leads to two possible conclusions: (1) wasting energy is a good idea, or (2) an analysis using incremental systems emissions is a faulty idea. The latter applies since the energy and emission benefits could have been realized without EVs if new efficient generation capacity were built to replace older equipment.

Besides different measures of emissions and energy use, two possible powerplants are considered in the report: combined cycle (CC), and combustion turbines (CT).^{*} The combined cycle plants were more efficient additions, but they had a higher initial capital cost than the combustion turbines.

The analysis of utility emissions examined the time of day for electric vehicle recharging. Two options were considered: unconstrained recharging, where vehicles were assumed to be recharged upon return home; and off-peak recharging. The combination of different unit additions and different times of day for recharging led to the following scenarios:

1. unconstrained recharging with combined cycle replacement units (UCC),
2. off-peak recharging with combined cycle replacement units (OCC),
3. unconstrained recharging with combustion turbine replacement units (UCT), and
4. off-peak recharging with combustion turbine replacement units (OCT).

The unconstrained recharging option had the highest requirement for new generating capacity. The combination of unconstrained recharging with the efficient combined cycle plants as the replacement units (UCC) provided the greatest advantage claimed for the use of EVs in the report under the incremental systems emission approach. Table 1 presents

^{*}The analysis for Chicago considered an integrated gasification combined cycle (IGCC) unit that Consolidated Edison had included in its resource plan.

the difference in the results for the Houston scenarios shown in Figure S.1 of the DOE report. For comparison, the total energy use for conventional vehicles in this scenario is 6,750 Btu/mile.

Table 1 Comparisons of Total Electric Vehicle Primary Energy Use with Different Options for Recharging and New Generating Units			
Recharging Option	New Units	Symbol	Primary Energy Use (Btu/mile)
Unconstrained	Combined-cycle	UCC	3,913
	Combustion Turbine	UCT	5,756
Off-peak	Combined Cycle	OCC	5,131
	Combustion Turbine	OCT	5,148

The *power generated* for recharging the electric vehicles is the same for all combinations.^{*} However, the *fuel used* to generate this power depends on the scenario considered. In addition, the incremental systems analysis for the unconstrained combined cycle case requires the addition of 171 MW of new generating capacity assumed to have a 50% efficiency. The fuel use for the new utility system with this new CC generating unit and a load for electric vehicles is less than the fuel use for the old utility system without this unit and no load for electric vehicles. Thus, the incremental system emissions analysis erroneously concludes that the recharging of electric vehicles can be done with a negative energy input and negative emissions.

This effect does not occur in the other operating scenarios. When off-peak charging is assumed, almost no additional generating capacity is required and the system emissions do not depend on the type of unit used for the new power. When combustion turbines are used as the replacement power in the unconstrained recharging case, there is no additional combined cycle unit that is dispatched earlier, giving overall lower system emissions.

Depending on the analysis method, the 2010 high EV penetration scenario in Houston with unconstrained vehicle recharging and combined cycle replacement units gives the following results for NOx emissions due to electric vehicle use:

^{*}There is a difference between the totals reported in the summary tables and the details in the Appendix. The total power generation for electric vehicles for Houston in 2010 (in the high EV scenario) is 849,026 MWh according to Table 2.2; the sum of the power generated for the individual seasons in Tables C.5.7 and C.5.33 is 799,299 MWh. Similarly, the incremental system NOx emissions for the UCC scenario are reported as -872 tons in Table 2.3 while the sum of the individual season values in Table C.5.7 is -840 tons.

- Incremental systems emission analysis -840 tons/year of NOx
- Marginal system emission analysis 1,169 tons/year of NOx
- Average system emission analysis 954 tons/year of NOx

In this case, the choice of the incremental systems emission analysis had a dramatic effect in understating the NOx emissions impact of electric vehicle use.

2. Emissions from conventional vehicles are substantially overstated.

The report authors correctly note that the current driving cycle used for emission tests is not representative of real-world driving. As a result, it is suggested that the analysis should be based on emissions occurring on the new LA-92 cycle (developed for CARB by Sierra Research). Because there is no well-established set of data that provides emission factors for this driving cycle, the authors started with the emission predictions from the EPA model MOBILE5a and described the procedure they used to adjust the emissions data to the LA-92 cycle as follows:**

Recent emission tests by the California Air Resources Board show that from the FUDS [the current Federal urban driving cycle] to the LA-92 emissions are increased by 12.5% for VOC, by 50% for CO, and by 31.4% for NOx (Gammariello and Long, 1993). These emission differences are used to adjust Mobile5a-estimated FUDS emissions to LA-92 emissions.

Although it was difficult to determine how the authors used LA-92 test results reported by CARB,^{1***} the more significant concern is that CARB work is cited in support of increasing the emission factors produced by MOBILE5a when CARB's view is that MOBILE5a substantially overstates the emissions of late-model vehicles. In addition, the emissions for gasoline-fueled vehicles used throughout the report are based on the assumption that so-called "Tier 1" vehicles continue to be sold forever. As shown in Figures 1-3, the combined effect of these assumptions is enormous.

*The DOE report computed the marginal emissions factor, EF_{MSE} (in lb/MWh), for the summer season only. The emission factor for average system emissions, EF_{ASE} , was available for all seasons. The marginal system emissions factor for other seasons was computed as follows:

$$EF_{MSE, season} = EF_{ASE, season} \frac{EF_{MSE, summer}}{EF_{ASE, summer}}$$

**Report page B-90.

***Superscripts denote references provided at the end of this document.

Figure 1

MOBILE5a vs. EMFAC7F Exhaust VOC Emission Rates

Figure 2

MOBILE5a vs. EMFAC7F Exhaust CO Emission Rates

Figure 3

MOBILE5a vs. EMFAC7F Exhaust NOx Emission Rates

Figures 1-3 show MOBILE5a predictions of emissions vs. mileage for passenger cars certified to Tier 1 standards compared to CARB's estimates for both Tier 1 and LEV vehicles using the EMFAC7F model.* As the figures show, MOBILE5a estimates are substantially higher than CARB's estimates for Tier 1 vehicles. The figures also show that substantial emission reductions will be associated with the use of NLEV vehicles. At the 50,000-mile point, MOBILE5a estimates for Tier 1 are higher than CARB's estimates for Low Emission Vehicles by 315% for HC, 193% for CO, and 116% for NOx. Although the authors of the report acknowledged the possibility that more stringent emission standards will apply in the future, they chose not to estimate their effect. As illustrated in Figures 1-3, this had a very large effect on the emissions projected for gasoline-fueled vehicles.

As mentioned previously, the authors further increased the MOBILE5a estimates for Tier 1 vehicles based on CARB's analysis of the difference between emissions on the standard driving cycle and the more representative driving cycle. Although the authors state a rationale for upwardly adjusting the MOBILE5a-based numbers, they completely ignore the fact that new certification requirements, referred to as the Supplemental Federal

*The MOBILE5a values shown in the figures are based on enhanced I/M with non-reformulated gasoline. EMFAC7F values are based on the 1990-1995 California I/M program and non-reformulated gasoline. The 1990-1995 California I/M program (BAR90) uses exhaust measurements at normal idle and high speed (2500 RPM) idle.

Test Procedure (SFTP), will provide substantially improved control of emissions during operation on more representative driving cycles, like the LA-92.

3. The summary results use misleading comparisons of Btu/mile for electric vehicles and conventional vehicles.

Although more meaningful comparisons of energy use appear in the body of the report, the Synopsis (page S-4) contains the following sentences:

The average energy efficiency of EVs (not accounting for electricity generation losses) is about 1150 Btu/mile. This is equivalent to 0.34 kWh/mile or 100 mpg.

One hundred miles per gallon is an impressive figure; it is also a gross misrepresentation of the true energy efficiency of EVs because it completely ignores the energy lost during the generation of the electricity required to recharge the vehicle. Based on results contained in the body of the report, it is clear that the real efficiency is less than 30 mpg equivalent.

4. Electric vehicles cannot replace conventional vehicles on a one-for-one basis as assumed in the DOE report.

The owner of a conventional vehicle purchases a vehicle that meets all of his or her requirements. This includes the ability to use the vehicle for extended trips, even if such trips are made only infrequently. The limited range available for electric vehicles means that they will be used as second cars or for limited fleet applications where daily range is short and daily recharging is available. Thus, the average electric vehicle cannot replace the average conventional vehicle. Owners who purchase electric vehicles as supplemental vehicles will retain their old vehicles for longer trips. When used on such trips, the older vehicles will have higher emissions than a new vehicle that could have been purchased in place of the electric vehicle. In addition, the old vehicle will continue to have evaporative emissions. Such emissions will not be reduced by the purchase of a supplemental electric vehicle.

The DOE report assumed that electric vehicles would replace conventional vehicles that were purchased for low-mileage applications. The annual mileage for these vehicles was determined from data in the Nationwide Personal Transportation Survey (NPTS). The data for the average travel distance per trip, for trips that were 30 miles or less, were used as the average trip length. The DOE report determined the total daily mileage by multiplying the average trip length by the average number of trips per day. However, according to a footnote in Table B.4.8, the average number of trips per day was computed *excluding the vehicles that made no trips*. This would inflate the daily mileage figures used in the report. An inflated estimate of the annual mileage for the electric vehicles would increase the benefits of such vehicles. The DOE report estimated that the electric vehicles were used between 24.4 and 30.0 miles per day, seven days a week, in the various

urban areas considered. Using the report's assumption that vehicles are operated 365 days per year, this corresponds to an annual range of 8,906 to 10,950 miles. By properly accounting for "no-trip" days, the actual annual mileage for vehicles used only for short trips is likely to be much lower. For example, business fleet vehicles used five days per week would accumulate 29% fewer miles.

5. The analysis is based on the inappropriate assumption that electric vehicles have lower aerodynamic drag and lower rolling resistance than conventional vehicles.

The rolling resistance coefficient and aerodynamic drag coefficient assumed for electric vehicles are significantly lower than the values assumed for conventional vehicles.^{*} Although some electric vehicles have been designed with very low values for aerodynamic drag and rolling resistance (as compared to a conventional vehicle), these design characteristics have required compromises in the ride, handling, and space efficiency of the vehicles that need to be taken into account. A comparison of electric vehicles and conventional vehicles should, insofar as possible, compare vehicles with similar capabilities and design features such as low rolling resistance tires or aerodynamic body design. This would include interior space for a passenger car and load capacity for a van. This was not done in the DOE report.

In addition, the analysis of vehicle weights uses the following steps to obtain the weight of the electric vehicle: (1) the weight of the conventional vehicle is decreased by 20% to account for the removal of the engine, engine accessories, cooling system, exhaust system, and fuel storage system, and the addition of the motor controller, and (2) weight is added for the battery pack as required to meet the vehicle performance characteristics. The net effect of these two steps is to produce an electric vehicle that is heavier than the initial conventional vehicle. However, no additional weight is added to the electric vehicle to account for any structural changes that might be required by the added weight of the batteries. In addition, there is no discussion of any changes in the vehicle size to maintain the same interior space in the two vehicles that are being compared.

6. The efficiency of electric vehicles assumed in the report is unrealistically high.

Various tables in Appendix B provide the following data for the 2010 compact vehicle with sodium-sulfur batteries:

- Aerodynamic drag coefficient, $C_D = 0.20$
- Rolling friction coefficient, $f_R = 0.0045$
- Drivetrain efficiency = 92.5%

^{*}For 2008-2010, the aerodynamic drag coefficient for an electric vehicle is assumed to be 0.20 as compared to 0.27 for a conventional vehicle; the rolling resistance coefficient is assumed to be 0.0045 for an electric vehicle as compared to 0.007 for a conventional vehicle.

- Motor efficiency = 92.5%
- Battery efficiency = 89%
- Charger efficiency = 90.0%
- Efficiency for transmission and distribution of electric power = 95%
- Efficiency of regenerative braking = 50%
- Battery weight = 803 pounds
- Curb weight without batteries = 2,034 pounds
- Payload weight = 225 pounds
- Total weight, $W = 3,062$ pounds

As discussed above, the aerodynamic drag and rolling resistance assumptions would result in reduced space efficiency and inferior ride and handling compared to conventional vehicles, which biases the results of the analysis. The analysis is further biased by the other assumptions.

The overall efficiency from the wall outlet to the rear wheels is the product of the individual efficiencies, which yield a net efficiency of 68.5% ($92.5\% \times 92.5\% \times 89\% \times 90\%$). With a transmission and distribution efficiency of 95%, the overall efficiency from power generated at the utility to the rear wheels of the electric vehicle is 65.1%. With this efficiency, the power generated by the utility would have to be 1/0.651, or 1.54 times the tractive energy required at the rear wheels of the vehicle.

Based on a previous Sierra analysis² of EV efficiency, the overall efficiency for an EV using state-of-the-art components and advanced batteries would be 58.3%, which requires power generation to be 1.72 times the tractive energy requirement. Compared to our analysis, the assumptions used in the DOE report reduce the power plant energy demand by 10.5%.

It should also be noted that the analysis in the DOE report ignores the loss of battery charge that occurs during periods of inactivity. Self-discharge of EV batteries combined with the power consumption during periods when the vehicle is parked (e.g., to run a clock, maintain computer memory, etc.) are not insignificant. Based on our preliminary analysis, even if the loss of charge is 1% per day, the net effect is approximately another 10% increase in annual energy consumption.

References

1. Robert T. Gammariello and Jeffery R. Long, "An Emissions Comparison Between the Unified Cycle and the Federal Test Procedure," *The Emissions Inventory: Perception and Reality*, Proceedings of an International Specialty Conference, VIP-38, Air and Waste Management Association, 1994, pp. 535-548.
2. Thomas C. Austin and Laurence S. Caretto, "Powerplant Emissions and Energy Consumption Associated with Electric Vehicle Recharging," 5th CRC On-Road Vehicle Emissions Workshop, April 3, 1995.

TO: Margaret Singh
FR: Marijke Bekken
RE: Comments to EVTECA, 7/97 Draft

(Note these comments reflect personal opinion and not necessarily the opinions of the Air Resources Board for whom I work. They are primarily in the order I first thought about the issue. Comments on the Technical Report are followed by specific comments on the appendices. Sorry it took so much longer than I thought. I have a million things to do before I go on maternity leave, and they all seem to take twice as long as they should.)

1. Lead emissions. It is unclear in the report and its appendices whether the SLI battery from the CV is included in the analysis. If it is assumed that all EVs also have a 12 volt battery to provide for accessories, there is no real reason to include it (providing it is reasonable to assume that the SLI battery and this system battery are generally similar in make-up, if not in performance characteristics), but if not, its exclusion tends to slightly overstate the lead impact of the use of EVs.

Several times in the report, it is noted that lead emissions are substantially higher with the use of EVs, even when it is assumed that the majority of EVs used will not be powered by PbA batteries. It is clearly noted in the Synopsis that copper production is the source of a lot of this additional lead, but it is not so clear in other instances that these emissions are not all from the PbA batteries. In addition, I believe it should be made clear that these high lead emission values associated with the copper reflect the mining and smelting of virgin copper, and that the use of recycled copper would reduce this impact (by how much, I cannot say, since the report does not really clearly say how much of the lead came from the PbA batteries versus the copper mining, and I am unable to backcalculate to anything near the numbers included in the report. Based on what I did backcalculate, the report appears to utilize PbA smelting emission to the air substantially higher than those observed in California, although perhaps appropriate for the two regions fully detailed in the report. The latest California numbers I have handy are 0.002% Pb emissions for secondary smelting, and 0.0025% for battery manufacturing. I believe that the USEPA has recently passed some stringent emission standards for metal mining and processing, which may be lower than the figures the EVTECA assumes).

Although the 400 percent increase noted probably correctly reflects the assumptions within the report, I am somewhat concerned about its "sound-bite" potential as written when in the hands of the stridently anti-EV groups. I think the copper contribution should be included wherever the 400% Pb increase is noted, and further, that the language should reflect that this is primary copper production. How do Pb emissions vary for primary versus secondary copper production? What percentage comes from secondary production, and why was no recycling assumed when recycling has lower energy requirements and leads to lower emissions (overestimates the energy requirements of EVs, as well as overestimating the lead, SOx and other pollutants associated with the use of EVs). I don't know about the nation as a whole, but copper (including encased wire) is certainly recycled in Southern California. In addition, second generation EVs should be better able to take advantage of recycled materials from the initial fleet.

2. Cities selected. I agree with the choice of cities selected for the analyses, but am unclear why the final results were only presented for Houston and Washington. It appears in my reading that most, if not all, of the required analyses were completed for Chicago and Los Angeles as well (Obviously, I am most concerned about LA!). The only section I recall that may not have been completed for the other cities is that of RFG production. Can the model/spreadsheet data computed for LA be made available so that the analysis can be readily completed for this region?

3. Electric Utilities. I have a problem with reading the sections on electricity generation. I would read one paragraph, puzzle through the terminology, figure out what was being done and why, but for some reason it just wouldn't stick around for the next time the issue was brought up. Is there a way that a more simplistic explanation could be provided that would be easier for those of us with no experience in the

power generation area to understand? I would like the reason that off-peak scenarios were run only for the summer (e.g., p. 2-3) to be provided (if I didn't miss it).

4. Vehicle analysis. It is noted on p. 4-1 that operation of CVs generates pollutants, followed parenthetically by "emissions to air". I think it is important to note that operation of CVs also results in liquid and solid wastes, such as spent oils and fluids, and used filters, that one would presume would be present in lesser quantities in EVs, if at all. One might want to note (see p. 4-4) that there are now electric truck models being offered by the OEMs, such as the Ford Ranger and the Chevy S10 pick-ups, although these seem to be OEM-certified conversions rather than ground-ups per se.

The LA-92 cycle is now more commonly referred to as the Unified Cycle (at least in California). Doesn't EPA's Mobil5a include exhaust PM measurements? If not, is the AP-42 data really the most current? In my experience, AP-42 data is often out-of-date. In estimating fuel economy, EMFAC7G includes miles driven and fuel consumed. Does Mobil5a not have this data? Or is it of questionable accuracy? According to our modeling people, EMFAC7G is indeed capable of model-year specific emission rates, although it is not a standard output. As the attached sample shows, the standard model output does include PM10 emissions for exhaust, tire wear, and brake wear. Tire wear and brake wear may not really be that similar for EVs and CVs in that EVs tend to use harder rubber which sticks less to the road, and regenerative braking can significantly reduce brake wear. Even with a vehicle with brakes designed for 2000 lb that currently weighs about 3000 lbs, I have not had to replace my brake pads in nearly 40,000 miles of EV operation. What is the basis for estimates that methane emissions are about 7% of the VOC emissions for CVs?

In the calculations of heating and cooling requirements on energy efficiency, is pre-heating and pre-cooling considered? Many OEMs offer or plan to offer remote or timed pre-heating/cooling for the vehicles, so that these power needs minimally impact vehicular range in situations where the vehicle is plugged in to the outlet before the trip start. In the same way, many new systems will remotely start charging at pre-arranged times, enabling the owner or operator to plug in at the end of the day yet effortlessly delay charging to whatever time the user or utility prefers.

In the daily recharge requirement discussion, I think it is unclear whether the trip lengths presented (p. 4-6 and elsewhere) are one-way or round-trips. In the section on battery recharge profiles, why does the analysis assume that the recharge starting point is 100% DOD? This level of discharge is generally considered to be bad for the batteries. Manufacturers generally recommend typical discharge be limited to 80% DOD.

In Table 4.3 et seq, it appears that the vehicles become less efficient between 1998 and 2003. For example, in Chicago, for the NiCd minivan (common to both time periods), spring electricity consumption increases from 0.297 kWh/mi to 0.318 kWh/mi (By 2008, the efficiency loss has been regained, as electricity consumption falls to 0.261 kWh/mi). Why is this so? Table 4.4 shows the assumed daily mileage of EVs. If the car and van fleet mileages are truly around 60 miles or less, why assume no PbA batteries will be used for fleet applications? These ranges are within the performance parameters of currently available PbA-powered conversions, so one would think the OEMs could do at least as well. Table 4.5 shows battery capacities over time. Why do these capacities appear to decline in the 2008 time frame to a value between the 1998 and 2003 capacities? This may be explained in an appendix (although I don't recall one), but a footnote to the table would be helpful. In Table 4.6 (and text discussing it), is the column entitled "EV/CV Mileage" properly titled? I think this column reflects the mileage of CVs being replaced by EVs? Else why does it appear to increase three fold under the 2010-high vs 2010-low LA scenarios (And for other locations as well)? Yet the mileage reported seems too high for it to be displaced mileage. Please clarify in the text and table. Similarly, I think the title of Table 4.7 needs to be clarified. If the 2010-low penetration emissions are lower than the 2010-high penetration emissions, it seems like these are the emissions displaced by the use of EVs instead. By the way, there's a typo in the top line of the table ("emmissions"). Maybe I'm reading these tables wrong.

5. Electric Utility Analysis. I understand the discussion about reliability and why charging increases power needs even if the capacity exists in the current capacity to provide that power. I also understand how off-peak charging could increase emissions even beyond those found with unconstrained charging. However, it makes no intuitive sense why constrained charging to off-peak period (such as 10 pm to 8 am) would increase power needs. Is this merely a function of the way reliability indices are calculated? If so, maybe the utilities should consider whether the current approach is truly a reasonable one.

6. Gasoline production/delivery. According to Figure 6.2, this chapter included a discussion of fuel oil transportation. If this is so, I didn't see it. I did see a discussion about the transport of RFG, as noted in Figure 6.1. Is there really no data available on PM-10 for crude oil production processes? Is crude oil associated with lead? You include it on Table 6.1 but then provide no data. Since one of the big issues that has been raised with EVs is the potential increase in emissions of lead, if there are associated lead emissions, I believe they should at least be noted with some concept of their magnitude.

7. Electricity production/delivery. In Table 7.1, it is difficult to believe that the extraction, processing, and transportation of coal has 0 PM10 (and Pb) emissions. Surely this should really say that they have not been characterized. I would imagine that some of the thousands of pounds of TSP emissions are of particles less than 10 microns. Are the residuals from electricity used in these processes included in the table? In Section 7.1.2, surface mined coal was assumed to come equally from Eastern and Western coal, because of a lack of other data. Could this not be determined from the sulfur content of the coal, since Eastern coal generally has more sulfur (or is this the case primarily because more Eastern coal is mined from underground and that surface mined coal in general has less sulfur)? Again, in Table 7.3, were the electricity residuals included in the total natural gas production residuals? Did you gather emission factors for California gas field equipment? I find it unlikely that the SCAQMD would allow the many oil drilling rigs in this area to use uncontrolled engines. Why in general does this chapter assume emission factors from uncontrolled equipment? Is it truly the case that the other states and air quality districts have not required any controls on this equipment (I know EPA regulations for these engines were not in place when this study was being completed, and are only now being phased in over the various engine sizes, so the lack of uniform nationwide numbers does not surprise me.)?

8. Vehicle/Battery manufacture. Is it realistic for future assessments (such as the emissions and energy requirements for 2008-2010 model year vehicles) to largely assume that no recycled materials are used? In discussing materials "unique" to EVs, one might consider that only the non-PbA batteries are unique since all conventional vehicles have a PbA SLI battery. What is the basis for assuming #6/7 fuel when the fuel type was not known? For battery manufacture, some battery types might only be made in certain regions of the country, such that national emission numbers might not be the most appropriate to use. Trojan, for instance, manufactures batteries for Southern California in Southern California where the emissions requirements tend to be very strict. While the EVTECA includes the emissions associated with producing, transporting, and consuming fuel for CVs, and while it includes emissions associated with producing electricity and batteries for EVs, it appears to ignore the production (and disposal) of other fluids that the CV uses that the EV uses either not at all, or in much lesser quantities, such as motor oil and antifreeze.

The EVTECA assumes that the PbA battery is replaced twice and other battery types replaced once over the life of the vehicle. What about the SLI battery in the CV? Why in Table 8.4 does the EVTECA assume such a large battery mass for the PbA vehicles (772 kg for a two seater; 878 for a compact. I have a 4 door, with about 490 kg of batteries; the EV-1 has, I believe, a 530 kg battery pack.)? Why would a 2003-2007 subcompact have even greater battery mass than a compact pre-2003 (1054 kg)? It is a smaller car, with presumable more advanced technology. The range is somewhat longer, but battery advances would presumable account for most of the greater range, since adding batteries to increase range is, to some extent at least, a losing proposition. Similarly, the NiCd minivan's battery pack weight nearly doubled. I don't have a handle on typical current weights for packs of the other types of batteries.

In Table 8.8, what lead is the lead listed in the materials table? Alloys? SLI battery for CVs? These emissions correspond to an emission factor for lead production of 0.01%, which seems high (See previous

comment about new EPA mining requirements and California requirements.). The TSP for the aluminum parts should be listed as 63100, in keeping with the other TSP numbers, rather than in scientific notation. Is it true that auto parts are not made with any recycled steel (perhaps, since virgin is 25% scrap). Is this true for imports or just for domestic vehicles? Page 8-31 provides primary lead smelting emission factors of 0.034 kg/tonne and for secondary lead production, 0.15 kg/tonne. (Are these "tonnes" metric tons (1000 kg), short tons (2000 lbs), or long tons (2240 lbs)? Please clarify.) The numbers seem wrong because secondary production should be cleaner than primary production. I presume the EVTECA assumption of 75% recycled lead is based on historical usage. How old were these usages? Do they reflect the very high recycling rate that SLI batteries enjoy now or that future EV batteries will presumably have? Are they uniform nationwide, or does California have a greater usage of recycled lead?

In Table 8.9, where did the totals for generated and purchased electricity come from if there are no inputs in the table?

Fluids and miscellaneous other materials may make up less than 8% of the total vehicle mass, but the fluids, at least, are periodically replaced and their total volumes may be significant (5 qts oil per 3500 miles for 130,000 miles is about 46 gallons of spent oil over the vehicle life, which is hopefully recycled, though much of it ends up in the storm drains, including all that leaks out of the vehicle, which is generally additional to this 46 gallons. Similarly, 2 gallons of antifreeze, changed every 13,000 miles is another 20 gallons of generally toxic antifreeze (that often goes down the drains as well).

The analysis presumably does not include emissions from recycling spent batteries, although the general processes are described. Does this mean that all the material is assumed to be emitted, or that the spent materials are simply ignored. Emissions for battery production, with the exception of PbA, assume all virgin materials. While this may be the case in the initial vehicle supply when the demand might be significantly higher than historical supplies, one would expect these materials to be recycled when those vehicles or components are retired to keep production and usage relatively balanced. When the battery replacements are assumed, are they assumed to be replaced with batteries providing the same performance, mass, et cetera as the original pack or are they assumed to be upgraded to the year in which the replacement occurs? Are the emissions normalized to the same vehicle age and mileage since life cycle assumptions are different for different batteries?

9. Access to Models/Data. The analyses in the report utilize a number of different models. Are these (or a combined model/spreadsheet) available for others to run scenarios for their areas, or to run scenarios with somewhat different assumptions if these may be more appropriate for their area/implementation date?

Appendix A2 - Unit Process Data Documentation. In the example shown for the distance model (Section A.2.1.2.2), the process of using a heavy duty truck notes "DNA" for waterborne and solid residuals. Clearly, operating such a vehicle is associated with water and solid residuals (such as spent fluids and filters). I disagree that these environmental factors are therefore "not applicable" Perhaps they would be better with a NA or NC notation. Why isn't diesel fuel an input to the process?

Appendix B1 - Projections of New Vehicle Sales & Stock. What is the basis for the assumptions of EV sales by EV type (B.1.3)?

Appendix B2 - Selection of Battery and Vehicle Types. In Section B.2.3, the text notes that no vans are selected for household use. Aren't there in fact a large number of minivans sold to individuals? There certainly seem to be in California.

Appendix B3 - Energy Consumption Estimates. In Table B.3.1a, why is the engine efficiency not included in the table (in the same line with the motor efficiency, since the engine is a type of motor)? In Section B.3.4, seasonal ambient temperatures, I note that June to August may be official summer, but is clearly not the hottest time of the year in Los Angeles, which is generally July through October or so. The use of the average daily low temperature may not be the best measure, since this is typically reached shortly before

dawn when few people are actually venturing out in their cars. This temperature will tend to overestimate heating requirements (which will make trivial impact for CVs, but potentially a greater impact for EVs, especially those powered by PbA batteries which do have a temperature effect). How much does it typically warm up between the overnight low and the typical morning commute start-time?

What is the source of the base kWh-mi number? The text just says "base case is estimated". How? Table B.3.8.a lists the base energy consumption, but not where the figures came from.

Appendix B4 - Travel Patterns. Assuming that EVs will only be used to make short distance trips rather defeats the purpose of having one (reducing the need to purchase gasoline, presumably reducing emissions, reduced vehicular maintenance and operating costs, et cetera). Although this may be the approach OEMs are taking to sales, the EV should actually be the primary car used in the multi-vehicle household, with the CVs reserved for trips of greater distances (or those that require a larger vehicle). I drive over 90 percent of my household miles electric, including a 60 mile daily round-trip commute.

Appendix B5 - Battery Recharging. In Section B.5.3, does the NPTS include the time distribution for trip ending times or was it assumed? If the latter, what is the justification for the distribution? Why assume, if one really did so, that vehicles arrive home evenly up to midnight? I would think most people would be home much earlier.

Appendices B6 and B7 - Estimates of CV Emissions and Emission Rates. Are you really using the LA-92 cycle if the process involves estimating FUDS emissions and then adjusting them to LA-92 emissions, or would it be more accurate to say that emissions are estimated using FUDS, then adjusted for off-cycle emissions based on the differences between the typical FUDS and Unified Cycle analyses?

EMFAC7G does provide estimates for exhaust PM emissions for gasoline vehicles, on the order of 0.006 g/mi for light-duty vehicles.. While it is true that EVs are generally heavier than CVs, which would tend to increase tire wear, since EV tires are generally made of a harder, low rolling resistance tire, I believe that the tire wear issue is largely a wash. Brake wear, which also contributes to particulate emissions may actually be lower in the EVs than the CVs, even though the heavier vehicles would generally use more braking power, since most EVs have, or will have, regenerative braking to provide much if not most of their typical stopping power. Most significant brake wear on my EV occurs for sudden stops, such as accident avoidance.

While it is true that methane is relatively nonreactive in terms of ozone formation, it is a greenhouse gas. Does this not almost automatically make it worthy of consideration in an energy analysis?

In Appendix B.7, I think an explanation in more detail of that these numbers mean and why they differ so much would be helpful. For instance, in Table B.7.1, Chicago, the g/mi springtime VOC emissions of 1998 cars increases from 0.56 in 2000 to 1.23 in 2010. Does this mean to say that the emissions deteriorate to that extent, or does it mean something else? Also, does this chart mean to imply that the model process assumes that the target year 2000 fleet is composed only of 1998, 1999, and 2000 model year vehicles? Or are these numbers supposed to be fleet averages achieved in intermediate years? Why are VOC emissions lower in the summer than in the spring? One would have more evaporation, and reduced fuel economy due to air conditioner usage. Obviously, I would appreciate some additional words surrounding these tables to clarify them.

Appendices C4 and C5 - Computational Procedure & Results. I think it would be helpful, at least on the first of the Tables (C.4.1) for a definition of the technology abbreviations. Obviously, NB and NP have to be nuclear, since those units are not associated with any conventional emissions, yet produce power. However, I don't know the difference between the two, nor what technologies the other abbreviations represent.

In using the term "unconstrained charging", one might note that in a way, the charging scenario proposed is constrained, in that it allows charging only at the end of the day's trips (beginning at 3 pm) rather than opportunity charging throughout the day. The way the analysis was done is fine; this is just a perhaps trivial nomenclature note.

Appendix D3 - Material Content. In the analysis of electric powertrain components, one might verify the weight of the controller presented. I have two controllers, one for my subcompact (4 door Rabbit conversion weighing 2970 lbs), and one for my mid-size truck conversion (which weighs around 4500 lbs). The subcompact has a 400 amp Curtis controller, weighing about 15 lbs, to my recollection. The 500 amp Curtis controller in the truck weighs about 20 lbs. The 70 lb figure cited in the report (D-42) seems a bit heavy, although the OEMs may be using heavier controllers.

SCENARIO TITLE: MVZ17G Emission Factors Scenario

FREDICTED CALIFORNIA VEHICLE EMISSIONS
OZONE PLANNING INVENTORY

RUN DATE: 09/17/97

CALENDAR YEAR: 2000 -- Model Years 1966 to 2000 inclusive

SOUTH COAST Air Basin

EMISSION UNIT: TONS PER DAY

MVZ17G ver 2.0c/DAILY EMISSIONS/STAGE

SEE COUNTY DETAIL FOR 1 & 4 STATUS

ALL ON-ROAD EMISSIONS

	LIGHT DUTY AUTOMOBILES				LIGHT DUTY TRUCKS < 6,000 lbs				MEDIUM DUTY TRUCKS(1) 6,001 to 14,000 lbs				HEAVY DUTY TRUCKS > 14,001 lbs				URBAN DIESEL BUSES	MOTOR- CYCLES	ALL VEHICLES
	NON-CAT	CAT	DIESEL	TOTAL	NON-CAT	CAT	DIESEL	TOTAL	NON-CAT	CAT	DIESEL	TOTAL	NON-CAT	CAT	DIESEL	TOTAL			
NO. OF IN USE VEHs	211434	676832	41585	7021951	14994	2653882	20027	2689903	33036	530949	89943	653948	9233	11582	137189	158004	3074	204667	10730449
DAILY VMT (X 1000)	3088	198379	696	202143	179	77715	292	78186	777	19132	3496	23405	244	850	13890	14984	427	1274	320439
NO. OF DAILY STARTS	906511	37155697	215571	38217781	77815	15290249	109255	15477719	134445	3351266	0	3485713	41691	144627	0	186318	0	103116	57532246
REACTIVE ORGANIC GAS EMISSIONS																			
RUNNING EXHAUST	20.80	50.63	0.24	71.66	0.56	25.99	0.30	26.65	1.61	7.27	1.59	10.57	0.76	0.60	16.41	17.77	0.84	2.51	130.01
START EXHAUST	6.99	57.64	0.09	64.71	0.46	27.92	0.08	28.45	0.18	4.93	0.00	5.03	0.00	0.00	0.00	0.00	0.00	0.57	98.74
SUBTOTAL EXHAUST	27.78	108.26	0.33	136.38	1.02	53.91	0.37	55.10	1.78	12.31	1.59	15.60	0.76	0.60	16.41	17.77	0.84	3.08	228.75
DIURNAL EVAPORATION	2.54	13.38	0.00	15.92	0.13	5.20	0.00	5.35	0.17	0.81	0.00	0.98	0.08	0.02	0.00	0.09	0.00	0.19	22.53
HOT SOAK EVAPORATION	3.86	13.69	0.00	17.55	0.28	5.80	0.00	6.06	0.15	0.92	0.00	1.13	0.05	0.06	0.00	0.12	0.00	0.04	24.89
REFUELING LOSSES	0.80	25.63	0.00	26.42	0.04	6.89	0.00	6.92	0.15	1.62	0.00	1.78	0.05	0.07	0.00	0.12	0.00	0.08	35.25
RESTING LOSSES	0.38	10.08	0.00	10.47	0.07	3.84	0.00	3.91	0.01	0.43	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.08	14.82
SUBTOTAL EVAPORATION	7.58	62.78	0.00	70.36	0.51	21.73	0.00	22.24	0.48	3.85	0.00	4.33	0.18	0.15	0.00	0.33	0.00	0.23	87.49
TOTAL ROG EMISSION	35.36	171.05	0.33	206.73	1.53	75.64	0.37	77.34	2.19	16.15	1.59	19.93	0.95	0.75	16.41	18.10	0.84	3.31	326.24
CARBON MONOXIDE EMISSIONS																			
RUNNING EXHAUST	145.42	920.87	0.93	1067.22	8.49	424.01	9.38	431.89	39.51	182.41	16.36	156.46	20.53	10.97	111.29	142.79	0.82	13.28	1814.46
START EXHAUST	40.11	588.78	1.38	630.18	3.39	292.51	0.68	296.49	0.61	58.46	0.00	51.08	0.00	0.00	0.00	0.00	0.00	2.42	980.17
TOTAL CO EMISSION	285.52	1509.64	2.32	1697.40	11.88	715.52	10.06	728.38	40.12	240.87	16.36	209.54	20.53	10.97	111.29	142.79	0.82	15.70	2794.63
OXIDES OF NITROGEN EMISSIONS																			
RUNNING EXHAUST	10.64	331.51	1.39	343.33	0.55	83.27	0.47	84.29	6.15	43.13	19.22	68.60	3.06	6.49	159.83	169.38	7.87	1.39	474.85
START EXHAUST	0.88	44.57	0.05	45.50	0.07	28.29	0.11	28.47	0.07	5.38	0.00	5.39	0.00	0.00	0.00	0.00	0.00	0.87	79.43
TOTAL NOX EMISSION	11.51	376.08	1.44	388.83	0.63	111.56	0.57	112.76	6.16	48.61	19.22	73.99	3.06	6.49	159.83	169.38	7.87	2.26	554.28
CARBON DIOXIDE EMISSIONS x100																			
RUNNING EXHAUST	18.38	667.52	N/A	685.90	1.04	389.57	N/A	310.60	0.20	62.45	N/A	62.65	N/A	N/A	N/A	N/A	N/A	N/A	1059.16
START EXHAUST	2.09	27.14	N/A	29.24	0.17	12.95	N/A	13.12	0.04	3.07	N/A	3.11	N/A	N/A	N/A	N/A	N/A	N/A	45.47
TOTAL CO2 EMISSION	20.48	694.67	N/A	715.14	1.21	402.52	N/A	323.73	0.24	65.52	N/A	65.76	N/A	N/A	N/A	N/A	N/A	N/A	1104.63
PARTICULATE MATTER EMISSIONS LESS THAN 10 MICRONS																			
EXHAUST	0.09	0.99	0.24	1.31	0.01	0.40	0.13	0.53	0.04	0.44	1.29	1.76	0.01	0.85	0.07	0.13	0.06	0.06	12.86
TIKE-WEAR	0.03	1.75	0.01	1.78	0.00	0.68	0.00	0.69	0.01	0.20	0.05	0.25	0.00	0.01	0.43	0.44	0.01	0.01	3.10
BRAKE-WEAR	0.04	1.74	0.01	2.79	0.00	3.07	0.00	1.08	0.01	0.26	0.05	0.32	0.00	0.01	0.19	0.21	0.01	0.02	4.13
TOTAL PM10 EMISSION	0.16	5.47	0.26	5.89	0.01	2.16	0.13	2.30	0.06	0.71	1.37	2.34	0.02	0.87	0.59	0.78	0.08	0.08	20.09
LEAD																			
LEAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SULFUR OXIDES- as SO2	0.05	3.82	0.08	2.80	0.00	0.86	0.00	0.90	0.03	0.87	2.01	2.53	0.01	0.04	0.00	0.05	0.25	0.01	13.71
FUEL CONSUMED IN 1000 GALLONS																			
GASOLINE	143.11	7104.86		7653.97	14.63	3440.02		3454.63	134.62	1862.87		1997.48	43.88	149.16		152.16		25.18	13323.72
DIESEL		23.26		23.26			11.73	11.73			567.70	567.70			2762.97	2762.81	78.95		2935.96

(1) - MEDIUM DUTY TRUCKS INCLUDES LIGHT HEAVY DUTY TRUCK EMISSIONS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY
2565 PLYMOUTH ROAD
ANN ARBOR, MICHIGAN 48105

OFFICE OF
AIR AND RADIATION

AUG 20 1997

Ms. Margaret Singh
Argonne National Laboratory
955 L'Enfant Plaza, S.W.
Suite 6000
Washington, D.C. 20024

Dear Ms. Singh:

Thank you for providing me the opportunity to review the July, 1997 draft DOE study "Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Analysis." I apologize for missing your August 15 deadline for comments, and hope that you will still be able to consider our input. My staff and I have reviewed the technical report and several appendices which contain information with which we are familiar. This letter and the enclosed document presents our comments on the study. Let me emphasize that we are transmitting these to you without having had upper management review, so you should consider these to be staff comments and not an "official" EPA response.

We have concluded that this is a very well done report. The level of detail of the analysis is impressive. The methodology is very similar to work we have done in the past, and it appears that you've used the most current data and references available. We have not previously considered emissions from the manufacture of the vehicles and batteries (having focused on fuel production and combustion), and hence have no basis on which to comment on those sections. However, I will note that we previously felt that vehicle manufacturing emissions would be the same for both EVs and conventional vehicles; your analysis makes a strong argument that this is not the case, particularly for emissions of TSP, SOx, and lead. As we consider future work in this area, we will reexamine our assumptions in light of your findings.

The enclosed document presents more detailed comments grouped into three categories: general comments, questions, and typographical errors. I have assembled these comments from my staff and have tried to make them as clear as possible. However, if you have any questions about them, don't hesitate to call me at (313) 668-4432 for clarification.

I look forward to receiving the final study, and expect that we will refer to it in the future when asked about the lifecycle emissions associated with electric and other motor vehicles. Thank you again for asking us to participate in this review.

Sincerely,

A handwritten signature in cursive script, reading "Susan L. Willis".

Susan L. Willis, Manager
Fuels Studies & Standards Group

cc: Chuck Freed, Director, FED

Enclosure

Comments on July 1997 draft EVTECA Report

General Comments

- While this report is designed to be a technical analysis, it raises policy implications and considerations that could (and perhaps should) be addressed. For example, a utility is likely to make different decisions about construction of new capacity depending on the information it has about future demand. This analysis shows that it is possible that additional electricity demand due to EVs could actually result in lower overall powerplant emissions, as cleaner and more efficient technologies are introduced into the system and used for daily electricity generation, not just to supply the demand of EVs. However, most policy analyses of future EV use focus either on initial introduction of EVs into the fleet (which is so small that it doesn't make a dent in demand) or some future scenario of substantial displacement of gasoline vehicles (requiring additional capacity). This study shows that both types of scenarios should be analyzed when trying to determine the environmental and energy implications of EVs relative to gasoline vehicles. Commentary on this subject would add value to the regulator or utility representative who reads the report.
- The scenarios studied are region specific, which impacts a wide-range of assumptions, from utility operation to driving patterns and climatic factors. These scenarios require consideration of how the utility industry is likely to respond to changes in demand, over specific time-frames, in specific areas. While the scenarios do not change very much between Houston and DC, the information is useful and appropriate, and often lacking from other EV lifecycle analyses. It is unfortunate that the data for all four cities could not be presented in its entirety.
- In the Summary, there appears to be a few inconsistencies with the conclusions presented later. On page s-3, it states that CH₄ emissions are expected to be lower. But on page s-5, and later in the more detailed results section, CH₄ emissions increase in all scenarios. The summary also indicates that NO_x, SO_x and TSP can be higher or lower - but the results sections indicate pretty clear trends. There are exceptions to the trends, particularly when one considers in-basin emissions vs. out-of-basin emissions, but the trends are clear. We recommend that the summary more clearly and accurately reflect the conclusions of the study.
- We support the message that a simple comparison between power plants and CV tailpipe emissions does not fairly compare EVs and CVs. It is important for people to realize this, and you do a very good job of stating this, and subtly reinforcing it throughout the analysis. It helps illustrate the importance of some of these other steps in the lifecycle.
- We found that, in reviewing the results, it was a bit repetitive to read that UCT and UCC are nearly the same, and OCC and OCT are also nearly the same. This would indicate that the second factor of the technology used is not quite as significant as concluded earlier in the

study. It might make the reporting a little less cumbersome if you combine, at a minimum, the off-peak scenarios. It would still be appropriate to report the unconstrained scenarios separately, since they do illustrate small differences.

- We recommend that you be more precise in your definition of similar. It ranges from a 1% difference in result to over 10% difference in result. This latter difference is large enough that we would hesitate to characterize it as "similar."
- The text states that some emissions are allocated over the life of the car, but the assumed useful life is not clearly identified. In addition, a figure of 704 million total miles is used, but it is unclear what this number is. We recommend that you clarify these two numbers, and identify their sources.
- The summary tables in Chapter 2, for methane, refer to "CH₄ emissions associated with fuel production" and "CH₄ emissions associated with production of fuel ..." If the reader isn't familiar with methane's production and use, the distinction between these two listings is probably not clear. We recommend that you clarify the terminology to make the distinction more obvious.
- More details about the coalbed methane and vented/flared/captured gas assumptions used would be helpful. While you do provide the source of the numbers and the emission numbers themselves, some idea of how those numbers were derived in the referenced study would be helpful. This is an area in which there are many discrepancies in the literature, and it helps to know the basis for the numbers.
- It is not clear from the explanation of why summer emissions vary as the results indicate. Perhaps you could explain why the analysis showed these changes in the summer months and what the implications for the TECA are, rather than simply calling attention to the differences. We found the inclusion of the summer data to be confusing without sufficient explanation to warrant its inclusion.
- The neutral tone used throughout the report minimizes the impacts of the results of some of the emission increases shown. While this tone was no doubt selected to communicate technical details, it would help if language were added to put the results in perspective. For example, just reading through the results, one notices that there is a 60% reduction in CO₂, over 90% reductions in NO_x and VOC, but very large increases in SO_x, TSP and lead (e.g., 400% increase in lead emissions). The reader will want to know if this tradeoff is acceptable. While to some degree this is a policy question, the study should at a minimum call attention to this question so these points are not overlooked.
- It appears that in evaluating gasoline production you include imported crude, but assume domestic practices for all wells. Considering the rates of venting/flaring in some other countries, we believe this could be an overly conservative approximation. We recommend

that you use domestic vent/flare rates for domestic oil, and some representative foreign vent/flare rates for imported oil.

- Throughout the summary, many acronyms, like UCC, UCT and TSP, are not defined. We recommend that you define them in the summary as well as in the body of the report.
- We recommend that you clearly differentiate between natural gas and gasoline by not using the term "gas" loosely. Many readers associate "gas" with gasoline, while others more familiar with some of the sectors involved in your analysis will assume "gas" means natural gas.
- It appears that, at the time Appendix B was initially authored, California Phase 2 RFG, Stage II vapor recovery systems, and enhanced I/M programs had not yet gone into effect. The final report should be updated to include these programs, or should acknowledge their omission and give at least a qualitative discussion of how this impacts the conclusions.
- The actual MOLBILE5a input files should be included in Appendix B for reference.
- (Referring to Appendix B) In-use conventional vehicles include model years spanning at least 25 years, though approximately 90% of those in-use conventional vehicles are less than 13 years old. Thus it may be appropriate to examine only 13 model years of conventional vehicles in year 2010 (model years 1998 through 2010). However, it would seem that examining only two model years of conventional vehicles in year 2000 (1998 through 2000) would bias the emission estimates towards the newest technologies and the cleanest vehicles.

Questions

- Why weren't emissions of N₂O included in the analysis? While we acknowledge that it is somewhat problematic due to the absence of sufficient data in some areas, this is often discussed as an important greenhouse gas. For those of us who evaluate lifecycle emissions, it stands out as the only commonly discussed greenhouse gas excluded.
- How will deregulation of the electric utility sector, permitting power plants to sell outside of their region, impact the results of the analysis in Chapter 5? How can regional emissions be tied to specific fuels/powerplants under such a scenario?
- Why was the California model EMFAC7G not used to estimate the emission effects of California Phase 2 RFG? (Appendix B, Section B.6.2)

Typographical Errors

page 2-1, paragraph 1 "though" should be "through"

page 2-17, paragraph 1 should have "magnitudes *are*" or "magnitude *is*"

page 7-1, paragraph 2 should be "based on" not "based in"

appendix B, B.6.2, Vehicle Emission Standards

"Tier 1 standards take ~~into~~ effect in 1994."

B.6.2, Federal and California Reformulated Gasoline (RFG) Requirements

"Nationwide, the EPA has established Phase ~~1~~ I and Phase ~~2~~ II RFG requirements."

B.6.2, Enhanced inspection/maintenance (I/M) program

"Vehicles are driven for 240 seconds on dynamometers during emission tests, as opposed ~~opposite~~ to the current I/M program under which vehicles are tested at idling."

Electric Power
Research Institute

Powering Progress through Innovative Solutions

September 10, 1997

Margaret Singh
Argonne National Laboratory
955 L'Enfant Plaza, S.W.
Suite 6000
Washington, DC 20024

Dear Ms. Singh:

The Electric Power Research Institute (EPRI) and the Electric Vehicle Association of the Americas (EVAA) are pleased to submit to you our comments on the draft report, *Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Analysis* (TECA Report). EPRI and EVAA conducted a two-week review of the TECA Report, the result of which is the attached document, which provides several suggested modifications to the report based on noted flaws in the analysis. These flaws include the use of out-of-date data, incorrect scenarios and wrong assumptions. EPRI and EVAA are providing these comments because the TECA Report is the first of its kind and want to ensure that the report and its results are credible from both a technical and policy standpoint.

EPRI and EVAA hope that the comments provided in the attached report are helpful to you and the other authors and we hope that the most important modifications suggested are indeed incorporated into the final version. Both EPRI and EVAA would like to thank you for the opportunity to review the draft report and provide comments.

Sincerely,

Ed Riddell
Manager, Electric Transportation
Electric Power Research Institute

Sincerely,

Robert Hayden
Executive Director
Electric Vehicle Association of the
Americas

REVIEW AND ANALYSIS OF THE DRAFT REPORT:

***TOTAL ENERGY CYCLE ASSESSMENT OF ELECTRIC AND
CONVENTIONAL VEHICLES: AN ENERGY AND ENVIRONMENTAL
ANALYSIS
(Draft)***

Prepared by:

Electric Power Research Institute
Palo Alto, California

and

Electric Vehicle Association of the Americas
San Francisco, California

September 15, 1997

1.0 EXECUTIVE SUMMARY

The Electric Power Research Institute (EPRI) was asked by Argonne National Laboratory (ANL), National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL) to review their draft report prepared for the U.S. Department of Energy (DOE) titled, *Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Analysis* (referred to herein as the "TECA Report"). EPRI put together an Issues Analysis Team (IAT) comprised of representatives from EPRI, electric utilities and the Electric Vehicle Association of the Americas (EVAA). The purpose of this report is to provide helpful comments and data to improve the credibility of the TECA Report. The IAT performed a brief analysis of the draft TECA Report to:

- provide an overall critique of the analysis;
- highlight positive portions of the analysis;
- identify areas and assumptions that require further work in terms of additional and/or updated data; and
- provide backup sources of data necessary to improve the validity of the report.

1.1 IAT Review

The IAT conducted a two-week review of the TECA Report which was conducted over a period of about four years. The TECA Report is comprised of three volumes, two of which are data- and methodology-intensive. It was difficult to review the large report in such a short period of time considering the complex methodology and significant amount of data. However, while the length of the IAT's review was brief, every effort was made to ensure the review was intense.

The IAT examined the TECA Report to identify the major strengths and weaknesses of the total energy cycle analysis in three areas:

- **Data** — The data relied upon was analyzed to determine if the sources used are accurate and the most recent available.
- **Analysis** — The analysis performed was examined to determine if the scenarios and assumptions used by the authors are appropriate and valid.
- **Presentation** — The results of the analysis were examined to determine if they are presented fairly.

1.2 Policy Framework

The stated purpose of the TECA Report is to provide an inventory of the energy use and emissions associated with using electric vehicles (EVs) in a number of metropolitan areas in the

United States. The TECA Report is one of the first efforts to assess the total fuel cycle¹ associated with both EVs and conventional vehicles (CVs) by examining them from the first steps of their production to their operation at the point of use. While the overall purpose of the TECA Report could begin to provide the DOE and the EV industry with a framework upon which to build the case for increased implementation of EVs into fleets and residential scenarios, its results are not credible. Significant work needs to be done to update the analysis to improve its validity and transform it into a stepping stone for further analysis and possibly environmental decision-making. However, the unevenness of the report, old data and poor scenario selection make it difficult to endorse its conclusions. Significant upgrades of data, analysis and presentation will be necessary to make the report credible and defensible. This review addresses the upgrades necessary to support the conclusions that EVs provide significant environmental benefits over CVs.

The primary weaknesses noted by the IAT are discussed in section 2. These weaknesses reduce the usefulness of the report in the public policy sector. The credibility of the report will be enhanced by using updated data and by addressing the uneven nature of the analysis.

1.3 Major Strengths and Weaknesses

Overall, the IAT supports the purpose of the TECA Report, as it is the second major effort undertaken to study the total energy fuel cycle of EVs and CVs. The authors do a reasonable job framing the total energy fuel cycle by including the major stages of production, operation and maintenance for both EVs and CVs. Specific strengths of the report include:

- providing a framework for analysis;
- its modeling that characterizes the total energy cycle;
- its identification and estimation of emissions of key pollutants;
- its perspective on the emission-reduction potential of EVs and total emissions; and
- its consideration of in-basin emissions.

While the TECA Report's results show that EVs are more favorable than CVs, the data used, analysis methodologies and method of results presentation are neither consistent nor evenly applied. In addition, the data is out-of-date. The IAT has identified what it thinks are the most important weaknesses of the TECA Report, those having the greatest impact on the emission results and its overall validity. General weaknesses are listed below and are discussed in greater detail in Section 2 of this report:

- reliance on out-of-date information related to EVs and batteries;
- use of detailed models fed by gross data assumptions negating the detail of the model;
- comparisons of mixtures of data and analysis that don't correlate or match (i.e., "apples to oranges");

¹ Acurex Environmental Corporation evaluated the emissions associated with the production and distribution of conventional and alternative fuels in their 1996 report, *Evaluation of Fuel-Cycle Emissions on a Reactivity Basis*.

- poor projection of future performance of both EVs and CVs;
- unsubstantiated characterization of electric utility systems; and
- unfair and unclear presentation of results.

The IAT's review of the TECA Report has resulted in a concern for the overall validity of the report's emissions results based on out-of-date data and uneven analysis. These weaknesses briefly discussed in section 2 reduce the usefulness of the TECA Report in the public policy sector. The credibility of the report will be enhanced by using updated data and by addressing the uneven nature of the analysis and make EVs look even more favorable relative to ICVs. While the effort to analyze the total energy fuel cycle of electric vehicles (EVs) and conventional vehicles (CVs) is applauded, the analysis and results of the draft TECA Report can not be supported at this time without major updates. Suggested modifications required to improve the results and make the report suitable for open discussion among key industry participants are discussed in section 2.

1.4 Impact on Emissions

Lead (Pb), nitrogen oxide (NO_x), sulfur oxide (SO_x) and particulate emissions calculations in the TECA Report are based on old data and incorrect assumptions that do not account for advances in EV technology and strengthened emission regulations. The changes necessary to make the TECA Report's results more credible would have a significant impact on the total emissions presented in the report as discussed below. These are discussed in greater detail in section 2.

- **Lead** - the assumed number of Pb-acid battery packs used over the life of the EV should be reduced from three to two. This correction would reduce Pb emissions by approximately 33 percent.
- **Sulfur oxide** - elimination of nickel-cadmium (Ni-Cd) batteries and inclusion of nickel recycling in the analysis would significantly lower SO_x emissions related to battery manufacturing.
- **Particulates** - elimination of sodium sulfur (NaS) and Ni-Cd batteries from the analysis would significantly lower particulate emissions associated with battery manufacturing and result in lower, more realistic levels of particulate emissions.
- **Nitrogen Oxide** - elimination of NaS and Ni-Cd batteries from the analysis would result in more realistic NO_x emissions from battery manufacturing. The report's off-peak charging scenario assuming combustion turbines (CTs) would supply off-peak electricity depicts NO_x emission levels that are unrealistic.
- **In-basin** - presentation of total emissions with no mention of in-basin emissions does not show the significant greater value of EV in-basin emission reductions in areas of high population.

1.5 IAT Response Structure

Section 2 of this report provides a detailed discussion of the issue points examined by the IAT. Specific areas examined fall into four categories — scenarios, battery-related issues, vehicle-related issues and electric utility issues. Specific weaknesses of the report in each of these four

areas are identified and discussed in terms of the assumptions made. New assumptions or suggested modifications to existing assumptions are presented for the benefit of the TECA Report's authors. References or sources for the new assumptions are provided. Section 3 of this report provides the IAT's conclusions relative to the use of the TECA Report as a policy tool for highlighting the emissions reduction potential of EVs. Also, additional areas of research that could be used to enhance the TECA Report and its results are provided.

2.0 DISCUSSION OF THE REPORT

The Issues Analysis Team (IAT), assembled by the Electric Power Research Institute (EPRI), reviewed the draft report, *Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Analysis* (referred to herein as the "TECA Report"), and provides a brief discussion of it in this section. The purpose of the IAT discussion is to provide the authors with helpful comments and data to improve the credibility of the TECA Report and its results. Specifically, the IAT performed an in-depth analysis of the draft TECA Report to:

- provide an overall critique of the analysis;
- highlight positive portions of the analysis;
- identify areas and assumptions that require further work in terms of additional and/or updated data; and
- provide backup sources of data necessary to improve the validity of the report.

Examination of the TECA Report led to identification of several weaknesses. These weaknesses occur as a result of the data relied upon, the analysis that was performed and the results that are presented. Specific weaknesses in the scenarios, battery-related issues, vehicle-related issues and electric utility issues analyzed are discussed in this section. Suggested modifications to the assumptions used by the authors are also provided.

2.1 A Policy Framework

The purpose of the draft TECA Report, prepared by Argonne National Laboratory (ANL), National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL), was to provide a policy framework in which the air emissions from electric vehicles (EVs) and conventional vehicles (CVs) could be compared. The TECA Report is the first of its kind to assess the total energy fuel cycle associated with both EVs and CVs by examining them from the first step in their production to their point of use.

The EV analysis includes energy use and emissions from electricity generation to charge EV batteries, the fuel extraction and transport needed to support the electricity generation, and battery and vehicle manufacture. These energy use and emissions are compared to CVs operating on reformulated gasoline and includes CV operation, the extraction, transport and processing required to supply vehicles with reformulated gasoline and vehicle manufacture.

While the TECA Report's results appear to be favorable to EVs, its weaknesses in terms of data, analysis and presentation outweigh its strengths. Essential data to the emissions analysis and results are out-of-date, primarily it seems a function of the fact that the report took a long time to complete. In addition, it uses a mix-and-match approach to compare EVs and CVs.

2.2 Scenarios

Weaknesses related to the scenarios analyzed by the authors of the TECA Report are discussed below.

2.2.1 Utility Analysis

The authors' basic assumptions on EV charging practices lead to them to conclude that additional off-peak capacity will be needed. They presume it will be supplied by either combustion turbine (CT) units or combined-cycle (CC) units, both on- and off-peak. Several of their assumptions are unrealistic. First, it is unlikely that fleet EV owners will charge their vehicles in the two hour time frame (between 4 and 6 p.m.) used in the report. Time-of-use rates and sophisticated charging equipment and fleet managers make this critical assumption unrealistic. New capacity is probably unnecessary unless the high penetration scenario is exceeded or the deregulated environment optimizes system capacity further.

The second scenario assumption to consider CT units for off-peak generation does not quite make sense. Most utilities are planning either gas or oil-fired CC units or coal units for base load and most are considering CT units for intermediates.¹ EV operation emissions will be overstated as a result of the inclusion of a CT off-peak charging scenario. The addition of a CT unit lowers plant operational efficiency, increases the emissions and is contrary to the use of off-peak charging and practice.

Particulate emissions are high in the TECA scenario that assumes off-peak charging demand will be supplied using CT units which have high heat rates and low efficiency (relative to CC generation units). Inclusion of the CT scenario is unrealistic and artificially increases particulate emissions. High EV nitrogen oxide (NO_x) emissions are also associated with the off-peak charging scenario that assumes CT units will supply the off-peak energy. Inclusion of this scenario in the TECA analysis also depicts NO_x emission levels that are unrealistic and unfavorable for EVs.

The IAT is not aware of any utilities that are planning to add CTs to meet off-peak requirements. The IAT recommends that the unconstrained charging scenario which assumes CTs will be added by utilities to meet the additional electricity demand be removed from the analysis.

The TECA analysis of utility operations is extremely detailed. However, the results of the analysis are based on the underlying assumption that all EVs will be charged at the same time. This assumption is flawed. Time-of-use rates make the unconstrained charging scenario unrealistic. Currently, the study's main assumption is that all charging takes place on-peak between 4 and 6 p.m. There is a small residential tail out to 12 p.m. The detailed utility model used can handle more complex scenarios than used in the study. In order for the study to be valid the charging scenario should be as detailed as the models. The charging assumptions effect all the

¹ Combined cycle units are anywhere from a 15 to 30 percent more efficient than combustion turbines. Their relatively high efficiency makes them more economical to operate and more likely to be used for base load.

emissions results and should therefore be revisited based on the number of utilities with time-of-use or EV-charging rates.

2.2.2 Regions

The TECA Report provides data for four metropolitan areas in the United States — Houston, Chicago, Washington, DC and Los Angeles. However, it only provides total energy cycle simulations for two areas — Washington, DC and Houston. The authors state that these regions were chosen because they are some of the worst regions for ozone attainment, are diverse with respect to the current mix of fuels and have different climates. However, the IAT does not believe these four metropolitan areas are the best choices because EV penetration to date has not occurred in three of these areas. The most viable regions for EV market penetration, such as California and Florida, should be the focus of the analysis.

2.2.3 Data

The data relied upon for the available or soon-to-be available EVs is out-of-date. None of the EVs included in the analysis are commercially-available in the United States nor are they expected to become available in the short-term. The EVs analyzed are, for the most, prototypes that were being developed when the analysis began about four years ago. As four years have passed, these vehicles are no longer representative of the current available EVs or those expected to be available over the next five years. The use of old data leads to a completely flawed analysis due to the wrong selection of EVs. This is discussed in greater detail in subsection 2.4.1. The IAT recommends that a completely new inventory of EVs be analyzed and the original EVs removed from the analysis.

2.2.4 Uneven Analysis

The authors present very uneven analyses. The analysis for a total energy cycle has many components and requires both modeling and projecting many different factors. This analysis models certain features in very fine detail and others in much less detail. This creates the potential for uneven treatment of data and results. This study has this uneven problem in two areas. The study uses very fine (5-minute) increments in its electric utility operation model but uses only a two-hour start block on charging. The materials assessment is similarly unbalanced. Detailed material manufacturing emissions are used with broad assumptions relative to vehicle engine and battery composition. The results appear detailed but are only as good as the broad assumptions that were used. This appears to be caused by inconsistent quality in the data set or detailed modeling with gross assumptions.

In the analysis of vehicle operations, the authors neglect to include the replacement of engine oil in CVs. A second example is their analysis of EV and CV shell composition. A detailed analysis of shell composition and materials is provided but the gross assumption is made that compositions will not change significantly in the near future and recommend only a 5% change in vehicle composition through the years leading to 2010. Not only is this is not a good assumption but the authors go through the trouble of conducting an in-depth analysis of composition and then assume

the changes will be minimal. Also, there is considerable detail on air emissions but no discussion of water pollution related to gasoline spills. This is a major oversight.

2.2.5 Emission Presentation

Current air quality emphasis is on the reduction of NO_x and reactive organic gases (ROG) to reduce ozone-related smog and on fine particulates to reduce respiratory effects. Reductions in these emissions is more important in highly populated areas or in areas where air exchange is limited. These emissions are referred to in the report as in-basin emissions. While reporting in-basin emissions is a report strength, the report lists in-basin emissions separately from total emissions. This creates a strong bias for CV's because they have much higher in-basin emissions where the health effects will be significantly higher. The IAT recommends that the report display in-basin emissions whenever total emissions are reported so the reader remembers the public health benefits of EVs and does not take total emissions out of context. Operation of EVs in-basin in the greater Los Angeles area have the potential to reduce smog-forming nitrogen oxides, reactive organic gases and carbon monoxide — the main target of mobile-source pollution-control efforts — by 99 percent. In addition, EVs produce over 70% less carbon dioxide than conventional vehicles.²

2.3 Battery-Related Issues

Four battery types are analyzed in the TECA Report — advanced lead-acid (Pb-acid), nickel-cadmium (Ni-Cd), nickel-metal hydride (Ni-MH) and sodium-sulfur (NaS). These four battery types were selected in 1994 based on the battery technologies vehicle and battery manufacturers were pursuing at the time. Specific characterization of these batteries includes weight, energy density, energy efficiency and battery materials. Battery performance was limited to the U.S. Advanced Battery Consortium goals. Issues related to the batteries analyzed in the TECA Report are presented in this section.

2.3.1 Types

While the NaS battery was selected based on what vehicle and battery manufacturers were working on in 1994, these batteries are not the current focus of research. According to information from the U.S. Department of Energy (DOE), the NaS battery is not currently included in their mid-term or long-term battery performance goals. In addition, information from EVAA does not list any EVs commercially-available in 1998 that will be powered by NaS batteries. The inclusion of NaS batteries biases the range of results. Assumptions made throughout the analysis about NaS batteries (e.g., NaS batteries will be used in mini-vans in 2002) are incorrect. A December 1995 report³ states that the company involved in the R&D of NaS batteries, Silent Power, decided to discontinue its funding of the NaS battery program. Deleting the NaS battery would appear to reduce the value of EVs slightly as the NaS battery is shown

² "Electric Vehicles Bring Large, Long-Term Pollution Cuts." EV Today. Electric Power Research Institute, 1996.

³ Kalhammer, F. R. et.al., *Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel*, Prepared for the California Air Resources Board, December 11, 1995.

with the highest efficiency (without thermal management losses) and therefore the lowest operating emissions. While it is difficult to estimate the impact on EV operating emissions by eliminating the NaS battery, its removal is justified given the fact it is no longer a realistic battery option. Elimination of the battery from the TECA analysis would reduce battery manufacturing emissions.

The report also includes Ni-Cd batteries which are not currently planned to be used in any light-duty (passenger cars, pick-up trucks or minivans) EVs that will be commercially available in the U.S. Ni-Cd is still being used for heavy-duty vehicles such as buses and military vehicles, and its use is widespread in Europe, but the technology is not being pursued for use in passenger vehicles destined for the U.S. In recent years, battery manufacturers have made a preferential shift toward the development of Ni-MH batteries for application in light-duty passenger vehicles. The promise of higher specific energy and absence of toxicity issues associated with Ni-Cd has prompted the switch from Ni-Cd to Ni-MH. Ni-Cd batteries should therefore be dropped from the analysis as well.

Other batteries are not given proper address or inclusion. For example, the analysis does not appropriately include the use of Ni-MH batteries in the pre-2003 scenario, and excludes Lithium-based batteries from the post-2003 battery performance scenario. The DOE's Office of Transportation Technology states in a July 1997 publication that the Ni-MH battery is the most likely technology to meet the ABC's mid-term (1998) goals and the Lithium-polymer (Li-polymer) battery is the most promising technology to meet the ABC's long-term (2003) goals.

Ni-MH will be used in the 1998 Honda EV Plus and the Toyota RAV4. Both Ford, GM and Chrysler also will be offering EVs using Ni-MH batteries. Panasonic EV Energy is building a Ni-MH battery factory and production is scheduled to begin in the fall of 1997. Production will be 240,000 cells per month — enough for use in 1,000 gasoline/electric hybrid vehicles and 250 pure electric vehicles⁴. Customers are said to be Toyota, Honda, Nissan and Ford.

Lithium-ion (Li-ion) and Li-polymer batteries are currently being pursued by a number of battery manufacturers including 3M/Hydro-Quebec, SAFT America, Sony, Varta and Duracell. It is expected that Li-polymer batteries will be commercially available by 2003. The technology is currently being used by Nissan. The Nissan Prairie Joy and FEV II both utilize a Li-ion battery. The Prairie Joy will become commercially available in 1998 to California fleet owners only.

The IAT considers the use of old battery technology coupled with the projective nature of the study to be a major weakness. Table 2-1 provides updated advanced battery availability projections. Updating the battery performance data to reflect progress in battery technology and inclusion of key battery types will be necessary to make the report credible. The IAT recommends that the NaS and Ni-Cd batteries be removed from the analysis entirely. The IAT also recommends that the Ni-MH be included in the pre-2003 scenario and the Li-ion and Li-

⁴ *Electric Vehicle Progress*, August 1, 1997.

polymer batteries be included in the post-2003 scenarios.⁵ Some of the information needed to include these three batteries is provided in the tables in sections below.

Table 2-1
AVAILABILITY OF ADVANCED EV BATTERIES

Battery Type	Pilot Scale (hundreds per year)	Production Scale (10,000-40,000 per year)
Nickel-Metal Hydride	1966-1997	1999-2001
Lithium-Ion	1998-2001	2001-2002
Lithium Polymer	1999	2002
Source: Kalhammer, F.R. et.al., <i>Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel</i> , Prepared for the California Air Resources Board, December 11, 1995.		

2.3.2 Operations (Performance)

Certain battery features and performance elements significantly impact both operations and manufacturing emissions. These are life expectancy, specific energy (wh/kg) and recyclability. The TECA Report needs to improve the credibility of this data as the performance data used for the analysis is less than that of current EV batteries.

Battery Life-Expectancy. The assumptions made regarding battery life-expectancy appear to be low. The authors estimate that three sets of Pb-acid batteries will be required during the life of the EV (i.e., batteries are replaced twice during the life of the vehicle for a total of three sets of batteries used) and that two of the other battery types analyzed — NaS, Ni-Cd and Ni-MH — will be required (i.e., batteries are replaced once during the life of the vehicle for a total of two sets of batteries used). The authors state that a Ni-Cd battery may not need replacement over the vehicle's lifetime but decide to replace it once anyway. These battery life assumptions increase lifetime battery weights considerably and subsequently increase materials emissions.

Battery life-expectancy has improved in recent years. Because the TECA Report does not identify battery life-expectancy in terms of life cycles, it is difficult to compare updated life cycle projections. Based on the battery life assumptions noted above, it appears that the TECA Report assumptions are low.

The cycle-life of batteries has been increased during the past few years through improved quality control, more uniform current distribution and better containment of active materials in advanced-design grids and cells. There appears to be consensus among major lead acid battery producers that a life of at least 500 cycles should be attainable.⁶ The life cycle characteristics of the lead-acid battery are expected to improve according to the following schedule provided in Table 2-2.

⁵ A rerun of the TECA analysis may even consider including Li-ion battery types in the pre-2003 scenario.

⁶ Kalhammer, F. R. et.al., *Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel*, Prepared for the California Air Resources Board, December 11, 1995.

Table 2-2
Pb-ACID BATTERY LIFE CYCLE

Source	Year	Life Cycle
Electrosorce (Horizon)	current	300
CARB Report*	current	300-400
Electrosorce (Horizon)	1998	600
Electrosorce (Horizon)	pre-2003	900
Electrosorce (Horizon)	post-2003	>900
Source: Electrosorce, 1997.		
* Kalhammer, F.R. et.al., <i>Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel</i> , Prepared for the California Air Resources Board, December 11, 1995.		

Lead emissions are related primarily to the manufacturing of Pb-acid batteries. The TECA assumption that Pb-acid battery packs will be replaced 3 times over the life of the vehicle is flawed for it assumes that the original expired Pb-acid battery pack will be replaced by another Pb-acid battery with the same performance characteristics and life-expectancy. It is more likely that original Pb-acid battery packs will be replaced by Pb-acid packs with improved performance characteristics and longer life-expectancy. The life-expectancy of advanced Pb-acid batteries is expected to improve significantly, from 300 cycles to 600 cycles prior to 2003. It is also likely that original Pb-acid packs will be replaced with a Ni-MH battery pack rather than another Pb-acid pack. The likelihood that the life-expectancy of replacement Pb-acid battery packs will increase, coupled with the possibility that Pb-acid batteries may even be replaced with Ni-MH battery packs make the TECA assumption incorrect and unfavorable to EVs. The IAT feels that the Pb-acid battery life cycle assumptions weigh significantly in the outcome of EV lead emissions calculations and should therefore be revisited. Reducing the number of Pb-acid battery packs used over the life of one EV from three to two would reduce EV lead emissions by approximately 33 percent.

The Ovonic Ni-MH battery is expected to last the lifetime of the vehicle. Ovonic claims that their Ni-MH batteries currently last for up to 100,000 + miles, based on a GM Impact-type vehicle⁷. Saft America is producing a Ni-MH battery which is expected to last up to 1,200 cycles. Life-expectancy estimates of the Ni-MH battery are provided in Table 2-3 below.

The IAT feels that the battery replacement assumptions have a significant affect on emissions from battery manufacturing. Updating battery life cycle projections to reflect the progress made in Pb-acid and Ni-MH technology in recent years will allow more accurate battery replacement assumptions and will make the report more credible.

⁷ GM Ovonic battery literature.

Table 2-3
NI-MH BATTERY LIFE EXPECTANCY

Technology Status	Life Cycles	Source
Present Technology	>600	GM Ovonic
Present Technology	750 to 1,000	CARB Report*
Pre-2003	1,200 (expected)	Saft America
Projected for 1997 - 2001	1,000 to 2,000	CARB Report*

* Kalhammer, F. R. et.al., *Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel*, Prepared for the California Air Resources Board, December 11, 1995.

Performance. The battery performance estimates relied upon in the TECA Report are also out-of-date. Specific energy estimates in wh/kg, provided for the batteries analyzed, are understated. The authors provide a specific energy estimate for Pb-acid batteries of 45 wh/kg for pre-2003 and 47 wh/kg for post-2003. Estimates obtained from Electrosorce, Inc. indicate that Pb-acid battery technology is improving at a faster rate than projected in the report. A battery's specific energy relates to its required weight, EV performance and range, and subsequent emissions from battery manufacturing. The authors are relying upon a specific energy estimates that are low compared to updated performance projections shown in Table 2-4 and thus reduce EV performance and increase emissions.

Table 2-4
PERFORMANCE CHARACTERISTICS OF Pb-ACID BATTERIES

Year	Specific Energy (wh/kg)	Specific Power (w/kg)	Source
Current-Projected	33-50	80-300	ALABC*
Current	45	223	Electrosorce
1998	50	>200	Electrosorce
Pre-2003	50	130	DOE, OTT**
Pre-2003	>50	>200	Electrosorce
Post-2003	>60	>200	Electrosorce

* Database of Lead-Acid Batteries for Traffic-Compatible Electric Vehicles, Advanced Lead Acid Battery Consortium, September 1995.

** EV Batteries, DOE, Office of Transportation Technologies Fact Sheet, March 1996.

In addition, the advancement of Ni-MH battery performance is also underestimated. The TECA Report estimates Ni-MH will have a specific energy of 80 wh/kg post-2003. As illustrated by Table 2-5, Ni-MH batteries with high specific energy are available today and post-2003 battery performance projections are better than the TECA Report assumptions.

Table 2-5
PERFORMANCE CHARACTERISTICS OF Ni-MH BATTERIES

Year	Specific Energy (wh/kg)	Specific Power (w/kg)	Source
Current	65	175	Saft America
Current	70	200	GM Ovonic
Projected	70	175	Saft America
Projected	80	400	GM Ovonic
Projected 1998	80-90	220	CARB Report*
Projected 2001	120**	250	CARB Report*
Post-2003	80	225	TECA Report

* Kalhammer, F. R. et.al., *Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel*, Prepared for the California Air Resources Board, December 11, 1995.

** Based on a GM Ovonic battery with advanced negative and positive electrode materials.

Lithium-based batteries are expected to outperform both Pb-acid and Ni-MH. Table 2-6 displays performance characteristics for Li-ion and Li-polymer batteries.

Table 2-6
PERFORMANCE CHARACTERISTICS OF LI-BASED BATTERIES

Year	Specific Energy (wh/kg)	Specific Power (w/kg)	Life Cycles	Source
Lithium Ion				
1998-1999	100-120	300	1,200	CARB Report*
2001-2002	120-140	200-300	>1,200	CARB Report*
Projected	140	200-300	1,200	DOE, OTT**
Projected	150	300	na	Saft America
Lithium Polymer				
Projected	130	200	1,000	DOE, OTT**
Projected	200	na	na	3M/Hydro-Quebec

* Kalhammer, F. R. et.al., *Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel*, Prepared for the California Air Resources Board, December 11, 1995.

** EV Batteries, DOE, Office of Transportation Technologies Fact Sheet, March 1996.

The IAT feels that battery performance values are significant to the operational efficiency of EVs and therefore affect EV operating emissions. The IAT therefore recommends that the battery performance estimates used in the TECA Report be updated based on independent third party evaluations to more accurately reflect recent advancements in battery technology.

2.3.3 Manufacturing (Materials)

Recycling. The authors provide a flawed analysis of battery recycling practices. The report assumes that only Pb-acid batteries will be recycled. However, it should be assumed that nickel-based batteries (e.g., Ni-MH) will also be recycled.⁸ Currently, the Ni-MH battery is 30% Ni and virtually 100% of Ni is recycled. International Metal Company (Inmetco), located in Pittsburgh, PA, currently recycles the used batteries. Ovonics is also working to develop a strategy to reclaim battery grade Nickel. Direct recycling of the battery contents will surely develop as more EVs using Ni-MH enter the market. Ni-MH is the only battery that has passed the EPA's toxic leak test which means it would be legal to dispose of in a landfill, although in reality the batteries will be recycled, not landfilled.⁹ It is also likely that Li-ion and Li-polymer batteries will be recycled.¹⁰ In general, the full size battery industry has the highest recycling of any material (97%) and EV batteries are likely to approach 100 percent recycling due to the large size of packs and their material which is valuable in secondary markets. In addition, USABC criteria for mid- and long-term batteries require that they be non-toxic and recyclable.

The IAT considers recycling assumptions to be significant factors affecting emissions from battery manufacturing and recommends that Ni-MH battery recycling be added to the existing materials analysis. Recycling of nickel will significantly reduce the sulfur dioxide (SO₂) emissions associated with battery manufacturing, which are overstated in the current analysis.

The TECA report links SO_x emissions to vehicle manufacturing¹¹. A significant amount of these emissions is directly related to EV battery manufacturing. The failure to include nickel recycling in the analysis artificially elevates SO_x emissions related to battery manufacturing. SO_x emissions from Ni-Cd and Ni-MH manufacturing are much greater than from Pb-acid or Na-S manufacturing.¹² The IAT recommendation to include nickel recycling in the analysis will significantly lower SO_x emissions related to battery manufacturing.

Emission Calculations. It appears that SO₂ emissions are primarily from vehicle manufacturing. As derived from the summary tables in Chapter 2 of the TECA Report, almost 90% of all SO₂ emissions are from vehicle manufacturing. Ni-Cd batteries are the largest contributor — over 30% higher than Ni-MH batteries. This is based on the battery manufacturing process. Since nickel is produced only in Canada and Norway, it is under the SO₂ standards. If Ni-MH batteries are recycled as suggested in the discussion above, Ni-Cd batteries are removed from the analysis as discussed in section 2.3.1, and battery life-expectancies are lengthened as discussed in section 2.3.3, the SO₂ emissions are reduced significantly. The IAT recommends that the emissions

⁸ SAFT America currently recycles nickel in Europe.

⁹ Telephone discussions with Greg Fritz, Applications Engineer at Ovonic Battery Company, August 1997.

¹⁰ 3M indicated they intend to produce a lithium battery that is fully recyclable and SAFT America plans to recycle their lithium batteries as well.

¹¹ According to TECA, 54% of EV SO_x emissions in Houston are related to vehicle manufacturing.

¹² SO_x emissions per 1000 lbs of finished battery are: Pb-acid - 6.13; Na-S - 22.7; Ni-Cd - 637; and Ni-MH 474.

calculations be revisited based on the suggested modifications related to battery types and battery operations.

The majority of battery production emissions are from NaS and Ni-Cd batteries. NO_x, SO_x, carbon monoxide (CO) and carbon dioxide (CO₂) emissions are caused primarily from the manufacture of the NaS and Ni-Cd batteries. These estimates would be significantly reduced by removing the NaS and Ni-Cd batteries from the analysis as already suggested. Table 2-7 shows the percent reduction in emissions from removing the NaS and Ni-Cd batteries under two different scenarios. The two scenarios illustrate changes in battery manufacturing emissions when the type and ratio of batteries are changed.

In the first scenario in Table 2-7, NaS and Ni-Cd are removed from the analysis and half the batteries manufactured are Pb-acid and half are Ni-MH. In the second scenario, NaS and Ni-Cd are removed and 25% of batteries manufactured are Pb-acid and 75% are Ni-MH. The purpose of Table 2-7 is to illustrate that significant emissions reductions could result by removing NaS and Ni-Cd from the analysis. The percent reduction values represent the amount of pollution that would be reduced (based on 1000-pound batteries) if NaS and Ni-Cd were removed from the battery mix and replaced by Pb-acid and Ni-MH in varying proportions. These reductions would obviously change depending on how the market penetration by battery type occurred as well as when Li-ion and Li-polymer batteries were introduced.

The TECA report links SO_x emissions to vehicle manufacturing¹³. A significant amount of these emissions is directly related to EV battery manufacturing. The inclusion of Ni-Cd in the analysis artificially inflates SO_x emissions related to battery manufacturing. SO_x emissions from Ni-Cd manufacturing are much greater than from Pb-acid, NaS or Ni-MH manufacturing.¹⁴ The IAT recommendation to eliminate Ni-Cd batteries from the analysis will significantly lower SO_x emissions related to battery manufacturing.

According to the report, sixty-eight percent of particulate emissions is directly related to vehicle manufacturing. A significant portion of these emissions on the EV side are related to battery manufacturing. A majority of the particulate emissions result from the manufacturing of NaS and Ni-Cd batteries.¹⁵ Elimination of the Na-S and Ni-Cd batteries from the analysis will significantly lower particulate emissions associated with battery manufacturing and result in lower, more realistic levels of particulate emissions related to EVs.

¹³ According to TECA, 54% of EV SO_x emissions in Houston are related to vehicle manufacturing.

¹⁴ SO_x emissions per 1000 lbs of finished battery are: Ni-Cd - 637; Pb-acid - 6.13; Na-S - 22.7; and Ni-MH 474.

¹⁵ PM emissions per 1000 lbs of finished battery for Na-S and Ni-Cd are 4.074 and 4.041 lbs. respectively, compared to Pb-acid and Ni-MH which emit 0.733 and 3.21 lbs. respectively.

Table 2-7
EMISSIONS REDUCTION POTENTIAL

	Market Penetration by Battery Type			
	Pb-Acid	NA-Sulfur	Ni-Cd	Ni-MH
TECA	25%	25%	25%	25%
Scenario 1	50%	0%	0%	50%
Scenario 2	25%	0%	0%	75%

Emissions	Emissions (lbs) per 1000 lbs of Finished Battery					
	Pb-Acid	NA-Sulfur	Ni-Cd	Ni-MH	Total	% Reduction*
Nox	2.21	10.8	6.69	6.85		37%
TECA	0.55	2.7	1.67	1.71	6.64	
Scenario 1	1.11	0.0	0.00	3.43	4.53	31.8%
Scenario 2	0.55	0.0	0.00	5.14	5.69	14.3%
Sox	6.13	22.7	637	474		26%
TECA	1.53	5.7	159	119	285	
Scenario 1	3.07	0.0	0	237	240	15.8%
Scenario 2	1.53	0.0	0	356	357	-25.3%
CO	0.154	57.4	12	28		51%
TECA	0.039	14.4	3	7	24	
Scenario 1	0.077	0.0	0	14	14	42.3%
Scenario 2	0.039	0.0	0	21	21	13.7%
Pb	0.915	0.000708	0.00469	0.0016		-129137%
TECA	0.229	0.000177	0.00117	0.0004	0.230	
Scenario 1	0.458	0.000000	0.00000	0.0008	0.458	-98.8%
Scenario 2	0.229	0.000000	0.00000	0.0012	0.230	0.2%
TSP	0.733	4074	4041	3.21		100%
TECA	0.183	1019	1010	0.80	2030	
Scenario 1	0.367	0	0	1.61	1.97	99.9%
Scenario 2	0.183	0	0	2.41	2.59	99.9%
CO2	989	6,210	4,290	4,544		27%
TECA	247	1,553	1,073	1,136	4,008	
Scenario 1	495	-	-	2,272	2,767	31.0%
Scenario 2	247	-	-	3,408	3,655	8.8%
CH4	0.0171	0.373	0.189	0.217		42%
TECA	0.0043	0.093	0.047	0.054	0.199	
Scenario 1	0.0086	0.000	0.000	0.109	0.117	41.2%
Scenario 2	0.0043	0.000	0.000	0.163	0.167	16.1%
NM VOC	0.0372	0.316	0.282	0.228		28%
TECA	0.0093	0.079	0.071	0.057	0.216	
Scenario 1	0.0186	0.000	0.000	0.114	0.133	38.6%
Scenario 2	0.0093	0.000	0.000	0.171	0.180	16.5%

Source of emission factors: Total Energy Cycle Assessment of Electric and Conventional Vehicles

*Percent Reduction From TECA Scenario

Highest Emissions for Battery Type (IN BOLD)

Italic Values Represents Percent Reduction when comparing the "highest emissions " battery with the "next- highest -emissions-battery", excluding both NA-Sulfur or Ni-Cd.
Note: for Pb emissions, the "lowest-emissions-battery" was compared with the highest.

NO_x emissions are also related to battery manufacturing. The highest NO_x emissions are associated with manufacture of the NaS battery and significant emissions are also associated with Ni-Cd manufacturing.¹⁶ Elimination of the NaS and Ni-Cd batteries from the analysis will result in more realistic NO_x emissions from battery manufacturing.

Manufacturing Assumptions. The necessary battery replacement in EVs should be likened to the necessary replacement of various engine parts in CVs. All CVs require replacement (and therefore production) of components during their useful lives. The TECA Report does not adequately consider the replacement of components in CVs. For example, the replacement of exhaust systems and even monthly oil changes are not included in its manufacturing analysis. The IAT recommends that the manufacturing assumptions related to CV component replacement over the life of the vehicle be reexamined.

2.4 Vehicle-Related Issues

2.4.1 Types

Another weakness of the TECA Report is that the EVs used in the analysis are out-of-date. The EV models analyzed are prototypes that were being developed four years ago and are currently not commercially available or being tested. The table below lists current (1997 and 1998) commercial EV models that more closely resemble the models that will be operating in the time-frame of the analysis.

The IAT recognizes that the length of time it took to complete the TECA analysis contributed to the problem of keeping data current. To be fair to EVs the analysis should include models that more accurately reflect the technological advances that have taken place in recent years. Manufacturers have made substantial progress in the areas of vehicle chassis, aerodynamics, low rolling resistance tires, lightweight composite materials, and efficient HVAC systems.¹⁷ The IAT recommends that the TECA analysis include commercially-available EVs identified in Table 2-8.

In addition, the analysis excludes light-duty fleet trucks. Currently, electric pick-up trucks (e.g., Chevy S-10 and Ford Ranger EV) are commercially available and being marketed to fleet operators. The IAT recommends that electric pick-up trucks should be included in the analysis.

¹⁶ NO_x emissions per 1000 lbs. of finished battery for Na-S, Ni-MH, Ni-Cd and Pb-acid are 10.8, 6.85, 6.69 and 2.21 lbs. respectively.

¹⁷ The GM EV1, unlike conversion vehicles was built from the ground up and features one of the lightest (290 lb.), simplest chassis for any vehicle of its size, a coefficient of drag of just 0.19 (25% lower than any other production car), a heat pump that uses 1/3 the energy of a traditional HVAC system, super low rolling resistance tires (25% lower than regular tires) and wheels that weigh 8.5 lb. Each (regular tires weigh approx. 15 lb.).

Table 2-8
COMPARISON OF EVs ANALYZED

TECA Report	Currently Available Vehicles and Prototypes
BMW E1 (2-passenger)	Ford Ranger EV (2-passenger pickup)
BMW E2 (4-passenger)	GM EV1 (2-passenger)
Citroen Citela	GM S-10 (2-passenger pickup)
Chubu Electric Dream (2-passenger)	Honda EV Plus (4-passenger)
Daihatsu Rugger	Hyundai Accent (4-passenger)*
Fiat Cinq. Elettra (2-passenger)	Nissan FEVII (2-passenger)*
GM Impact 3 (2-passenger)	Nissan Prairie Joy (4-passenger)
Demi/APS Saturn (2-passenger)	Solectria Sunrise (4-passenger)*
Honda Elect Vic (4-passenger)	Solectria Force (4-passenger)
Mazda Miata/Eunos (2-passenger)	Solectria E-10 Pick-Up (2 passenger)
Mercedes 190E (5-passenger)	Toyota RAV-4 (4-passenger)
Nissan FEV (4-passenger)	Chrysler EPIC (8-passenger mini-van)
Nissan Cedric/Gloria (4-passenger)	
Opel Impuls (4-passenger)	
Opel Twin (4-passenger)	
Toyota Town-Ace Van (4-passenger)	
Toyota EV-50 (4-passenger)	
VW City/Stromer	
Chrysler Caravan (5-passenger)	
Ford Ecostar	
GM G-Van	
GM Griffon	
Source: 1. TECA Report, Appendix B, Table B.2.4.	Sources: 1. <i>EVs Coming to Market</i> , EVAA, June 1997. 2. CALSTART Electric Vehicle On-line Product Catalog. * Prototypes

According to the TECA Report (p. 4-4), light-duty trucks as well as cars and vans were included in the projections of new vehicle sales because the zero-emission vehicle (ZEV) sales requirements of the California Air Resources Board (CARB) apply to all light-duty vehicles. When assessing the likely market niches for EVs, the study found no electric light-duty truck models or prototypes being developed by OEMs. The study states that it does not include electric light trucks in its analysis. Appendix B of the report states that vans and light trucks are combined into one category. It would appear that the study compared IC light trucks and vans to electric vans as there were no electric pickup trucks available at the time. This is not an equal comparison. The discussion presented in the main text and Appendix B is not clear.

In the high penetration scenarios (page 4-11), the TECA Report assumes up to 60 percent of the total number of EVs will be electric vans between 1998 and 2000. The TECA Report assumption

that electric vans will penetrate the market at such a high percent is outdated and unrealistic given the availability of electric pickup trucks. Electric pickup trucks are much lighter and more energy efficient than the electric vans and therefore will produce fewer emissions. The IAT recommendation to include electric pickup trucks in the analysis will reduce the ratio of electric vans and should affect EVs in a positive manner.

The TECA Report also makes the assumption that no electric vans will be sold for household use. Currently, gasoline powered mini-vans are saturating the family car market and one would expect this trend to continue and shift over to electric mini-vans as they become available. The IAT recommends that that a small percentage of mini-vans be contributed to the residential market penetration estimates.

2.4.2 Operations (Performance)

Most of the EVs used in the analysis are prototypes and are not currently being manufactured. Because an out-of-date selection of EVs was used, the projected operational performance of the vehicles is also out-of-date. Table 2-9 shows the EVs analyzed in the TECA Report and their performance characteristics. Tables 2-10 and 2-11 show the updated and suggested EVs and their performance characteristics. Without further analysis into the TECA basis for setting the EV efficiencies used, it is difficult to determine the percent improvement in performance and emissions calculations. For example, the energy efficiency of the EVs is expressed in kWh/mile at the wall outlet (Appendix B-55) while efficiencies of EVs in the table below are based on field operations only. The source of EV energy efficiencies used in the TECA Report should also be referenced.

The IAT recommends that the EV performance data be updated to accurately reflect the state of EV technology as shown in the Tables 2-10 and 2-11 which identifies characteristics comparable to Table B.2.4 of the TECA Report and display additional specifications.

2.4.3 Manufacturing (Materials)

Replacement of Parts. Analysis of CV and EV materials replacement is uneven. The authors do not include, for example, the replacement of the CV exhaust system. In reality, this would occur at least once during the life of the vehicle. The analysis of EV component replacement is therefore potentially biased. While the IAT does not believe that the replacement of the exhaust system will have a significant impact on the overall results, CV replacements that are not common to both vehicles should be mentioned and included.

Table 2-9
VEHICLE SPECIFICATIONS: TECA REPORT TABLE B.2.4 (EV MODELS AND PROTOTYPES AND THEIR PERFORMANCE)

Model	Manufacturer	Capacity	Weight (lbs)	Battery Type	Range (Miles)	Top Speed (mph)	Acce. Rate (sec.)	Status/Year	Source
Passenger Cars									
<i>TECA Report</i>									
E1	BMW	2-seater	1,940	Na-S	155	75	18 (0-50)	PT	Auto. Eng. 1992
E2	BMW	4-passenger	2,200	Na-S	267	75	15.6 (0-50)	PT	Auto. Eng. 1992
Citela	Citroen		1,740	Ni-Cd	68	68	8.5 (0-31)	PT	Auto. Eng. 1992
Elec. Dream	Chubu	2-seater	1,540		75 (25 mph)	50	10 (0-40)	PT	Auto. Eng. 1992
Hijet	Daihatsu			Pb-Acid	80 (25 mph)	50		PT	Auto. News, June 7, 1993
Rugger	Daihatsu			Pb-Acid	125 (25 mph)	56		PT	Auto. News, June 7, 1993
Cinq. Elettra	Fiat	2-seater		Ni-Cd	62	50-53	10 (0-25)	PT	Auto. Eng. 1992
Impact 3	GM	2-seater	2,910	Sealed Pb-Acid	70-90	75	8.5 (0-60)	CA	GM, 1993
APS Saturn	Demi/APS	2-seater	2,100	Zinc-O2	218 (37 mph)	124	10 (0-87)	PT	Auto. Eng. 1992
Elect Vic	Honda	4-passenger	3,330	Pb-Acid	65 (40 mph)	81		PT	Road & Track, Oct. 1993
Miata/Eunos	Mazda	2-seater	3,100	Ni-Cd	120 (25 mph)	80	4.2 (0-25)	PT	Auto News, Feb. 22, 1993
190E	Mercedes	5-passenger		Na-Ni	93	75		PT	Auto. Eng. 1992
FEV	Nissan	4-passenger	1,985	Ni-Cd	155 (25 mph)	80		PT	Auto Eng. 1992
Cedric/Gloria	Nissan	4-passenger	3,810	Sealed Pb-Acid	75 (25 mph)	56		PT	Clean Fuels Report, Feb. 1993
Impuls	Opel	4-passenger	2,930	Pb-Acid	65			PT	Auto. Eng. 1992
Twin	Opel	4-passenger	1,630	Li-C		75	7 (0-31)	PT	Auto. Eng. 1992
Town-Ace Van	Toyota	4-passenger	2,870		87 (15 mph)	53	10 (0-31)	PT	Auto. Eng. 1992
EV-50	Toyota	4-seater	3,200	Sealed Pb-acid	68 (urban) 155 (25 mph)	72		PT	Toyota (1994)
City-STROMer	VW			Na-S	75	65		PT	Auto. Eng. 1992
PT = Prototype CA = Commercially Available									

Table 2-10

NEW EV SPECIFICATIONS: BASED ON TECA REPORT TABLE B.2.4 (EV MODELS AND PROTOTYPES AND THEIR PERFORMANCE)

Model	Manufacturer	Capacity	Weight (lbs)	Battery Type	Range (Miles)	Top Speed (mph)	Acce. Rate (sec.)	Status/ Year	Source
<i>New EVs</i>									
<i>2-Seater and Compacts</i>									
EV1	GM	2- passenger	2,970	Pb-acid	70 (city) 90 (highway)	80	9 (0-60)	1997	EVs Coming to Market, EVAA, 6/97
FEV II	Nissan	2-passenger		Li-ion	120	75	na	PT	Calstart Catalog
Sunrise	Solectria Corp	4-passenger	1,694	Pb-Acid	120		17 (0-60)	PT	Solectria Corp.
Sunrise	Solectria Corp	4-passenger	1,494	Ni-MH	200		17 (0-60)	PT	Solectria Corp.
Force Sedan	Solectria Corp.	4-passenger	2,460	Pb-Acid	50@45mph	70	18 (0-50)	1997	Solectria Corp.
Force Sedan	Solectria Corp.	4-passenger	2,260	Ni-MH	105@45mph	70	18 (0-50)	1997	Solectria Corp.
Ethos 3 EV	Unique Mobility	4-passenger	2,600	Ni-MH	128 @ 50mph	78	11 (0-60)	PT	Unique Mobility
Accent	Hyundai	4-passenger		Ni-MH	242	87	15 (0-60)	PT	Calstart Catalog
EV PLUS	Honda	4-passenger	3,586	Ni-MH	60-80	80+	18.7(0-60)	1998	Honda Spec Sheet
RAV4-EV	Toyota	4-passenger	3,230	Ni-MH	118	79	17 (0-60)	1998	EVs Coming to Market, EVAA, 6/97
Prairie Joy EV	Nissan	4-passenger	3,726	Li-ion	120	74	na	1997	EVs Coming to Market, EVAA, 6/97
<i>Pick-ups</i>									
E-10 Electric Fleet Pick-up	Solectria Corp.	2- passenger Pick-up	4,050	Pb-acid	60@45mph	70	15 (0-50)	1997	Solectria Corp.
Ranger EV	Ford	2- passenger Pick-up	5,400	Pb-acid	58	75	12.5 (0-50)	1998	EVs Coming to Market, EVAA, 6/97
S-10 Electric	GM	2- passenger Pick-up	4,300	Pb-acid	40-60	70	13.5 (0-50)	1997	EVs Coming to Market, EVAA, 6/97
<i>Mini Vans</i>									
EPIC	Chrysler	8- passenger Mini van	5,100	Advanced Pb-acid	60	80	16 (0-60)	1997	EVs Coming to Market, EVAA, 6/97
<i>Vans</i>									
Delivery Van	Solectria Corp.	3,500 lb.	7,500	Pb-acid	46	45	18(0-45)	PT	Solectria Corp.

Table 2-11
DETAILED VEHICLE PERFORMANCE SPECIFICATIONS BASED ON NEW EVs COMING TO MARKET

Model	Manufacturer	Capacity	Curb Weight (lbs)	Battery Type	Battery Weight (lbs)	Battery Capacity (kWh)	Range (Miles)	Top Speed (mph)	Acce. Rate (sec.)	Status/ Year	Energy Consumption (kWh/mi.)
<i>Passenger Cars</i>											
EV1	GM	2- passenger	2,970	Pb-acid	1,175	16.2	70-90	80	9 (0-60)	1997	.30 city/.25 hwy 0.164 ¹ 0.25 ³
FEV II	Nissan	2-passenger		Li-ion			120	75		PT	
Force Cmpet	Solectria Corp.	4-passenger	2,246	Ni-MH	560	15.7	84 ¹	70	18.5 (0-50)	1995	0.173 ¹
Force Sedan	Solectria Corp.	4-passenger	2,460	Pb-Acid			50@45mph	70	18 (0-50)	1997	0.14
Force Sedan	Solectria Corp.	4-passenger	2,260	Ni-MH			105@45mph	70	18 (0-50)	1997	0.14
Sunrise	Solectria Corp.	4-passenger	1,694	Pb-Acid			120		17 (0-60)	PT	
Sunrise	Solectria Corp.	4-passenger	1,494	Ni-MH			200		17 (0-60)	PT	
EV PLUS	Honda	4-passenger	3,586	Ni-MH			60-80	80+	18.7 (0-60)	1998	.49 city/.51 hwy
RAV4-EV	Toyota	4-passenger	3,329	Pb-Acid	1,213	15.8	68	78	13 (0-50)	1996	0.235 ¹
RAV4-EV	Toyota	4-passenger	3,439	Ni-MH	992	30	118	79	17 (0-60)	1998	.31 city/.38 hwy 0.35 ³
Ethos 3 EV	Unique Mobility	4-passenger	2,600	Ni-MH	945	28	128@50mph	78	11 (0-60)	PT	.18 ²
Accent	Hyundai	4-passenger		Ni-MH			242	87	15 (0-60)	PT	
Prairie Joy EV	Nissan	4-passenger	3,726	Li-ion			120	74		1997	
<i>Pick-ups</i>											
E-10 Electric	Solectria Corp.	2- passenger	3,790	Pb-acid	1,263		55 ¹	68	17 (0-50)	1995	0.283 ¹
E-10 Electric	Solectria Corp.	2- passenger	4,050	Pb-acid			60@45mph	70	15 (0-50)	1997	0.23 ¹
Ranger EV	Ford	2- passenger	5,400	Pb-acid	1,950	23	58	75	<12.5 (0-50)	1998	0.31 ² 0.4 ³
S-10 Electric	GM	2- passenger	4,300	Pb-acid	1,400	16.2	40-60	70	13.5 (0-50)	1997	0.29 ¹
<i>Mini Vans</i>											
EPIC	Chrysler	8- passenger Mini-van	5,100	Advanced Pb-acid	1,400	27	60	80	16 (0-60)	1997	0.36 ² 0.66 ³

Table 2-11
DETAILED VEHICLE PERFORMANCE SPECIFICATIONS BASED ON NEW EVs COMING TO MARKET
(continued)

Model	Manufacturer	Capacity	Curb Weight (lbs)	Battery Type	Battery Weight (lbs)	Battery Capacity (kWh)	Range (Miles)	Top Speed (mph)	Acce. Rate (sec.)	Status/ Year	Energy Consumption (kWh/ml.)
<i>Vans</i>											
Delivery Van	Solectria Corp.	3,500 lb. pyld	7,500	Pd-acid			46	45	18 (0-45)	PT	
<p>Source: EVs Coming to Market, <i>EVAA</i>, June, 1997, CALSTART Electric Vehicle Online Product Catalog, and Vehicle Manufacturer's Information.</p> <p>PT = Prototype</p> <p>1. EV America Performance Test: Driving Cycle Range per SAE J1634. 2. Calculated by ERG using battery capacity (kWh) and range (mi.) data. 3. Southern California Edison, Electric Vehicle Road Test.</p> <p>EV1 Pb-Acid Batteries have a 3 year/36,000 mile warranty. Ford Ranger Pb-Acid Battery has a 2 year warranty. Solectria Force Sedan Pb-Acid battery has a 2 year warranty.</p> <p>Source of data was provided by manufacturers and/or vehicle literature unless otherwise specified.</p>											

Body Shell Composition. Vehicle composition projections are flawed. The authors assume the same material composition for EVs and CVs in both the short-term and long-term and state only small changes are expected over the next ten years. The assumption that preferential shifts in the use of lighter materials in the EV shell does not occur, does not make logical sense. Manufacturers have begun to produce new, purpose-built EVs that have essentially been built from the ground up using components designed specifically for EVs.¹⁸ Purpose-built vehicles tend to be lighter, more aerodynamic, and therefore more efficient than conventional vehicles in order to minimize drain on the battery and maximize EV performance and range.¹⁹

While the IAT believes that CVs would eventually use similar shell composition materials and components to EVs, this would not be the case immediately. CVs are expected to lag behind the EV in material design for some time. The IAT recommends that the shell composition analysis of EVs and CVs be reexamined.

Recycling of Old Parts. The TECA Report makes incorrect assumptions related to the recycling of old car parts. It assumes no copper recycling and assumes that very little plastic is recycled from autos. This is not the case. New Chrysler and Toyota vehicles are being designed and manufactured to allow recycling of almost and 75% of the vehicle components. Most of the recyclable components are comprised of metal and approximately 25 percent is comprised of plastics, rubber, glass and fluids.

2.4.4 EV Market Penetration

The TECA Report analyzes two EV market penetration scenarios — a low and a high. The low scenario is based on a national EV sales projection provided in the 1993 Annual Energy Outlook. This source is out-of-date. The IAT recommends that a more recent projection from a more recent Annual Energy Outlook be used and estimates be revised based on the modified California ZEV mandates.

2.5 Electric Utility Issues

2.5.1 Characterization of Utility Systems

The authors provide a detailed analysis of the utility systems in terms of current operations, unit dispatch and forecasted units to provide additional off-peak capacity. However, the assumptions used in the modeling are not correct. Changes in these assumptions will affect the emissions results by both dispatch order and type of unit and could have a critical effect on the view of EVs.

¹⁸ The Honda EV Plus boasts that over 95% of the automobile is composed of all-new components.

¹⁹ To-date, only two purpose-built electric vehicles, the Honda EV PLUS and GM EV1, are on the market in the U.S. while the remaining purpose built vehicles are prototypes.

Potomac Electric Power Company (PEPCO) was requested by EPRI and the IAT to review section 5 of the TECA Report and provide comments relative to the characterization of their utility system. Their comments are provided below.²⁰

- The report does appear to use a dispatch order for PEPCO units based upon PEPCO's last integrated plan. However, the production model used to simulate dispatch appears to treat PEPCO as an isolated system. In reality, PEPCO's dispatch is tightly integrated, on an economic basis, with the other number companies of the PJM interconnection. The isolated system analysis causes several potentially significant errors:
 - it typically overstates PEPCO generation and resulting emissions;
 - it creates a need for new capacity sooner than is the case with PJM integrated operation;
 - it causes the geographical location of emissions, which appears to be important in this analysis, to be incorrect.
- Even assuming that the deficiency associated with the item above is not significant, the dispatch modeling used is not relevant to the electricity market which will exist long before the year 2010. Wholesale competition exists today as a result of FERC's open access rulemaking. Retail competition likely will exist in Maryland and possibly in D.C. soon after the year 2000. FERC, in its open access proceeding, modeled regional dispatch and resulting emissions in the 2010 time-frame. This modeling would appear to be more appropriate than that used in the subject study.
- FERC, in its open access modeling, concluded that older coal-fired generating units would be replaced by more efficient, lower-cost natural gas combined-cycle units. The subject study does not recognize this possibility.
- As a result of open access and retail competition, PEPCO has no plans for installing any additional capacity; but rather, will participate in the market and consider new capacity as appropriate.
- The study does not include the impact of the Clean Air Act TITLE IV and TITLE I on the NO_x emissions from PEPCO units. Starting approximately in the year 2000, PEPCO's emissions (total tons per year) will be 65% less than its 1990 emissions. Hence, the NO_x emissions in the report are significantly overstated, even assuming a representative dispatch of PEPCO units.

2.5.2 Charging Scenarios

The study assumes that all EV charging under its unconstrained charging scenario starts on-peak. The utility modeling performed assumes half of the necessary EV charging occurs between 4 p.m. and 5 p.m. and the remaining half occurs between 5 p.m. and 6 p.m. This charging assumption biases electric utility analysis by forecasting that the utilities will need to support additional load during the peak hours. This leads to an excess of added capacity on-peak.

Added capacity using combined-cycle plants will have the lowest emission rates as new plants are the most efficient and usually the cleanest. In effect, this offers the lowest emissions for EV

²⁰ Letter from Jim Potts, Vice President of PEPCO, dated August 28, 1997.

operation. Removing the unconstrained scenario could potentially increase EV emissions, however, in most systems, new capacity which would supply energy during EV charging periods would also be combined cycle with low emissions. In other scenarios where baseload is used, a higher percentage of emissions-free, nuclear capacity is used.

Since the technology and rate incentives are already in-place for charging anytime (preferably off-peak), considering the tightly constrained charging period is inappropriate.

It is suggested that the utility scenarios be revisited based on the availability of off-peak or EV-charging rates. Fleet owners currently operating EVs are taking advantage of EV charging rates by recharging their vehicles during off-peak hours. Utilities now offering off-peak or EV charging rates include but are not limited to Detroit Edison, Duke Power, Los Angeles Department of Water and Power, Pennsylvania Power & Light, Potomac Electric Power, Sacramento Municipal Utility district and Boston Edison Company. The IAT recommends that the recharging scenarios be reexamined to determine the true additional capacity requirements, by assuming that all of the utilities analyzed will offer off-peak charging rates, thereby reducing the amount of unconstrained charging reported in the results.

In addition, the authors assume that fleet EVs will not be charged on the weekends. This is not a correct assumption. For example, UPS, Federal Express and other mail/package carriers all operate on Saturdays. In addition, car rental agency and hotel shuttles at airports along with shopping mall shuttles operate on Saturdays and would therefore require recharging over the weekend.

Rerunning the utility scenarios with new generation under a more deregulated environment should lead to similar emissions results to the unconstrained scenario as new generation will be added to serve the market place. This will reduce both in-basin emissions and overall emissions by providing an end-use management tool for optimizing generation use. Therefore the IAT recommends a revision to the analysis that includes recognition of unconstrained charging using combined-cycle generation.

3.0 IAT CONCLUSIONS

The IAT's review of the TECA Report has resulted in a concern for the overall validity of the report's emissions results based on out-of-date data and uneven analysis. These weaknesses briefly discussed in section 2 reduce the usefulness of the TECA Report in the public policy sector. The credibility of the report will be enhanced by using updated data and by addressing the uneven nature of the analysis. While the effort to analyze the total energy fuel cycle of electric vehicles (EVs) and conventional vehicles (CVs) is applauded, the analysis and results of the draft TECA Report can not be supported at this time without major updates. Suggested modifications required to improve the results and make the report suitable for open discussion among key industry participants are identified below. In addition, additional areas of research that would compliment or improve the report are provided.

3.1 Key Changes

Based on the discussion presented in section 2, this brief effort highlights the ten most important modifications to the TECA Report necessary to improve the validity and credibility of its results.

1. Remove the NaS and NiCd batteries from the analysis. Increase the use of NiMH in the short-term and add Li-ion and Li-polymer batteries to the analysis in the long-term.
2. Update the life-expectancy estimates of all batteries as those used and projected are already being met with today's technology.
3. Update the battery performance estimates of all batteries as those used are already being met with today's technology.
4. Update the EVs analyzed by removing those models that out-of-date and adding new models to the analysis such as the electric pick-up truck.
5. Remove the combustion turbine (CT) off-peak unconstrained charging scenario from the analysis. In the constrained scenario, one path assumed CTs supplied the charging energy. However, most utilities will not use CTs for base or intermediate power. The use of CTs significantly increases the emissions created by this scenario as the efficiency of a CT is much lower than for a combined-cycle (CC) unit.
6. Reexamine the manufacturing of EVs and CVs to ensure an equal comparison in the area of replacement parts.
7. Change EV recharging scenarios to incorporate primarily off-peak charging due to the availability of utility EV charging rates. The unconstrained charging scenario — charge at any time — packs all the charging into the same time-frame, clearly requiring new generation. This assumption is unrealistic and charging should be spread over the course of the day and week. With time-of-use rates, charging can occur more economically during off-peak hours and this method is already in use.
8. Reexamine battery recycling capabilities.
9. Update vehicle performance estimates based on data provided in section 2.
10. Change presentation of emissions results to always show in-basin emissions, on the same page with total emissions.

While some of the modifications listed above will require additional research, these changes are necessary. There are numerous typographical as well as data entry errors that also impact on the report's credibility. For example, Consolidated Edison serves New York City and not Chicago as mentioned several times in the report. Errors noted in the Appendix on lead emissions are carried through the analysis with a footnote that says it has little impact on the final results. Another error relates to vehicle weights. In Volume 1 of the report, vehicle composition is expressed as kilograms but in Appendix B, the same numbers are used but referenced as pounds (i.e., a two-seater EV in the main report weighs 1,782 kg while in the Appendix, it weighs 1,782 pounds). These types of errors reduce the overall credibility of the report. Significant review and editing would further help this report.

3.2 Additional Areas for Research

After our brief review of the TECA Report, the IAT identified several areas for further research that would enhance the results of the report and are beyond the effort that can occur in the review time-frame.

1. In-basin air emission reduction is worth far more from a health perspective. Further analysis could demonstrate this.
2. Improved lead-acid batteries will carry over to CVs reducing CV emissions from battery manufacture.
3. Improvements in automotive bodies starting with EVs and carrying over to CVs are important areas for research.
4. Addressing water and land use issues are important considering gasoline and oil impacts on water quality.
5. Upgrading emission factors and utility performance to meet current and projected standards would provide a better projective assessment.
6. Streamlining the analysis such that current data can be used will improve the credibility as well as the usefulness of the report.
7. Making the analysis more transparent so the flow of the data, analysis and results can be easily tracked would add credibility.

ELECTRIC VEHICLE ASSOCIATION OF GREATER WASHINGTON, DC

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David Goldstein, President
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September 29, 1997

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Dear Ms. Singh,

Thank you for the opportunity to review and comment upon the latest draft of the Total Energy Cycle Assessment (TECA) of Electric Vehicles (EVTECA). We believe this study to be a groundbreaking and challenging effort conducted over a period of several years during a time of rapid change within the automotive industry, the electric utility industry and the still-emerging electric vehicle industry. Former EPA official and EVTECA National Review Committee Member Morris Altschuler and I are aware of many challenges that you have faced in coordinating the data and efforts of the various federal laboratories, energy providers and manufacturers, and of the patience and perseverance that you have shown in the face of often-conflicting comments and advice from diverse and frequently opposing interests.

This has also been a challenging study to analyze. However, having reviewed the latest three-volume draft report, including the data for Washington, D.C., we agree upon the critical issues, finding serious omissions, outdated information, flaws, contradictions and unrealistic or incorrect assumptions throughout the three-volume study. As a result, we believe that the EVTECA study, at this stage, is both fundamentally flawed, outdated and has fallen short of its objective of comparing the net energy consumption and net emissions of electric vehicles (EVs) with combustion engine vehicles (CVs).

We believe that this study should be recalled and restructured, updated with more current information and reissued with a more fluid approach that would permit energy modelers, policy analysts, business groups and environmental organizations to include more highly-detailed and/or proprietary data and to determine for themselves which assumptions are valid and which are not.

At present, EVTECA lacks sufficient accuracy and detail to accomplish its objective, in part for the following reasons:

I. EVTECA is based upon fundamentally incorrect assumptions about the nature of electric utility load planning, capacity reserves, power pools, fuel sources, independent power providers, environmental constraints, electric vehicle characteristics, battery chemistries and recycling processes, both now and in the future,

II. EVTECA is based upon outdated information, particularly with regard to battery chemistries and vehicle characteristics, which skews the results by overstating the energy requirements and net emissions for electric vehicles.

III. The EVTECA Study appears to be incomplete and inconsistent, lacking data for two of the four metropolitan areas studied and in some cases providing conflicting data (as increased vs decreased methane.) Excessive resources appear to have been allocated to highly unrealistic "unconstrained" scenarios, whereas insufficient resources appear to have been devoted to conducting a more thorough investigation of factors identified in items #1 and #2, above, and other critical data that a more comprehensive study should reasonably demand. It is evident that "short cuts" have been taken.

IV. EVTECA's four metropolitan study areas are not representative of regional or national trends in utility baseloads, future fuels or emissions. Other important EPA Non-Attainment Areas - such as Denver, with its notorious "brown cloud" problem - are not adequately represented.

V. EVTECA emissions results are highly variable, contradictory and significantly at odds with previous studies conducted by DOE, Argonne Laboratories, EPRI, the Union of Concerned Scientists, NESCAUM, CARB and individual utilities operating with the areas studied.

VI. A projected "eight to eleven times" increase in SO_x associated with both power plants and battery manufacturing is unrealistic, fails to adequately consider increasingly stringent environmental regulations, and may be based upon incorrect assumptions about Sodium-Sulphur (NaS) and nickel battery manufacturing emissions and life cycles.

VII. Projected methane (CH₄) emissions do not appear to correlate with utility fuel types and some figures appear to contradict one another. Also, there is no consideration of *natural gas powered vehicles (NGVs)* in the CV comparisons.

VIII. EVTECA's projected utility fuel sources are also highly questionable, particularly under "unconstrained" scenarios, and may be based upon partial or incorrect *utility dispatch orders*. This should be readily apparent in the case of Washington, D.C., for which EVTECA projects a dramatic shift from a present-day 85 percent (approximately) coal baseload to 60 percent oil dependency by the year 2010. This would be unprecedented, contradicting information provided to us by the local utilities and running counter to the national trend from coal to natural gas rather than from coal to oil.

IX. The use of renewable energy sources such as solar, wind, geothermal, hydroelectric and pumped storage for incremental EV power requirements appears to have been inadequately addressed. These energy sources are unavailable to CVs, yet they are increasing and should reasonably be expected to become more widely available by the year 2010.

X. Battery life cycle characteristics and recycling practices have not been appropriately characterized or separated from "emissions". This is the case for both *lead-acid (PbA)* and *nickel-based* chemistries, which comprise the majority of battery types surveyed. The emissions results for lead are highly suspect and fail to differentiate between dissipative and confined byproducts. Similarly, EVTECA fails to recognize or account for the fact that *nickel-based* batteries are currently being recycled under controlled emissions — information that is currently available from NREL (but which may not have been available when the study commenced.) Furthermore, EVTECA's *battery life-cycle/replacement assumptions* are outdated and fail to capture the continuing life-cycle improvement in both PbA and Ni- based chemistries. Nickel Metal Hydride (NiMH) batteries, for example, have progressed to the point that they may last for the lifetime of the vehicle (100,000 miles +), rather than requiring replacement every three years as EVTECA assumes. Thus, estimates of battery manufacturing emissions — particularly SO_x — may be overstated by a considerable margin.

Discussion and Additional Points

I. Fundamentally Incorrect Assumptions:

A. We believe that the "unconstrained" option has been grossly overemphasized and improperly defined, which contributes greatly to the confusing variability and incompleteness of the reported data. It should be evident, based upon existing practices, that electric utilities will encourage off-peak charging through demand-side management (DSM) practices associated with time-of-day (TOD) pricing and that consumers do respond to this by modifying their behavior. *We are aware that TOD rates for EVs are currently in effect in Washington, D.C. and in Los Angeles, and this should be properly reflected in EVTECA.*

B. EVTECA fails to adequately reflect the common electric utility industry practices of pooling electric power within reliability regions and wheeling electric power through regional grids from other metropolitan and *non-metropolitan* areas. Instead, EVTECA appears to focus upon the electric utilities within the identified study areas as *isolated entities*. We fail to see how this approach might be relevant in any of the identified study areas under present circumstances. Furthermore, as the EVTECA timeframe progresses toward the year 2010, it should be evident that *deregulation* will permit utilities in *different regions* to provide increasing amounts of power to metropolitan areas such as Washington and Los Angeles. The implications are at least fourfold:

(1) This strongly argues against EVTECA's undue reliance upon individual utility dispatch orders and fatally weakens incremental power demand projections within a given metropolitan area,

(2) This dissipates or shifts the environmental effects associated with electric power generation *away from metropolitan population areas* — where EVs (because of their range limitations) will be concentrated — to diverse and less-populated outlying regions, where the potential effects, if any, are more difficult to measure or project.

(3) It means that EVTECA has completely overlooked the increasing role of *independent power providers* (IPPs) in helping to fulfill the power demands of the future and in calculating the emissions associated with newer power plants,

(4) Consequently, EVTECA's focus upon utilities in specific metropolitan areas is simply not relevant — not now, and even less so in the future, and begs for some effort to obtain a national perspective. Additional resources are needed to adequately capture this information. *But typical electric utility practices can and must be adequately assessed, if a net energy and environmental study of this type is to have any true meaning.*

C. It should also be evident that there is no need for additional power plant capacity in any reasonably "constrained" off peak charging option. *It is estimated by EPRI that 20 million EVs can be accommodated nationally with off peak charging, using current plants.* The in-depth analysis of the "Unconstrained" option clearly has taken away critical resources that could have been used for a more in-depth and significant analyses of the comparative impacts of EVs and CVs.

D. It is fundamentally incorrect to assume a "one-on-one" replacement of CVs by EVs. Because of range limitations associated with battery energy storage, EV owners are likely to engage in significantly fewer *Vehicle Miles Traveled (Vmt)* than equivalently-sized CVs, using their EVs for local commuting and niche-market applications with greater reliance upon mass transit. Longer trips are more likely to be assigned to hybrid vehicles or to additional CVs within the same household or fleet operation. This characteristic has been well-defined in DOE fleet evaluation studies and should be appropriately reflected in EVTECA. *It should be evident that Vmt factors, when appropriately considered, would significantly reduce the need for incremental power capacity under any reasonable scenario.*

E. The Study fails to adequately characterize Electric Vehicles in terms of mass and rolling resistance. There is an overemphasis upon heavy, inefficient vans and fleet vehicles in general. Curb weights do not adequately reflect currently available models but are *assumed to be "80 percent"* of "equivalent" CVs, not including the battery weights. Many of the vehicles characterized are no longer available or were never available in the U.S., and the increasing use of *composite materials* in the newer EVs should cause these assumptions to be reevaluated. Table B.2.4 ("EV Models and Prototypes") and the various EV categories in Table B.2.5 ("Combinations of Battery Types and EV Types . . .") and Tables 8.4 and 8.5 ("Assumed Composition of Electric Vehicles . . .") need to be thoroughly updated and the newer lighter-weight vehicles factored in to recompute energy demand. This is critical, because, as EVTECA points out in the introductory comments on Page S-1, *"Of the factors, energy efficiency of the EVs is one of the most significant."* The incorrect curb weight estimates adversely influence the projections of *vehicle rolling resistance* — one of the most critical factors in determining EV efficiency, thereby overstating energy demand.

F. The study fails to adequately consider *vehicle life-cycle differences* between EV's and CVs. EVs, because of fewer moving parts and the increasing utilization of composite shell materials, tend to *last longer* — 10 years or longer for EVs, for example, vs. 6-8 years for CVs. Therefore, emissions associated with "shell" production should be factored accordingly. This also presents the likelihood that more "older" EVs will remain in the vehicle population by the year 2010, *but will have their battery packs upgraded* to more advanced chemistries with longer range and improved cycle life characteristics. This would reduce a sizeable proportion of subsequent battery pack replacements factored into the study *from two to one*, thereby reducing battery manufacturing-related emissions — a subtlety that has been apparently overlooked.

G. The fuel mileage and RFG-related emissions estimates for CVs may be overly generous in view of a now well-established consumer trend towards relatively low-efficiency and higher-emissions pickup trucks and sport utility vehicles. EVTECA's assumptions appear to be out-of-date here and should be reevaluated. There have also been reports associating RFG with *reduced gas mileage*, a situation analogous to the higher power plant CO₂ projections for the Chicago region on the basis of other emissions constraints. This should be factored into EVTECA accordingly.

H. The use of the Mobile 5A EPA model is not appropriate to and was not intended to be used for a comparison with between CVs and EVs. In addition, Mobile 5A fails to capture the degradation in CV emissions as the CV ages. Neither EVs nor electric generating plants, by comparison, degrade significantly in efficiency, since they contain relatively few moving parts. Over time, regulations tend to constrain electric power plant emissions (requiring, for example, the addition of scrubbers or the substitution of low sulphur coal,) while CV engines and their emissions control devices continue to degrade.

I. Do the Crude Oil Refining and Fuel Formulation Processes (S5, S6) include an estimated 15% loss of energy at the refinery as well as the associated emissions? Do the calculations for CV emissions include a representative component from the CH₄, SO_x, NO_x, VOCs and CO₂ resulting from Oil Field activities? Table D.1.1, "Oil Field Production", is confusing on these points, and this is not clear, either, in the separate discussion of CV emissions. This issue further illustrates that although there are a commendable number of detailed illustrations of the various subprocesses examined in EVTECA's extensive analysis, *there is a lack of detail regarding the combination of these energy efficiency factors and the environmental contributors associated with these processes*. More energy and emissions flow charts would be helpful.

II. Outdated information:

A. Incorrect and Inadequate Coverage of Battery Chemistries: The study shows an undue emphasis upon outdated battery chemistries and fails to adequately account for, or project, the leading battery types. This is a significant issue that has been raised previously¹ but inadequately addressed, apparently because of insufficient funding or resources to pursue (reference, also, to Item 1.D.). However, the question of what types (proper mix) of battery chemistries (are) likely to be used is fundamental to the determination of net charging efficiency.

B. Because of the rapid pace and continuing progress in battery development, assisted in large measure by the DOE-USABC (US Advanced Battery Consortium) Partnership, it is highly inappropriate to base such a vital study as EVTECA upon 1994 data.

C. Directly related to this point is the undue emphasis upon *Sodium Sulphur* (NaS) batteries, a relatively *low-efficiency*, experimental battery chemistry that has been rejected by every major automobile manufacturer and is no longer considered to be a viable USABC candidate. Yet, despite earlier warnings, EVTECA has persisted in factoring in a "30 percent" projection of Sodium-Sulfur batteries into its net energy projections — a very bad guess — thereby biasing the results with an incorrect and relatively poor energy factor.

D. A similar overemphasis has been placed upon *Nickel-Cadmium* Batteries, which although widely available in Europe, are seldom used in the U.S. and are rapidly giving way to NiMH. Together with the incorrect NaS battery projection, this would account for 58 percent of the batteries modeled in the year 2010. This is significant not only in terms of net energy efficiency but in terms of battery cycle life. In the case of NiMH, cycle life is estimated at 3-5 times that of PbA and as much as twice as long as NiCad. This would strongly suggest that there may be errors in the analysis of environmental issues associated with processing and recycling of NIMH — particularly the SOx projections associated with nickel battery manufacturing, which is represented as "the major source of the [SOx] emissions."

¹ Morris Altschuler, a member of the EVTECA National Review Panel representing the U.S. Environmental Protection Agency (EPA), had criticized the list of batteries selected for study and commented upon their energy efficiency and environmental impact in his written *Peer Review Comments* of December 15, 1994.

E. There is no consideration of Lithium Ion or other lithium combinations, Zinc-Air, or of the growing acceptance of relatively high-efficiency (presently 91-94 percent² efficient) *inductive charging methods*³, or of the various types of fuel cells that are now beginning to appear. *Nor is there any capability to model any of this information.*

F. Recognizing the resource limitations that have constrained EVTECA's scope and played a role in "freezing" the battery assumptions, it is nonetheless apparent that a continuing emphasis upon incorrect battery energy efficiency and cycle life factors unduly influences the remainder of the study and strongly suggests that the overall design and execution of this study are fundamentally flawed.

III. The EVTECA Study appears to be incomplete and inconsistent:

A. The four metropolitan areas studied have not been treated equally. Data is missing and the documentation indicates that adequate resources have not yet been allocated to complete these portions.

B. Although the study attempts to differentiate between *marginal*, *average* and *"incremental"* system emissions associated with EV charging, the results are entirely unconvincing, frequently resulting in wildly skewed numbers for similar factors in different metropolitan areas.

C. The marginal/incremental approach, which appears to be predominate in this study, is generally considered to be less accurate in evaluating long-term impacts, because it is extremely difficult to project what the marginal generation will be years in the future. This would appear to be reflected in the wild variations in some of the charts for similar factors in different metropolitan areas, *which makes any degree of national or regional policy analysis highly problematic and virtually impossible*. Many other factors are involved, and for each of the identified cities, the study has done a less than adequate job in attempting to correlate local issues as load factors, economic growth, PUC regulatory considerations, proposed mergers, construction schedules and emissions constraints.

² Quoted from literature supplied by Virginia Power Company and the Delco Electronics Division of General Motors Corporation.

³ This might also affect battery charging profiles by shortening the *duration*, a key ingredient in EVTECA's unconstrained charging assumptions.

D. Whereas the energy efficiency calculations for EVs implicitly captures electricity *transmission line losses*, there is no equivalent mention of *petroleum spillage and evaporation* during shipping and storage, which are in fact measurable and significant components.

IV. EVTECA's four metropolitan study areas are not representative of regional or national trends:

A. EVTECA fails to adequately capture or project a representative fuel sampling for electricity generation. There is an overall failure to capture or reflect the average national power plant fuel sources, which vary somewhat from year to year but are relatively well-defined by DOE's Energy Information Administration (EIA). Although EVTECA *implies* in its introduction that the selected sites are representative of the various regions, this is simply not the case with respect to fuel types.

B. Statements about the future projection of oil as the primary fuel source for Washington, DC power plants should be rechecked with PEPCO and Virginia Power. The trend is from coal to gas, not oil, in most of the country, so, in any case, this is not representative nationally. *Currently the national average for oil as a fuel for electricity production is about 4 percent and is not expected to grow.*

C. EVTECA fails to provide an adequate or representative sampling of the various emissions factors for metropolitan areas across the U.S. Full coverage was only given to Washington and Houston. We have seen only very limited data from *Los Angeles* or *Chicago*. Other critical non-attainment metropolitan areas such as *Denver* — which experiences a "Brown Cloud" from November to February, 'directly attributed to car emissions — were not included. We strongly question how and in what way these limited samples are representative of the entire nation — as they are supposed to be. How can such a vital study impact national policy and lead to appropriate options if it fails to meet this objective?

D. Although there is some mention of nuclear and renewable energy sources, we do not believe that hydroelectric and other renewable energy generation sources have been appropriately considered. Studies have shown that the use of such renewables is increasing and is expected to increase further by the year 2010.⁴ This has been pointed out previously to the EVTECA Review Committee⁵, but apparently no resources been committed. An appropriate consideration of nonpolluting renewable fuel sources such as solar & wind power – which would extend the environmental benefits of EVs -would be consistent with DOE's overall mission and should not be overlooked.

V. EVTECA emissions results are highly variable, contradictory and significantly at odds with previous studies:

A. It is worth restating at this point that far too much attention was given to the "unconstrained" option, which contributes greatly to the confusing great variation in the reported data. Power plants will encourage off peak charging and range limitations until 2010 will discourage long trips requiring the unconstrained option. This will be minimally used and it should be so stated or ignored.

B. Washington, D.C. Data is Skewed and Unreliable. It should be evident that something is very wrong with Washington, D.C. data, based upon projections of 60% oil use for electricity. Inadequate consideration and allocation of the baseload fuel mix between PEPCO and Virginia Power, failure to consider power contributions from the regional power grid, the wheeling of power from Ohio Edison, comparative load factors, growth rates and net summer capacity (improperly characterized), *an overly simplistic allocation of EV load requirements between PEPCO & Virginia Power on the basis of comparative overall energy sales*, are among various shortcomings.

⁴ Reference: Charging Ahead, The Business of Renewable Energy and What it Means for America by John J. Berger, Copyright 1997, Henry Holt & Co., New York, points out that California currently relies upon 20 percent renewable energy including hydro. Maine has a 35% renewable fuel source. By the year 2010 we can expect a further increase in non-polluting renewables, such as wind and solar, as power plant fuels. This would greatly benefit the EV option over the ICEV option, since the effect from each EV fueled by renewables would be virtually zero net pollution.

⁵ Ibid, footnote #1.

VI. A projected "eight to eleven times" increase in SOx associated with both power plants and battery manufacturing is unrealistic and fails to adequately consider increasingly stringent environmental regulations.

A. SOx emissions from power plants and industrial processes will continue to be reduced, as well as other emissions, as EPA regulations become increasingly more constraining. Why is this not assumed? Apparently, because of an *unwarranted emphasis upon emissions credits trading*, which improperly suggests that electric utilities will operate entirely in their own economic self-interest without regard to public pressures or the demands of environmental organizations. It is inconceivable that a "1000 percent increase" or anything significantly above present SOx levels be allowed without triggering an environmental and regulatory backlash.

B. Even more importantly, SOx projections appear to be overly affected by emissions from battery production, to which EVTECA assigns an incorrect 30% NaS assumption and incorrect life-cycle factors for nickel-based batteries and EV shell manufacturing.

VII. Projected methane (CH₄) emissions do not appear to correlate with utility fuel types and some figures appear to contradict one another:

A. There can be no significant reason for coal-burning power plants — which predominate in Washington, D.C. — to generate significant amounts of methane (CH₄), as EVTECA predicts. Obviously, the greatest amount of CH₄ would be associated with Natural Gas power plants. But that would be a fuel to be burned, and CH₄ "emissions" would be insignificant compared to NOx & SOx. In short, we do not see why CH₄ would be a significant emission from Washington, D.C. power plants — or why this should be a lesser factor during Washington summers.

B. It is hard to envision or understand the sources of methane in coal power plants. It should not be significant, and the figures in our view represent a "red flag issue" that something is wrong. Further explanation is needed here of the impact that is likely to occur. Does the CH₄ escape into the atmosphere or get burned? Oil & NG will produce methane, but coal should be a relatively insignificant contributor. Yet coal-based PEPCO's CH₄ estimates are projected at 641,000 lbs per 10¹² BTUs (p 7-3) vs. 154,000 lbs of methane for equivalent btus of oil in the entire crude oil production process. (p 6-9) This is a questionable issue. The numbers appear to be high and vary from Houston without explanation, making any comparison meaningless.

C. The CH₄ projections for CVs do not appear to include a component for the *CH₄ released to the atmosphere during oil well drilling and pumping*, nor any consideration of the growing numbers of *natural gas-powered CV's* and diesels, and apparently assume that the only CV fuel used will be RFG.

D. What is the impact of 1,000 lbs of methane? Over what period of time? From a *Global Warming perspective*, 1 lb of methane has the impact of 25 lbs of CO₂. The CO₂ number is 1.6 million lbs of CO₂. The source of methane is inconceivable, representing 4 times the CO₂ in Houston, and appears to be (incorrectly) oil-based.

E. A statement on page S-3 on emissions is inconsistent with figure S-2 on CH₄, and again with table S.1. There are also inconsistencies and great variations for SO_x/NO_x/TSP between Table S.1 and page S-5. An statement to the effect that NO_x is always lower for EVs contradicts page S-3 where it says "higher or lower".

VIII. EVTECA's projected utility fuel sources are also highly questionable, particularly under "unconstrained" scenarios, and may be based upon partial or incorrect *utility dispatch orders*.

A. It has been indicated to us previously that the analysis of *utility dispatch orders* has been one of the most difficult aspects of this study and that a considerable number of the affected utilities may not have cooperated directly with EVTECA by providing requested survey information. It is our understanding that additional information pertaining to these issues may be obtained through various FERC filings that are required by law. If sufficient resources were assigned to EVTECA, a more thorough review of this data might prove to be helpful. We recommend that EVTECA attempt to make use of this data and reevaluate its approach on the basis of our previous comments.

B. The use of such data may provide a more extensive picture of electric power generation, but it also must be combined with a more comprehensive understanding of both regional and local characteristics. For example, rate structures that vary according to use and TOD from \$.02/kWh to \$.32/kWh — as can be the case in Los Angeles — *do* affect customer choices and hence, a purely "unconstrained" demand scenario is not a rational choice. On the other hand, the possibility that some core metropolitan areas might, in the future, restrict access by ICEVs — as is now the case in some European cities — could lead to an increase in unconstrained demand. The issue is more appropriately addressed as *a matter of degree* rather than as an "either/or" situation.

C. Both tables 2-7 and 2-1 are very difficult to understand in their breakdown of gas/oil/coal fuel sources for power production. A large negative number (as for coal) under some circumstances compared to a large positive number under other circumstances may reflect an alternative power plant decision (or a shutdown) under varying load assumptions, but it is also a potential indication of a high degree of uncertainty or an inadequately defined methodology.

IX. The use of renewable energy sources such as solar, wind, geothermal, hydroelectric and pumped storage for incremental EV power requirements appears to have been inadequately addressed. This issue has been adequately discussed in previous statements.

X. Battery life cycle characteristics and recycling practices have not been appropriately characterized or separated from "emissions".

A. EVTECA's characterization of all lead byproducts as "emissions" is *misleading*, because the term "emissions" implies that lead waste products enter the environment and are dissipated rather than *controlled and recycled*. Because EVTECA's inventory-based approach fails to separate controlled vs. uncontrolled and airborne vs. solid lead residuals, the resulting presentation of Resource Summary Data in Volume III. is *misguided*, providing an inadequate portrayal of lead byproducts, sullyng the reputation of the lead recycling industry, and wrongfully implying that lead batteries and EVs (as a result of their lead and copper content) are harmful to the environment.

B. Similarly, Tables D.4.24 and D.4.25 (Primary and Secondary Lead Smelting Processes) in the Volume II appendices, speaks only of "airborne residuals" and fails to separate controlled vs. uncontrolled emissions⁶. In addition, the reported values are approximately 2-3 times too high, according to the latest study from Princeton University's *Center for Energy And Environmental Studies*⁷.

⁶ The discussion on page 8-31 and 8-32 in Volume I. indicates that the types of emissions focussed upon are "oxides . . . released as particulates during both primary and secondary (recycling) operations," and that "these particulates are usually controlled with a baghouse, with control efficiencies exceeding 99%." One obvious question to ask here is: *If these particulates are captured prior to leaving the smokestack, can they truly be considered to be "emissions"?*

⁷ "The Industrial Ecology of Lead and Electric Vehicles", Sokolow & Thomas, 1997, Princeton University, reports that, based upon a 1994 EPA Toxic Release Inventory in combination with production-weighted air emissions factors from 17 of the 18

C. A footnote on Table D.4.24, "Primary Lead Smelting" - which is assumed to represent 25 percent of battery lead⁸ - indicates that *a factoring error of several orders of magnitude for lead emissions* "was incorrectly included in the final study calculation as 0.19 rather than 0.082," arguing that although "This error could affect the magnitude of final study results, . . . it is unlikely that the conclusions of the study would be different." We disagree, and feel that EVTECA should correct the error. We strongly suspect that when all factors are appropriately considered (including our suggestions in Item "B", above), the surprising "400 percent increase" in lead emissions associated with EVs will rapidly diminish.

D. Separate statements that "98 percent of spent batteries in the U.S. are currently recycled" (page 8-30) and that EVTECA is "not an impact analysis" (page S-6) do little to correct the egregious implications of this flawed reporting methodology and simply leave the matter open to interpretation. We feel that EVTECA has an ethical obligation to:

(1) review this data and to separate "controlled byproducts" from "emissions", and

(2) to fully disclose the nature of the emissions, the extent of dispersion, and the potential health implications, if any.

E. It should be further stated that the inventoried lead residuals, for the most part, represent a *confined and recyclable use*, not a *dissipative use* as would be the case in the gaseous form associated with leaded gasoline. Gaseous emissions have a definite and easily predictable and imaginable impact and an impact analysis is not critical. Not so for lead. Here its presence doesn't automatically describe an impact and in this case, *only* an impact analysis will describe attributed concerns. In addition, as a result of increasingly stringent regulations, lead is a very well-controlled emission in all associated activities.

secondary lead smelters in the U.S., "The production-weighted average air emissions factor (including both fugitive and point emissions) is .006 percent," which is equivalent to 0.12 lb of lead emissions per ton of secondary smelted lead, as opposed to EVTECA's reported "National Average - U.S." factor of 0.29 lbs of emissions per ton. We have recently provided you with a copy of this report, which was unavailable to EVTECA until now.

⁸ We disagree with this factor also, and agree instead with the Princeton Study, that the correct proportion of primary lead in all lead-acid batteries should be 20 percent.

F. Why does EVTECA not assume that nickel will be recycled and its emissions controlled as is lead and its emissions? In addition, the life-cycle expectations for *NiMH* batteries, which are now expected to capture a growing share of the EV market, should be updated, eliminating the need for a replacement battery pack during the lifetime of the vehicle. It is likely that these combined factors will result in a significantly reduced contribution to SOx emissions.

CONCLUSION

EVTECA has made immense and significant strides in examining the fundamental processes and relationships necessary to compare the net energy and environmental effects of EVs vs. CVs, but has still fallen far short of its goal, in part, because of inadequate resources to complete this ambitious assignment in the face of:

- rapid and continuing progress in the automotive industry,
- continuing battery progress and competition,
- fundamental changes in the nature of the electric utility industry.
- rigid assumptions that are unable to respond to these changes.

As a result, EVTECA is not supportable in its present form, is confusing, misleading and inaccurate on many critical points. We recommend that the study be held back, reevaluated and redefined as follows:

(1) A more comprehensive approach must be adopted to better reflect regional and national trends.

(2) Incorrect and outdated assumptions must be reevaluated, ,

(3) Missing data must be filled in and incomplete analyses updated,

(4) Energy and environmental flow charts should be added so that policy analysts and energy planners can appropriately debate the results.

(5) Finally, *a more fluid and robust approach is needed* to help respond to the challenges of evolving technologies and competing assumptions from opposing industries. To help meet these challenges, EVTECA must evolve into a dynamic model with sufficient flexibility to examine and modify the key assumptions and components.

EVA/DC EVTECA Comments, September 29th, Page 16

Once again, it has been our pleasure to be included in this important and challenging study effort, and it has caused us to reexamine many of our own assumptions and to investigate factors that we had not previously considered. *From a national perspective, there can be little doubt that the EV technology can offer significant net energy and environmental benefits, but the debate is far from over.* Many unanswered questions remain that are vital to America's energy and environmental future. It is our hope that the necessary resources can be provided so that EVTECA can be revitalized into a more dynamic instrument that will encourage policy analysts and energy planners from all economic sectors to reexamine their own assumptions and to explore the fullest range of possibilities.

Sincerely,

David Goldstein,
President

Morris Altschuler
Environmental Chairman

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Alternative Fuel Vehicles

Fax

To: Margaret Singh

From: Sheral Arbuckle - Ford AFVC

Fax: (202) 488-2444 *or 2413 or 2471* Pages: 4

Phone: (202) 488-2440

Date: September 15, 1997

Re: Review of Draft DOE TECA Report

CC: Brad Bates, Marty Friedman, Walt Kreucher, Mike Tamor

☐ Urgent ☒ Review Comments ☐ Please Comment ☐ Please Reply ☐ Please Recycle

• **Comments:** As a member of EVAA's Technical Advisory Group, Ford was solicited to comment on the subject draft DOE report, "Total Energy Cycle Assessment of Electric Vehicle and Conventional Vehicles: An Energy and Environmental Analysis."

First, let us compliment you on this relatively good start in answering the principal question your report addresses, i.e., "How do EVs compare to CVs with regard to energy resource consumption and environmental residuals?" Our review, however, has uncovered several errors and omissions in both the assumptions made and the methodology used which detract from any meaningful conclusions.

Herewith are comments from our internal review team which includes Ford's Alternative Fuel Vehicles, Scientific Research Lab Alternative Power Source Technology, and Environmental & Safety Engineering staffs. We offer these comments for your consideration in developing your final report. We strongly urge you to review the many assumptions questioned and suggest that you continue your analyses to address these concerns.

• **Synopsis: Study Results:**

- ⇒ We suggest that you emphasize and clearly state, in this section of your report, that all variances (increases and decreases) in life cycle integrated emissions are for a single EV relative to a single CV and not the total transportation fleet for each region. A novice skimming through this report would interpret your results as applying to more than what is intended.
- ⇒ We also suggest that your discussion on the impact on total air quality for the regions studied, i.e., Houston, Washington D.C., Chicago and Los Angeles, be made more conspicuous, i.e., you should clearly state the impacts on total air quality by region. The study would be more meaningful if analysis in the other two regions not discussed in this draft report (Chicago and Los Angeles) be continued and included as well. You may even consider expanding this analysis to other regions of the country, i.e., Northeast given the drive to continue with a ZEV sales mandate.

September 15, 1997

- **Section 2.0 - Summary of Total Energy Cycle Results:**

- ⇒ **CV Fuel Economy:** Your study assumes a Tier I fleet average gasoline vehicle (21 mpg) is displaced by a compact passenger car (or minivan) EV. This assumption is not realistic and should include the phase-in of NLEVs and Tier II gasoline vehicles to determine the variance in emissions reduction of an EV (versus a comparable CV) and to provide a more comparable fuel economy for the CV. In addition, it appears that you've assumed the weight of a compact gasoline vehicle is 5,700 pounds...much too high for compact vehicles.
- ⇒ **EV Batteries :** The mix and types of EV batteries that will be in the marketplace for the 1998-2010 time frame is also inaccurate. We concur with EPRI's Issues and Analysis Team's response that your assumptions on batteries do not reflect today's trend in EV battery technologies. The current battery trend for EVs does not include use of NaS batteries to power EVs of tomorrow to any great degree. You've estimated that EVs using NaS batteries in the 1998-2010 period is 30% which is certainly unlikely. OEM EVs on the road today are using lead-acid (PbA) and nickel metal hydride (NiMH) battery technologies. USABC development efforts are focused on nickel metal hydride as the mid-term battery of choice (1998-2003) with longer life, better performance lithium batteries being the battery of choice in the future (2003 - 2010).
- ⇒ **In-basin versus Out-of-basin Analysis:** Your report should be structured to clearly quantify the results of in-basin and out-of-basin impacts for each region. In-basin results are discussed in some cases and are ignored in others. This should be more clearly stated and quantified. Including a separate section for this discussion would help sort through this muddled issue.

- **Section 4.0 - Vehicle Analysis**

- ⇒ **EV Stock:** Your assumption of what vehicles will be on-the-roads during 1998-2010 does not include light trucks. You state that you found no electric truck models or prototypes being developed by OEMs. Not true! Ford is introducing the Ranger EV this year as its first production EV for sale nationwide. GM has also launched its Chevy S10. Both of these trucks are being marketed to fleet customers...the early EV adopters. Your analysis must be updated to reflect light trucks and other auto manufacturers' announced vehicle introductions.
- ⇒ **Mileage:** The household mileage for a CV was derived from 1990 data. This data should also be updated to represent the automotive world of today.
- ⇒ **Battery Life:** Your assumption of the number of battery replacements over the life of the vehicle seems to be rather low, particularly for lead-acid batteries. The average life of a vehicle is 13 years, which means with a PbA powered EV there would certainly be more than 2 replacements of the battery pack. You should state your assumptions for both vehicle life and battery life.
- ⇒ **Daily Recharge Requirements:** Your analysis assumes EV fleet owners will charge their vehicles in a two hour period, 4:00 pm to 6:00 pm in the *unconstrained* (on-peak) scenario. This assumption is unrealistic since charging schedules will vary depending on number of EVs in the fleet, their daily usage (miles driven) and the number of charging stations available to service the fleet. This assumption will greatly impact utility loads and emissions and should be revisited.

- Section 4.0 - Vehicle Analysis (continued)

- ⇒ **Charging Duration:** As noted in the previous comment, your assumption of two hours to recharge an EV should be clarified, since charge times is dependent on battery SOC, battery pack size, recharging power levels, charging system efficiency, etc. How was the 2-hour charge time derived?
- ⇒ **EV Charging:** It also appears that you've assumed Level 2 charging is all that will be available for EV charging. You should also address the impact of Level 3 fast charging if used significantly by fleets and for public charging.

- Section 5.0 - Electric Utility Analysis

- ⇒ **Utility Optimization:** We have several comments to your assumptions on the utilities' selection of generators to meet marginal demands for EV charging:

- * The underlying assumption of which generator choices will be made to meet the marginal electricity demand for the various scenarios, i.e., combined-cycle gas-fired generators or combustion turbines, is obviously in error since it assumes utilities have no pressure today to reduce powerplant emissions. With deregulation right around the corner, i.e., January 1998, the growing competition in the utility industry should certainly increase efforts in areas of improved powerplant efficiency and emissions reduction.
- * The difference between utility base-, swing-, and peak-load generating systems has been improperly treated. The assumptions on generator choices for unconstrained charging and off-peak charging seems to be driven purely by cost rather than a combination of cost, generation response time and generating efficiency. All three of these factors should be considered in your analysis.
- * We also suggest that you revisit the *constrained* charging case with more care assuming: 1) the utility can manage the regional EV charging load within the constraints of expected usage and 2) that the newly increased base-load capacity is provided by the best available (as defined in the previous bullet) base load technology appropriate for that region. This could have a significant impact on emissions and the utilities' overall capital usage.

- Section 8: Manufacturing Emissions: The manufacturing emissions estimates do not match those recently generated by MIT/Ford for gasoline and electric vehicles. We would be happy to provide you with a copy of this report.

- General Comments

- ⇒ As a result of your many and varied assumptions, several questions come to mind:

1. With the assumption that utilities will optimize their capacity mix to support the demand for EV charging, will there be an optimum market penetration above which emissions begin to rise?
2. Is there a maximum fleet size above which the pre-dawn charging load exceeds the base operating generation capacity for each region?

September 15, 1997

- General Comments (continued)

- ⇒ Many aspects of this study are incomplete. The synopsis and introduction should specifically state that this report is 'work-in-progress'. It would also be helpful to provide a workplan, including reviews such as this, that gets you to a final published report.
- ⇒ It would be easier reading if the figures and tables were arranged in the order in which they are referenced/discussed in the report.

We hope these suggestions, along with those forwarded to you by EPRI's IAT, are seriously considered and addressed in your final report.

Mobil Oil Corporation

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BRIAN M. HARNEY
MANAGER
POLICY AND ISSUES MANAGEMENT

September 10, 1997

Margaret Singh
Argonne National Laboratory
955 L'Enfant Plaza S.W.
Suite 6000
Washington, D.C. 20024

Comments on EVTECA Study

Dear Ms. Singh:

In response to the above referenced opportunity for comment, Mobil Oil Corporation offers the following information.

Mobil Corporation is a major, integrated, international energy company which, through its subsidiaries and affiliates, conducts exploration, production, refining, chemical, transportation and marketing operations. Through subsidiaries, Mobil owns and operates five petroleum refineries in the U.S. with a combined capacity in excess of 900,000 barrels per day. In the U.S., Mobil's subsidiaries and affiliates operate more than 50 marketing terminals that distribute gasoline and distillate, over 8,500 branded retail outlets in 29 states, and several hundred oil and gas production facilities. These domestic operations are supported by over 35,000 employees who are committed to protecting the environment and operating these facilities safely and efficiently while providing quality goods and services to the public.

We appreciate the opportunity to comment on Argonne's Electric Vehicle Total Energy Cycle Assessment (EVTECA). A report like this one could become a valuable tool to be used in meeting some of the requirements of the Energy Policy Act (EPAct) regarding consideration of "Full Life Cycle" emissions analysis when developing alternative fuel policy. We also appreciate the tremendous amount of work involved in properly conducting such a study and your willingness to extend the comment period.

The cover letter indicates that the study has been underway for "*several years*". Reports such as the EVTECA may be used by the Department of Energy and perhaps other federal and state agencies to justify policy decisions that could cost the U.S. economy millions and even billions of dollars. A report of such magnitude deserves a proper and thorough peer review. Outside, impartial consultants should also be sought out and given the opportunity to review and comment on this study before it is finalized. Below is an outline of some basic concerns we have with the study.

THE STUDY CONTAINS OVERLY GENEROUS ASSUMPTIONS

One of the assumptions in the study includes the projection that Electric Vehicles (EVs) will replace Conventional Vehicles (CVs) on a one for one basis. This assumption may be a logical sensitivity of

the base case to explore but should not constitute the base case. Instead, we would suggest that a more likely base case would be one where EVs are purchased as a second or third car to supplement, rather than replace, existing CV use. The EV would most likely be used in limited applications for short trip, around town driving. In this more logical base case, EV use would only displace a portion of the CV mileage. This means that the emissions for EVs should include all the mileage associated with the EV, PLUS the incremental emissions attributable to the older CV that is still in use and was not completely replaced by the EV. The purchase of an EV which does not replace an older CV precludes the retirement of older, more polluting vehicles which could have been replaced with newer, lower emission CVs. The emission reductions provided by the EVs limited reduction of mileage on the existing CV may be more than offset by the reductions that would have been realized if the older CV were completely replaced by a new, lower emission CV.

The study's high EV use scenario for Los Angeles assumes an EV penetration of 50%. This is a highly unrealistic assumption given only 13 years to reach this reported 50% market share. The report summary also indicates that EV batteries are expected to be replaced at least once in the life of the vehicle. This also appears to be a rather generous assumption. Neither Appendix B, nor C seem to address the battery replacement issue. No mention of replacement batteries could be found in the section on battery types and performance (Appendix B.2) or in the section on simulation of EV loads (Appendix C.3). Both of these areas have a significant bearing on the emissions attributed to EVs. Most studies today indicate that battery packs need to be replaced every 2 to 5 years. This would mean that for a 10 year life, an EV would have from 2 to 5 battery replacements. A more likely base case for the study would entail 2 to 3 battery changes.

The emission estimates for conventional vehicles in the EVTECA report, which are based on MOBILE5a and Tier 1 vehicles, are much too high and do not represent the latest technology for gasoline vehicles. MOBILE5a does not include National LEV or Tier 2 vehicles which will probably be introduced nationally after 2000. MOBILE5a also contains assumptions for California LEVs that are more pessimistic than the assumptions in the CARB EMFAC model. Additionally, recent in-use data indicates that MOBILE5a significantly overestimates emissions from vehicles built in the 1990s (EPA presentation to In-Use Deterioration and Modeling Workgroups of Mobile Source FACA).

Currently, both CARB and EPA assume that either LEV or NLEV with enhanced I&M will have in-use emissions that are roughly equivalent to vehicle certification standards, but the projected emissions for conventional vehicles used in EVTECA (listed in Table B.7.1) are several times LEV/NLEV certification standards for NMHC, CO and Nox. The analysis also assumes that emissions on the LA-92 cycle will be higher than those on the standard federal urban cycle. However both EPA and CARB have adopted regulations to limit emissions on the aggressive driving contained in the LA-92 cycle. These regulations will phase-in beginning with the 2000 model year, therefore the assumption of increased emissions on the LA-92 cycle for new conventional vehicles is incorrect.

The energy efficiency of EVs is somewhat optimistic. Some of this may be attributable to the fact that the study does not comprehend the energy transmission losses that occur in normal electrical distribution. Also, in page S-4, it is misleadingly stated that the efficiency of the base CV is assumed to be 21 mpg, while the EV is 100 mpg. Obviously, the greatest part of this difference is due to the fact that conversion of the fuel to energy (which is the least efficient of all of the production chain processes) occurs onboard the CV, whereas for the EV, it occurs at the power plant. Further, while the assumptions predict tremendous improvements in EV efficiency over the study period (~25%), CVs are shown to have little improvement in efficiency (~7%). This despite the fact that there already exists CVs with mpg ratings of 45-50 mpg and that new internal combustion engine technology, such as fuel-efficient direct injection gasoline engines and clean-burning diesel engines, are currently being introduced into the market place.

As we pointed out in earlier comments to this study (sent to NREL in April 1994 (attached)), the comparison of EVs with CVs of similar performance characteristics is of utmost importance to make the analysis credible. Despite the discussion on efficiency in the Appendices (and commented on above), it remains unclear if the study compares a 2 passenger EV with a payload of around 225 pounds with a 4-door conventional sedan with at least 3 times the payload. In the Summary, at page (S-4), it indicates that a CV with 21 mpg is used as the base case. If this 21 mpg CV is not compared to a similar EV with nearly identical payload and range, the analysis will unfairly advantages EVs. Even Appendix B (page B-49) of the report does not give proper credit to existing highly efficient CVs with mpg ratings of around 45-50 (i.e. Geo Metro).

THE SUMMARY OF EMISSIONS DATA IS SKEWED

Given that the results of the emissions reductions are already skewed by the generous assumptions mentioned above, the reporting of those reductions is further biased by the way the report portrays them. For example, the claimed EV emission benefits are reported as a percentage reduction, while emission increases attributable to EVs are reported as whole number multipliers. A 97% reduction in CO from EVs appears as a highly significant number. However, if the reader was made aware that CO emissions from a new vehicle running on reformulated gasoline approaches zero, the reader would be able to conclude that a 97% reduction from next to nothing is still nothing. On the other hand, in identifying an increase in SOx emissions, the report says that EV emissions could be 8 to 11 times as high. For consistencies sake perhaps this could be reported as an 800% to 1100% increase caused by EVs.

The report indicates that battery recycling was assumed to occur "out-of-basin" and that while recycling could occur in-basin, it was not addressed. We would suggest that battery recycling would, in all likelihood, occur in basin. If not, there would certainly be a significant in-basin emission contributions associated with the transport of the batteries to the out-of-basin recycling /disposal site.

Therefore, if the assumption remains that recycling occurs out-of-basin, at a minimum, the emissions of transporting recycled or disposed batteries must be accounted for in the data as additional EV emissions.

In the beginning of the executive summary at page S-1, the report identifies that the emissions associated with EVs are compared to CVs operating on RFG. This, however, is misleading unless the reader digs into the details of the report. The emission benefits of EVs, portrayed at Table S-3 report the tons and percentage of VOC reductions anticipated with increased EV use. This data is measured against a baseline that does not include RFG. Therefore, the benefits of EV usage is overstated, casting a more than optimistic light on the anticipated emissions reductions. Later, the report correctly points out that using a 1990 emission inventory does not account for the use of RFG. This appears to contradict the statement made earlier at page S-1 (stating EVs are compared to CVs operating on RFG) and may confuse the reader.

Finally, the report points out that increased production of heavy metals associated with battery production is not comprehensively addressed. We appreciate that this information is brought to the reader's attention. However, policy makers reading this report may not be able to easily identify this important exclusion unless the omission is made obvious. The increased introduction of heavy metals into the environment, brought on by the increased use of EVs, is a significant portion of the pollution attributable to EVs and should not be taken for granted. By ignoring this portion of the "full life cycle" analysis, one could argue that it was intentionally omitted in order to portray EVs in a more favorable light.

ECONOMICS WERE OMITTED

Despite the fact that the study does not address economics, a quick analysis (with the proper caveats) would be useful in putting the benefits claimed in perspective. Even with all the generous assumptions made, the study indicates that EVs contribute only a 0.6% reduction in total VOCs (Table S-3). Without a rigorous analysis, a quick estimate would indicate the following for Washington D.C.:

Tons of emission reductions ($3.3 \times 365 \times 10$) (3.3 tons per day for 10 years)	- 12,045 tons
Cost of EVs ($141,000 \times \$12,000$) (\$6,000 first cost increment plus two battery replacements at \$3,000 ea.)	~ \$1.7 billion
Dollars per ton of emissions ($\$1.7B / 12,045T$)	~ \$140,000 per ton

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Page 5

These numbers would reflect even less cost effectiveness for EVs if the assumptions that we have previously identified were corrected. Additionally, if the baseline were corrected to reflect RFG usage, the 3.3 tons per day of reduced emissions reported would be less, making EVs even less desirable as an emission control measure.

SOME TABLES AND CHARTS ARE UNCLEAR AND MAY NOT MATCH THE TEXT

In discussing power plant emissions page S-3 states: "*Table S-1 presents total, not in basin, emissions*". It is unclear what the report means by this statement. Does it refer to the total emissions outside the basin, or, is it not just the in basin emissions but rather the total emissions (including in basin and out)? Keeping in mind the question of what total emissions means (from above), Table S-1 then shows negative emissions for Houston (using Combined Cycle Units or UCCs). It is unclear how total emissions can ever be negative. If it is assumed that older, coal fired units are replaced by UCCs and the emission benefits of the entire load served by the newer UCCs is attributable to EVs, then the information is misleading, at best. The emissions from the new UCCs, although low, are not zero and those emissions attributable to the load for charging of EVs should be reported as being caused by EV use. The added emission benefits (for the remainder of the load), realized by replacing the older coal fired units with UCCs could have been realized with, or without, the introduction of EVs. Therefore these emission reductions should not be claimed as benefits of EV usage.

A final bit of confusion appears on this subject at page S-5. In discussing SOx emissions in Washington and Houston, the report indicates that there are SOx decreases (in basin) with unconstrained charging and the addition of UCCs. This debatable statement of fact is at least consistent with the tables for Houston (assuming the erroneous assumptions identified above are made), however, despite the dialogue at page S-5, Table S-1 shows no such SOx decrease for Washington. In fact, Washington shows increases across the board for SOx. Therefore, it is extremely unclear what information the report is attempting to convey in this section.

Mobil actively participated in the development of API's and WSPA's comments and hereby support those comments by reference.

Should you have any questions or need additional information, please contact Tom McDonald (703) 849-7505.

B. M. Harney

attachment

Mobil Oil Corporation

3225 GALLOWAY ROAD
FAIRFAX, VIRGINIA 22037-0001

MARKETING AND REFINING DIVISION

April 20, 1994

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
Attn: Carol J. Hammel

Dear Ms. Hammel:

This is in response to your March 15, 1994 request for review of the Total Energy Cycle Assessment of Electric Vehicles: Study Plan, (Draft). I have reviewed the Study Plan with several members of our organization in order to provide valuable input to the process. The following comments are provided for your consideration.

-Assumptions and study inputs can have a significant effect on study results. A detailed characterization of the assumptions and acknowledgement of uncertainties contained in study inputs, specifically regarding electric vehicles, should be included to determine whether electric and gasoline powered vehicles will be compared on a consistent basis.

-Every effort must be taken to ensure that an appropriate comparison is made between an EV fleet with similar performance to the CV fleet it will replace. For example, an EV with a 2-passenger, 360 pound payload should be compared to a CV with similar performance characteristics. Another example would be electric delivery vans needing to drive more vehicle-miles to deliver the same payload as gasoline powered vans.

-The study plan properly chooses cities that exhibit a diversity of fuel uses (Los Angeles, Chicago, Houston and Wash. D.C.) but they do not represent a cross section of U.S. electric power generation by energy source. That is, the aggregate of these four cities should not be misrepresented as portraying the U. S. average. Washington is probably closest to the national average (56% from coal), but taken as a whole, they are not "typical".

Accordingly, the environmental impacts of electric vehicles are expected to be more favorable in Los Angeles than any of the other cities studied due to the electricity generating mix in Los Angeles (large non-fossil contribution, little coal contribution).

National Renewable Energy Laboratory

April 20, 1994

Page 2

-Features that may be considered for electric vehicles (i.e. low weight, low aerodynamic resistance, low rolling resistance) in order to achieve performance similar to gasoline vehicles must also be considered for gasoline vehicles in order to fairly compare the core difference in technology, electric vs. gasoline fueled.

-Electric vehicles, which will replace gasoline driven vehicles, are only being considered as part of a California low emission vehicle program (CA LEV). Emissions associated with electric vehicles should therefore be compared to emissions from new gasoline vehicles meeting CA LEV standards and not the in-use gasoline fleet in 2000 or 2010.

-Although the study is not designed to address costs for new vehicles, electric or otherwise, high electric vehicle costs may delay fleet turnover and therefore reduce emissions reductions associated with electric vehicle requirements.

-There is an environmental impact associated with battery production and recycling that does not appear to have been considered.

-The assumption that Washington, D.C. will be affected by the CA LEV mandated penetration levels (for electric vehicles) is incorrect at this time. The low emission vehicle program developed by the Ozone Transport Region (OTC) and submitted to EPA for approval does not include a zero emission vehicle mandate. This has been confirmed by OTC officials and is consistent with EPA's position that a zero emission vehicle mandate for that region is not before EPA for consideration.

Although the study is not designed to analyze costs of the various alternatives, it should be noted that as state and local entities consider air pollution control strategies, a major factor in selection of those strategies will be cost-effectiveness. Analyses of the costs and benefits of alternatives, careful allocation of limited resources, and the effect of that allocation on sensitive economies will be critical.

If there are any questions, I can be reached at (703) 846-4759.

--

C. E. Doumas
Environmental Issues Coordinator
Mobil Oil Corporation

cc: B. M. Harney
C. R. Kennedy
T. B. McDonald
C. H. Schleyer

Margaret Singh
July 28, 1997
THE-01-97
Page 2

In this spirit, INEEL has the attached comments to this report. If you need clarification or justification for any of the attached comments, please contact INEEL as shown below. INEEL is in hopes that its comments will help to improve the quality of this report and looks forward to receiving a copy of the released version.

Sincerely,

Thomas Hickman,
Advisory Engineer
Automotive Systems & Technology
P. O. Box 1625, MS 3790
Idaho Falls, ID 83415-3790

Contact information:
(208) 526-1871 voice
(208) 526-2818 or -1400 fax
E-mail: hickte@inel.gov

Attachment: Comments to referenced report

cc: G.L. Hunt, MS 3830
T. E. Hickman letter file

LOCKHEED MARTIN

Lockheed Martin Idaho Technologies Company

P. O. Box 1625

Idaho Falls, ID 83415-3790

Telephone: 526-1871

July 28, 1997

Margaret Singh
Argonne National Laboratory
955 L'Enfant Plaza, S. W.
Suite 6000
Washington, D.C. 20024

TRANSMITTAL OF DOE DRAFT REPORT REVIEW COMMENTS-
TEH-01-97

Dear Ms. Singh:

Thank you for the opportunity to review the report entitled "Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Analysis". It contains a great deal of detail, is rather comprehensive in scope (within its funding limitations), and does an excellent job of providing traceability for the analysis and conclusions. However, Idaho National Engineering and Environmental Laboratory has found some issues that should be addressed to improve the quality of this report. This report will doubtless be used as the definitive work on this subject and will have an impact on legislators, regulators, intervenors, and lobbyists actions. This makes it desirable for the report to be comprehensive, timely, and valid.

IDAHO NATIONAL ENGINEERING & ENVIRONMENTAL LABORATORY (INEEL)

Review of Report Entitled

**TOTAL ENERGY CYCLE ASSESSMENT OF
ELECTRIC AND CONVENTIONAL VEHICLES:
AN ENERGY AND ENVIRONMENTAL ANALYSIS**

Report prepared by

Argonne National Laboratory,
National Renewable Energy Laboratory, and
Pacific Northwest National Laboratory

for

U. S. Department of Energy
Office of Energy Efficiency and Renewable Energy

*Draft dated July, 1997
3 volumes*

Executive Summary

This report represents a great deal of effort and contains some excellent analysis and supporting derivations with references. Prior to releasing this report, INEEL does recommend several improvements, some of which are key to the report's conclusions. These are:

- Report assumes that Electric Vehicle's (EV's) lifetime is the same as a Conventional Vehicle (CV). More likely the EV will outlast the CV by a factor of at least 1.25-2.00, at least for EVs built after 2003. The term of the report does not extend beyond 2010, but this will have a significant energy and emissions impact in the longer term.
- CVs have much greater operation and maintenance needs than EVs. Things like oil changes, replacement of broken engine parts, etc. are not accounted for.
- Most at-home charging will be done off-peak because of the much lower cost of electricity at that time. Many utilities already have time-of-day rates (at least optionally). The large amount of electricity that an EV uses will make all but the richest or dumbest EV owner charge his EV when rates are cheapest, much like most folks shop for cheaper gasoline prices now. Electric vehicle chargers will doubtless build in a feature for automatically delaying the start of charge until later in the evening. Your report does an excellent job of analyzing both off-peak and unconstrained EV recharge, but it needs to conclude that most EVs will be charged off-peak unless financially incentivized to do otherwise. The cost of on-peak electricity will be 3 to 10 times the cost of off-peak.
- Omission of opportunity charging upon arrival at work or an urban parking area (like a shopping mall) seems to be ignoring a very large effect.
- Electric utility deregulation will cause major shifts in electric generation, independent of EVs. There will be more natural-gas fired Combined Cycle and Combustion Turbine generation resulting in lower emissions in many areas. These will be small compared to present generating stations and will be distributed in urban areas. This will tend to reduce transmission and distribution losses also.
- It is recognized that it is a substantial effort to make a report of this scope, but the first half of the report seems a bit dated, with references primarily 1994 or older. A quick check of a couple of its key premises against newer sources—if available—will make the report's conclusions seem more valid.
- As with most government documents, a list of abbreviations will greatly help the uninitiated reader.
- Battery assumptions appeared dated. Na-S and Ni-Cd battery (included) usage in EVs seems doubtful near-term, while Ni-MH and Li-Ion are likely, but not included.
- The delay in the mandates for EVs causes a large error in the numbers of EVs in the 1998-2002 timeframe. This particularly affects the LA EVs numbers in that the low penetration numbers are more like what the highs should be and the highs are now unrealistic.
- EV weights seem high

I liked the report, but would hate to see time or budget constraints prevent incorporation of the suggested improvements. If these are not done, the report will appear out-of-date and be too easy to "poke holes" in it when it is challenged in technical, legislative, and lobbying circles.

Volume I: Technical Report

Page #	Comment	Impact
general	Please include a list of abbreviation, preferably right after Table of Contents.	Make report much easier to read.
S-2	No water pollutant data collected for electric power plants seems valid given the stringency of regulations already in place at electric generating stations. However, no solid waste pollutants analysis would seem to be a large error for coal and possibly nuclear electric generation. Note that fly ash from coal plants has become a product for some utilities like Arizona Public Service.	Impacts pollutants traceable to electricity usage in Houston, Chicago, and perhaps Washington, DC.
Sections 1 to 4	References are all 1994 or older.	Gives report a sense of staleness and invalidity. Can results/conclusion be checked against newer sources in some cases to validate analysis & conclusions?
2-1, & 4-4	The mix of batteries assumed appears obsolete. More realistic estimate of batteries and %s is: Na-S=0%, AdvPb-acid=40%, Ni-MH=40%, Li-Ion=20% in 2003, with the %s moving more to Li-Ion or some other advanced battery towards 2010.	While the analyses of the individual battery types was well done, the overall conclusions would appear to be impacted by an obsolete distribution of battery types. If it was important to differentiate the four types, then it seems important that they be the correct ones and roughly in the right proportions.
2-2	Unconstrained charging of EVs as the norm seems highly unrealistic for more than say 10% of them. (For expanded comment, see 5-7.) Opportunity charging while parked at work or in urban shopping areas seems highly likely. Consumers will likely pay on-peak electric rates for opportunity charging and not mind if parking is included.	Your analysis includes both, but should draw a conclusion that off-peak constrained is most likely for evening charging. It may well be true that nearly half of EV recharging will be done by opportunity charging just after arriving at work or the shopping mall/district.
2-3	EV charging is most likely to occur partly by opportunity charging (above comment) via gas turbine electric generation or by charging off-peak. It is likely that most of the new electric generation will be done in a distributed manner.	New generators will be state-of-the art in efficiency, emissions compliance and O&M operation and will be in-basin. Many will be modest in size (as small as 50 kW) and as a result will have reduced transmission and distribution losses.
2-5	2.2.1 Utility deregulated and the low price of natural gas nationally is likely to lower the amount of oil used for electric generation in the Washington, D.C. area.	Error in the electric power generation plant type distribution, especially in Washington, D.C.
2-5	Gasoline spillage produces a lot of VOCs. I have seen some data somewhere that this is significant, but I forget the specifics.	Is this worth including? Perhaps at least add a sentence to say that the report was not revised to include this, but that it may be significant.
3-3, 3-11	With the modification of the EV mandates in the 1998-2002 timeframe, the EV market penetration in these years is higher than realistic. Perhaps shifting the Low EV Market Penetration scenario to the High and redoing the Low for these years would be closer. More realistic Low numbers might be something like: '98=0.1%, '99=0.5%, '00=1%, '01=2%, '02=4% for LA area and 0.5% for '01 for Chicago & DC.	Overestimation of EV effects, especially in LA area in 1998-2002 timeframe.

Volume I: Technical Report (cont.)

Page #	Comment	Impact
3-12	Highs are also much too high for '98 and '99 across the board and likely for '00-'02 for non-LA.	(See above). It could be said that leaving these alone, but with an added comment is not bad, because it would show what mandated/accelerated EV adoption impacts would be.
4-15	Despite your best analytical efforts, I don't believe this data for households. This assumes EVs will be treated just like CVs. It ignores the fact that the early adopters of EVs will be primarily in 2 classes: 1) those rich enough to afford a new "toy" and 2) those who drive a great many miles so that the reduced O&M costs of EVs is significant. The latter are likely to be people who use 2/3 of the EV range getting to work, opportunity charge, and use another 2/3 getting home. As the EV market increase, these folks will become prevalent. Better numbers are: LA=50, Houston=45, Chicago=40, DC=45 for early EV years. As EVs become more mainstream, these numbers will lower closer to—but still larger than—those in this table. Perhaps GM has some data available on EV1 leasees.	Will increase EV's impact.
5-7	As electricity deregulation hits, electric rates will all be based on usage at price broken into intervals from 5-15 minutes long. These will reflect the true cost of power production and will no doubt vary from about \$0.04/kWh off peak in your target cities to 3 to 10 times that much on peak (10 being for on seasonal peaks). This will occur with or without EVs. Since EVs are essentially a high energy use "appliance", consumers will no doubt pay attention to these rate variations and recharge accordingly. Smart chargers will make this consumer transparent. My guess is that EV recharging will be: 20% unconstrained evening, 30% opportunity between 8 AM and noon, 10% opportunity between noon and 3 PM, and 40% off-peak between 10 PM and 5 AM.	Substantial shift in your utility impacts of recharging.
6-4	Seems like there should be a shift to lighter EV shells, especially in the 2003 timeframe. Weight minimization is critical to an EV. This will occur as more EVs are not just "electrified" CVs, but have their own shell design like a GM EV1.	Errors in wt. @ EV shell and therefore its material makeup. This will ripple into EV efficiencies, energy required for recharge for given miles traveled and their resulting emissions.
6-6 to -8	(See attached spreadsheets for suggested numbers.) This shows a hazard of modeling. If EVs are to succeed they need goals and achievement, not extrapolation of "electrified" CVs. Li-Ion batteries have improved lifetime, better kWh/kg and higher energy efficiencies than PbA or NiMH.	Also disagree with some of the battery selections and therefore lifetime weights. (See also above)

Weight Comparison of CV vs. EV 2-Seater Automobile

Your Numbers

Element	Year Sold		
	Pre-2003	2003-2007	2008-2010
CV Weight	1970	1970	1948
EV Weight	2552	2836	2614
w/o batt	1780	1782	1710
battery only	772	1054	904
lifetime batt's	2316	3162	2712

EV battery should get lighter with time due to technology progress.

EV battery should last longer with time due to technology progress.

Suggested Numbers (heuristic)

Element	Year Sold		
	Pre-2003	2003-2007	2008-2010
	AdvPbA	NiMH	Li-Ion
CV Weight	1970	1970	1948
EV Weight	2472	2370	2200
w/o batt	1700	1650	1600
battery only	772	720	600
lifetime batt's	2316	2160	1200

Battery

EV "shell" should be weight minimized better than CV.

EV battery should get lighter with time due to technology progress.

EV battery should last longer with time due to technology progress.

Weight Comparison of CV vs. EV Compact Automobile

Your Numbers

Element	Year Sold		
	Pre-2003	2003-200	2008-2010
	AdvPbA	NiMH	NiMH
CV Weight	2605	2605	2516
EV Weight	3147	3283	3053
w/o batt	2269	2269	2180
battery only	878	1014	873
lifetime batt's	2634	2028	1746

Battery

EV battery should get lighter with time due to technology progress.

EV battery should last longer with time due to technology progress.

Suggested Numbers (heuristic)

Element	Year Sold		
	Pre-2003	2003-200	2008-2010
CV Weight	2605	2605	2516
EV Weight	2978	2800	2620
w/o batt	2100	2000	1900
battery only	878	800	720
lifetime batt's	2316	2400	1440

EV "shell" should be weight minimized better than CV.

EV battery should get lighter with time due to technology progress.

EV battery should last longer with time due to technology progress.

Weight Comparison of CV vs. EV MiniVan

Your Numbers

Element	Year Sold			
	Pre-2003	2003-200	2008-2010	
	NiCd	NiMH	NiMH	Battery
CV Weight	3580	3580	3420	
EV Weight	4549	4084	3053	
w/o batt	3191	3191	2180	
battery only	1358	893	873	EV battery should get lighter with time due to technology progress.
lifetime batt's	2716	1786	1746	EV battery should last longer with time due to technology progress.

Suggested Numbers (heuristic)

Element	Year Sold			
	Pre-2003	2003-200	2008-2010	
	AdvPbA	NiMH	Li-Ion	Battery
CV Weight	3580	3580	3420	
EV Weight	3893	3750	3565	
w/o batt	3000	2900	2800	EV "shell" should be weight minimized better than CV.
battery only	893	850	765	EV battery should get lighter with time due to technology progress.
lifetime batt's	2679	2550	1530	EV battery should last longer with time due to technology progress.

Weight Comparison of CV vs. EV Full-Sized Van

Your Numbers

Element	Year Sold			
	Pre-2003	2003-200	2008-2010	
	AdvPbA	NiMH	NiMH	Battery
CV Weight	4440	4440	4246	
EV Weight	5229	5284	4880	
w/o batt	3835	3835	3645	
battery only	1394	1449	1235	
lifetime batt's	4182	2898	2470	

EV battery should get lighter with time due to technology progress.
EV battery should last longer with time due to technology progress.

Suggested Numbers (heuristic)

Element	Year Sold			
	Pre-2003	2003-200	2008-2010	
	AdvPbA	NiMH	Li-Ion	Battery
CV Weight	4440	4440	4246	
EV Weight	5094	4850	4450	
w/o batt	3700	3600	3450	
battery only	1394	1250	1000	
lifetime batt's	4182	3750	2000	

EV "shell" should be weight minimized better than CV.
EV battery should get lighter with time due to technology progress.
EV battery should last longer with time due to technology progress.

Volume I: Technical Report (cont.)

Page #	Comment	Impact
8-9	EVs have fewer parts and should require less assembly energy and assembly materials than CVs.	This may not be a large effect.
general	Life-cycle O&M analysis except for battery replacement is ignored. CVs need much more O&M materials—like oil changes, fuel & air filters, etc.; replacement of worn/defective parts—like water pumps, fuel injectors, etc.	This effect would favor EVs except for battery replacement, which you have already included.
8-19	8.2.1.4 makes reference to a copper carburetor in an EV. I think motor controller is what is intended.	Typographical error.
8-29	EV lifetime should be greater than CV. Generally engine, transmission, or a crash dictate CV's lifetime. While EVs will crash too, it is more likely that EV motor(s) will greatly outlast CV engine and it is also more cost-effectively replaced with a "remanufactured" one. Battery pack replacement is already assumed. Motor controllers would also be modular and easily replaced with a newer unit. I think that 15 years is a more realistic EV shell life (w. no motor replacement, but possibly one controller replacement) and at least 180,000-250,000 miles—if not more. Note that I have previously claimed that EVs are more likely to be used in higher average miles/day uses within their range capability. Your analysis assumes 10,000 miles/year for the vehicle, this number should be more like 12,000-15,000 or more miles/year for EVs. Many fleet EVs may go 40,000-50,000 miles/year, especially with quick charging.	This effect will show up more strongly if the analysis had projected through 2-3 vehicle lifetimes. This kind of detailed projection (say to 2050) would be shaky at best, but the effect should be stated and is real.
8-30	Invites a question: did they? If not, why not? Would be better to say that it began pilot production in 1995 and is in limited production now.	Suggest that you ask Mike Semmens for his input to that paragraph.
8-30	PbA batteries have a step called formation where the plates are cycled up to 3 cycles prior to integration into the battery or after battery assembly, but before shipment. This involves significant electrical energy. I believe that the Horizon battery requires this or it is at least done for QA purposes. Verify with them when you ask above.	Account for formation cycling energy.
8-33	Doubtful that any EV will use NaS battery, at least prior to 2005.	Move to appendix and replace with Li-Ion if you have the info to do so.

Volume II: Appendices A-D to Technical Report

Page #	Comment	Impact
A-1	3 rd paragraph, 1 st sentence: "on" should be "one"	typographical error
A-15	Process Description: "flue" should be "fuel"	typographical error
B-1	Run a check on new vehicle sales from '93-'96 and see whether these figures compare favorably w. projections from '92 base. If not, then adjust projected sales ('92 was 5 years ago!) DOE should be able to get these from the "Big Three" or the Department of Commerce just for asking.	
B-5	4 th paragraph, 5 th sentence: "area" should be "are"	typographical error
B-15	Assumes vehicle life is equal for CV and EV. (See comment at 8-29).	(See 8-29)
B-30	1 st paragraph, 6 th sentence: "horizon" should be "Horizon".	Typographical error. This likely is a registered trademark, do you need to say that?
B-31	2 nd paragraph, 3 rd sentence: (same as above)	(same as above)
B-36	I believe that a vehicle like the EcoStar will have a continuing market. It is basically a mini-truck with a shell. Ask the "Big Three" what the market for mini-trucks in the U.S. is if you like. They once thought that Toyota and Nissan (nee Datsun) didn't have much of a market for these either. They are the perfect vehicle for light delivery service. If Ford and other American vehicle manufacturers don't sell many EVs like the EcoStar, then Japan will.	Should include it in later years of analysis.
B-36	Wherever Na-S or Ni-Cd batteries are referred to in this study, they should be replaced with AdvPbA or Ni-MH.	Effect is at least as large as differentiating between batteries to begin with.
B-40	EVs should be much lighter than CVs, except for the batteries because efficiency in an EV is so much more vital.	(See previous comment at 8-6)
B-91	Paragraph B.6.5: twice says "GV" should be "CV"	typographical error
C-1	Several utilities daily cycle and some have tried load following with nuclear power plants. Agreed, that most utilities prefer to run their nuclear plants near full load all of the time because fuel costs are so cheap.	Correct as stated as long as it doesn't leave the impression that they can't.
C-13	3 rd paragraph: "So ₂ " should be "SO ₂ "	typographical error
D-45	EV's body & trim should be less than for a CV. EV's Electrical Components number also seems high. These numbers may be close for "electrified" version of a CV. I don't think that they are valid for a "ground-up" EV like a GM EV1.

Sandia National Laboratories

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August 18, 1997

Dr. Margaret Singh
Argonne National Laboratory
955 L'Enfant Plaza, SW
Suite 6000
Washington, D.C. 20024

Dear Dr. Singh:

I have briefly reviewed the draft report entitled "Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Assessment." My comments will address technical and report format issues.

From a format perspective, I have the following suggestions. In the synopsis please use a spell checker ("conclussions" in the first line). Also, please spell out acronyms on the first use and add a list of acronym definitions (VOC, ZEV, LDV, MTBE, TSP, etc.) The use of the personal pronoun "we" is excessive and rather distracting (e.g. See item 3 in 5.3). The use of informal jargon is also distracting (i.e. Item 4 in 5.3 "up front", item 3 in 5.3 "this under a dispatch order"). Tables 5.1 and 5.2 seem too detailed and inappropriate in the synopsis. There are also some grammatical problems scattered throughout (e.g. Section 5.0, 3rd paragraph, 1st sentence; Section 5.1, last sentence).

I have several technical concerns about the report. While I understand that studies of this type take significant time, the document seems dated and it is not yet published. The inclusion of sodium/sulfur batteries while nothing is reported on lithium-ambient temperature rechargeables is a significant weakness. This should at least be explicitly explained or reconsidered for further work. Also, the report needs to more fully consider battery recycling effects. Recycling is not mentioned in 5.1, so I assumed it was not covered at all. However, it is discussed in 5.3 item 5, but only for lead-acid. There are various citable studies on battery recycling that are relevant and should be more fully utilized.

In 5.1 in the paragraph that starts with "Estimates of emissions . . ." the terminology "power plant capacity" is used. Utilities typically refer to this as generation, as opposed to transmission and distribution capacity. All three capacities may need to be increased for EV use. Further, electromagnetic field emissions are not addressed and should at least be mentioned. A further utility issue is that on page 5-5, in the discussion on Energy Storage, distributed storage technologies are ignored. Also the literature cited is rather dated. I work on a DOE/Office of Utilities Program which is addressing this and other applications for distributed storage. Some of our work may be useful in this study.

Regarding lead-acid batteries, I question the use of 50 Wh/kg on page 8-29, Section 8.3.1. A better number would be 35 Wh/kg. Also, quoting Horizon sales literature (p. 8-30) is inappropriate; independent evaluation data would be more credible. In addition, I strongly question the estimates for lead emissions. The 400% increase cited on p. 5-5, and the almost 1 lb per 1000 lb of finished battery in Table 8.15 need additional justification and should be checked. They seem very high. You may wish to consult with the International Lead Zinc Research Organization (ILZRO) on this issue. Also the cause of lead emissions increase must be clarified - is it due to lead-acid battery use or copper manufacture for EV's in general? Also, on p 8-19, why is it implied that EV's have carburetors? Are hybrid vehicles part of this study?

Finally, I recommend carefully reviewing the number of significant figures used throughout the report. Numbers with more than 2 or 3 significant figures seem inappropriate.

Please contact me if you have any questions regarding my comments.

Sincerely,

Paul C. Butler, Manager
Energy Storage System
Analysis and Development

pcg/PCB

Copy to:
Eric Peterson, DOE
MS-0613, P. C. Butler (1525)
MS-0613, Day File (1525)

VIA FACSIMILE & OVERNIGHT MAIL

September 15, 1997

Margaret Singh
Argonne National Laboratory
955 L'Enfant Plaza S.W.
Suite 6000
Washington, D.C. 20024

Re: **Comments on DOE's Draft Report Titled "*Total Energy Cycle Assessment of the Electric and Conventional Vehicles: An Energy and Environmental Analysis*"**

Dear Ms. Singh:

In response to the above referenced draft report, Western State Petroleum Association (WSPA) offers the following comments. WSPA is a trade association whose member companies engage in the exploration, production, refining, transportation and marketing of petroleum and petroleum products throughout the Western United States. We appreciate the opportunity to comment on Argonne's Electric Vehicle Total Energy Cycle Assessment (EVTECA) and your willingness to extend the comment period while we evaluated your extensive document.

WSPA has coordinated their review of this draft report with the American Petroleum Institute (API). WSPA endorses the API comments in their entirety. WSPA has the following comments based, in part, on its observations of electric vehicles in use in California and the restructuring of the electric power industry in California.

THE STUDY OVER ESTIMATES THE CAPABILITIES OF ELECTRIC VEHICLES

The study assumes that electric vehicles (EVs) will replace conventional vehicles (CVs) on a one for one basis. This is clearly not the way EVs are being marketed, purchased [in practice, leased], or operated. For the following reasons, an EV is suitable as an additional car; not as an replacement for a conventional vehicle:

- Consumers have a long history of buying vehicles that serve almost all of their personal mobility needs, the EV only satisfies a fraction of their needs,
- EV-1 advertising focuses on its use as an additional car for those who already own other vehicles,
- the lessee selection process weeds out those potential lessees whose vehicle use patterns don't match with an EV.

Clearly the most convincing evidence that EVs are not one-for-one replacements of conventional vehicles is GM's experience in the market place leasing the EV-1. Even after they cut the lease

price, GM has been only getting 10-12 new leases a month total for the four metropolitan areas including Los Angeles and Phoenix where the EV-1 is available.

The uncertainties of EV operation and range lead to restricted activity for the vehicle. Many factors can lead to reduced and uncertain range¹:

- hot weather and use of air conditioning
- rainy weather
- unexpected traffic or detours to the normal route
- hills
- lack of attention to careful steady driving with few accelerations and no rapid accelerations
- battery aging or discharge between recharging

Current EVs are clearly a second or third car to supplement, rather than replace, an existing CV one for one. The EV is used for well defined routine trips such as commuting or local errand-running around-town driving; but not for both commuting and local errand-running. Based on the personal experience of an EV-1 operator, the one-for-one assumption is unrealistic. Hence any implications that EVs can perform as assumed in this study must be very highly qualified and identified as very speculative.

In a more logical case, EV use would only displace a portion of the CV mileage. Therefore the emissions for EVs should include those associated with the EV plus all those emissions attributable to the older CV that the EV owner still keeps in service. The purchase of an EV keeps an older CV in service rather than leading to the retirement of an older, higher emission vehicle.

In addition, the study has assumed that EVs, which significantly underperform current gasoline vehicles, would be acceptable and salable in the marketplace. For example, the predicted performance of EVs in MY2000-2002 in the study is 13.0 seconds zero to 60 mph acceleration for two-seater and compact car EVs and 18.0 seconds for minivan and van EVs. Per the EPA [Heavenrich and Hellman August 1996,] gasoline vehicles were averaging 10 and 12 seconds for 2 seaters and compact cars and 13 seconds for vans back in MY1990-1992. Newer cars have continued to improve and future reduce their acceleration times significantly.

THE STUDY MISREPRESENTS THE ELECTRIC POWER INDUSTRY

A wave of restructuring is sweeping the electric power industry in California and throughout the nation. The result of this wave is that electric power will come from the lowest cost power

¹ Note, there is little opportunity to observe the impact of cold weather on EV performance in Southern CA; however, cold weather is likely to be a significant detrimental factor in several of the cities highlighted in the DOE study.

available at the specific hour of need [cost including the cost of transmission;], not necessarily from the local power companies facilities. New high efficiency electric power generation will immediately become the base loaded generating capacity. The marginal power for EV recharging will come from one of the nation's lowest cost power generating sources at the hour of recharging. Thus the power for recharging comes from the least efficient power generator operating; not the most efficient as implied by the analysis of "incremental emissions" in the report. The least efficient power plants have the highest fuel consumption and therefore tend to have the highest NOx and SOx emissions. The report should base its analysis on the "marginal emissions."

The additional power demand for EVs is only a very small portion of the total electric power consumption increase expected in the future. The study's example for Chicago shows 23 new power plants required by 2010; the high EV scenario would add a 24th. To allocate any emissions benefit for base loading the 24th new power plant to any particular segment of demand growth, as is done in the "Incremental Emissions" analysis presented in the study, is misleading.

The experience from California EV operators is consistent with that of EV operators elsewhere; the operator does not plug in the EV to recharge it; but the operator unplugs the EV to drive it. A high proportion of the California EV-1 owners have a recharger at their home and at their place of work. Hence roughly half of the recharging is done during the day; peak hours in many utility systems. Since this coincides with the time of maximum stress on electric power generation, EV recharging will lead to higher emissions than shown for the marginal emissions analysis in this report based on a high portion of off-peak recharging.

THE STUDY HAS OVERESTIMATED EMISSIONS FROM GASOLINE VEHICLES

The study should make it very clear that whereas the projections for the capabilities of EVs are highly speculative conjectures, better conventional gasoline vehicles than those projected in the report (for many years into the future) are currently available and widely marketed.

California Air Resources Board estimates emissions, exhaust plus evaporative, from vehicles meeting California low emission vehicle program LEV standards are about 13 pounds per year of (NMHC + NOx) for the average year of the vehicle's life [10,000 annual miles traveled]. LEV standard vehicles are currently available from several manufacturers in California. One OEM now offers ULEV standard gasoline vehicles that have even lower emissions. The California new car average in MY2000 will have lower emissions than the LEV standard and future year new cars will have even lower emissions. These vehicles, both meeting the LEV and ULEV standard, are being sold outside California as well. The cost premium for such emissions performance is low; at most a couple of hundred dollars per vehicle.

The energy efficiency of EVs assumed in the study is too high. GM's descriptions of the EV-1 imply the power consumption of this small, ultra-aerodynamic, ultra low drag coefficient vehicle will be about 0.20 kWh/mile in the city and 0.15 kWh/mile on the highway. The clear message

of California EV-1 users that they generally get about 55 miles on a maximum battery charge; or about 0.25 kWh/mile. The difference between calculated expectations and real world drivers is large. The study's expectation of power consumption in the range of 0.20 to 0.25 for larger cars and mini-vans is highly speculative and should be so stated.

The marginal emissions for power generation in Chicago in 2010 reported in the study are 7.45 lb NOx/MWh. For recharging an EV with a energy efficiency of 0.25 kWh/mile travelling 10000 miles per year NOx emissions alone are 19 pounds per year! Thus the EV emissions from speculative vehicles in 2010 are higher than those of gasoline vehicles currently available.

SIERRA RESEARCH REVIEW OF DOE EVTECA FOR WSPA AND API

WSPA commissioned the attached report by Sierra Research dated August 20, 1997 to utilize their experience in analysis of both automotive emissions and electric power industry emissions. This work was sponsored by WSPA in behalf of itself and the API. Sierra Research finds:

"the results highlighted in the synopsis of the {DOE EVTECA} report are driven by a series of assumptions that consistently exaggerate the emissions associated with conventional vehicles while underestimating the emissions and energy consumption associated with EV recharging"

WSPA endorses the analysis of the DOE EVTECA and conclusions presented by Sierra Research in their report.

This concludes WSPA's comments. If you have any questions, or require further clarification, please contact me at (916) 498-7756. Thank you for the opportunity to comment on the draft DOE EVTECA report.

Sincerely,

Aeron Arlin
Environmental Coordinator

September 12, 1997

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Sacramento, CA 95814
(916) 444-6666
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Ms. Aeron Arlin
Western States Petroleum Association
1115 11th Street, Suite 150
Sacramento, CA 95814

Dear Ms. Arlin:

This letter describes our limited review of the report "Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Analysis," which was prepared by Argonne National Laboratory, the National Renewable Energy Laboratory, and the Pacific Northwest National Laboratory under funding from the Department of Energy (DOE). The objective of Sierra's review was to provide WSPA and the American Petroleum Institute with a summary of any errors or questionable assumptions we could identify related to the estimates in the report of the effect that electric vehicle (EV) recharging is likely to have on energy use or air emissions. The attachment to this letter describes in some detail the most significant problems we identified. In general, we found that the results highlighted in the synopsis of the report are driven by a series of assumptions that *consistently overstate the emissions associated with conventional vehicles while understating the emissions and energy consumption associated with EV recharging.*

The assumption that most significantly affects the results highlighted in the report involves the use of what is referred to as an "incremental" energy use and emissions analysis. Under this assumption, increased electricity demand caused by EV recharging is assumed to be met through the construction of new powerplants that are substantially more efficient than current powerplants. These new powerplants also have lower emissions per kWh generated than older stations. Since these new power plants are highly efficient, they are base loaded; that is, they are assumed to be used to satisfy *existing* demand for electricity in addition to handling any new demand from EV recharging. Using this same rationale, energy and emissions benefits would be assigned to a strategy encouraging people to *lower* their thermostats during hot weather so that air conditioning systems would run more and *increase* the peak electricity demand. The unstated premise of this calculation approach is that the energy conservation, emissions, and long-term economic benefits of replacing old, inefficient powerplants can only be realized through strategies to increase peak demand. This premise is inappropriate, especially given the deregulation and restructuring now occurring in the electric utility industry, and it results in a misrepresentation of the effect of EVs on energy consumption and emissions.

September 12, 1997

Another major problem with the analysis is that the emissions estimates for gasoline-fueled vehicles are substantially overstated, for two reasons. First, the analysis totally ignores the virtual certainty that vehicles designed to meet the California Low Emission Vehicle (LEV) standards or the more stringent Federal Tier II vehicle standards will be sold in all states, regardless of whether other states adopt the California standards and regardless of whether a National Low Emission Vehicle (NLEV) program is implemented. Under the most likely scenario of a 49-state NLEV program, California LEVs will be the norm. Second, the emissions estimates used in the analysis are based on MOBILE5a. CARB's position is that the emissions projections in MOBILE5a substantially overstate the emissions of late-model gasoline vehicles. There is no valid basis for adjusting MOBILE5a emission estimates upwards based on the CARB LA-92 cycle.

Another problem with the analysis worth highlighting is that all scenarios assume EVs will replace gasoline-fueled vehicles on a one-for-one basis. This is a "best case" assumption that is clearly inconsistent with the typical situation that can be predicted from market research. Relatively few motorists or fleet operators are expected to rely exclusively on EVs. When one or more gasoline-fueled vehicles remain available, they are likely to be used to satisfy travel demand that exceeds the range or carrying capacity of the EV. Because the EV will have been purchased instead of a new gasoline-fueled vehicle, older, higher emission vehicles end up being used to satisfy the travel demand that otherwise would have been provided by a newer, cleaner gasoline-fueled vehicle.

Because of factors such as those summarized above, it is our opinion that the report is based on assumptions reflecting a consistent and substantial bias in favor of EVs. The problems with the assumptions are so severe that the results of the analysis, especially the results highlighted in the synopsis, lead to inaccurate conclusions about any emission differences between the use of gasoline vehicles and electric vehicles. Although it is clear that this report required a huge financial investment and commitment in time and resources by the DOE, the problems with the basic assumptions discussed above make the report unsuitable for making policy decisions such as additional government subsidies for the development of EVs and an EV infrastructure. In our opinion, a detailed review of the report to quantify the effect of correcting erroneous assumptions is needed.

Please refer any questions or comments on our analysis to me or Larry Caretto.

Sincerely,

Thomas C. Austin
Senior Partner

attachment

Comments on:

Total Energy Cycle Assessment of Electric and Conventional Vehicles: An Energy and Environmental Analysis

prepared by:
Sierra Research, Inc.
September 11, 1997

1. The energy and emissions benefits assigned to EVs inappropriately result from the use of new powerplants to satisfy *existing* electricity demand.

The analysis of recharging emissions from powerplants and the fuel used for that recharging is done in three different ways in the report. Each method compares emissions and energy use with and without electric vehicles.

1. *Incremental emissions* are defined as the difference between the total system emissions (or energy use) with electric vehicles in place minus the total system emissions without electric vehicles in place. If electric vehicles required new powerplants, new powerplants that were very efficient (50% efficiency for combined cycle plants) were assumed. Thus, the incremental emissions were the difference between two different utility systems: (1) a currently planned system to meet the utility generation needs for the target year, and (2) an expanded system to meet the planned needs plus the extra generation requirements for electric vehicles.

In the expanded system, the newly added, very efficient units would be used almost continuously because, being the most economical to run, they would be dispatched first. As a result, almost all of the electricity produced by the new powerplants would be used to satisfy base-load demand, which is unrelated to EV recharging. In the analysis based on incremental emissions, electric vehicles were credited with 100% of the reduction in emissions (and energy use) resulting from the use of these new powerplants instead of older powerplants.

2. *Marginal emissions* are defined as the difference between the emissions from the same utility system with and without electric vehicles. In this case, the utility system is expanded to meet the future needs, including electric vehicles. Then the energy use and emissions are compared, for the same utility system, examining only the electricity generation used for electric vehicles.
3. *Average emissions* are simply the average emissions from all units in the utility system. The system considered in this case is the expanded system that meets the planned future needs, including electric vehicles.

The incremental emission and energy results are the only ones presented in the report synopsis and summary chapter. The report authors state their preference for incremental system emissions (ISE) in the utility analysis chapter:

... we believe the focus of the assessment should be placed on the ISE emissions because they most appropriately capture the overall effect of EVs on the emissions of the affected utility systems.

Although this rationale may superficially appear to be appropriate, it is based on the implicit assumption that new, more efficient powerplants will not be available in the absence of increases in peak demand. This assumption is inappropriate, especially given the deregulation and restructuring now occurring in the electric utility industry. Using this same rationale, energy and emissions benefits would be assigned to other strategies resulting in the construction of new, more efficient power generation plants such as encouraging people to *lower* their thermostats during hot weather so that air conditioning systems would run more and *increase* the peak electricity demand. Thus, energy conservation measures would be counterproductive since they would have energy and emissions disbenefits. This leads to two possible conclusions: (1) wasting energy is a good idea, or (2) an analysis using incremental systems emissions is a faulty idea. The latter applies since the energy and emission benefits could have been realized without EVs if new efficient generation capacity were built to replace older equipment.

Besides different measures of emissions and energy use, two possible powerplants are considered in the report: combined cycle (CC), and combustion turbines (CT).^{*} The combined cycle plants were more efficient additions, but they had a higher initial capital cost than the combustion turbines.

The analysis of utility emissions examined the time of day for electric vehicle recharging. Two options were considered: unconstrained recharging, where vehicles were assumed to be recharged upon return home; and off-peak recharging. The combination of different unit additions and different times of day for recharging led to the following scenarios:

1. unconstrained recharging with combined cycle replacement units (UCC),
2. off-peak recharging with combined cycle replacement units (OCC),
3. unconstrained recharging with combustion turbine replacement units (UCT), and
4. off-peak recharging with combustion turbine replacement units (OCT).

The unconstrained recharging option had the highest requirement for new generating capacity. The combination of unconstrained recharging with the efficient combined cycle plants as the replacement units (UCC) provided the greatest advantage claimed for the use of EVs in the report under the incremental systems emission approach. Table 1 presents

^{*}The analysis for Chicago considered an integrated gasification combined cycle (IGCC) unit that Consolidated Edison had included in its resource plan.

the difference in the results for the Houston scenarios shown in Figure S.1 of the DOE report. For comparison, the total energy use for conventional vehicles in this scenario is 6,750 Btu/mile.

Table 1 Comparisons of Total Electric Vehicle Primary Energy Use with Different Options for Recharging and New Generating Units			
Recharging Option	New Units	Symbol	Primary Energy Use (Btu/mile)
Unconstrained	Combined-cycle	UCC	3,913
	Combustion Turbine	UCT	5,756
Off-peak	Combined Cycle	OCC	5,131
	Combustion Turbine	OCT	5,148

The *power generated* for recharging the electric vehicles is the same for all combinations.^{*} However, the *fuel used* to generate this power depends on the scenario considered. In addition, the incremental systems analysis for the unconstrained combined cycle case requires the addition of 171 MW of new generating capacity assumed to have a 50% efficiency. The fuel use for the new utility system with this new CC generating unit and a load for electric vehicles is less than the fuel use for the old utility system without this unit and no load for electric vehicles. Thus, the incremental system emissions analysis erroneously concludes that the recharging of electric vehicles can be done with a negative energy input and negative emissions.

This effect does not occur in the other operating scenarios. When off-peak charging is assumed, almost no additional generating capacity is required and the system emissions do not depend on the type of unit used for the new power. When combustion turbines are used as the replacement power in the unconstrained recharging case, there is no additional combined cycle unit that is dispatched earlier, giving overall lower system emissions.

Depending on the analysis method, the 2010 high EV penetration scenario in Houston with unconstrained vehicle recharging and combined cycle replacement units gives the following results for NO_x emissions due to electric vehicle use:

^{*}There is a difference between the totals reported in the summary tables and the details in the Appendix. The total power generation for electric vehicles for Houston in 2010 (in the high EV scenario) is 849,026 MWh according to Table 2.2; the sum of the power generated for the individual seasons in Tables C.5.7 and C.5.33 is 799,299 MWh. Similarly, the incremental system NO_x emissions for the UCC scenario are reported as -872 tons in Table 2.3 while the sum of the individual season values in Table C.5.7 is -840 tons.

- Incremental systems emission analysis -840 tons/year of NOx
- Marginal system emission analysis 1,169 tons/year of NOx
- Average system emission analysis 954 tons/year of NOx

In this case, the choice of the incremental systems emission analysis had a dramatic effect in understating the NOx emissions impact of electric vehicle use.

2. Emissions from conventional vehicles are substantially overstated.

The report authors correctly note that the current driving cycle used for emission tests is not representative of real-world driving. As a result, it is suggested that the analysis should be based on emissions occurring on the new LA-92 cycle (developed for CARB by Sierra Research). Because there is no well-established set of data that provides emission factors for this driving cycle, the authors started with the emission predictions from the EPA model MOBILE5a and described the procedure they used to adjust the emissions data to the LA-92 cycle as follows:^{**}

Recent emission tests by the California Air Resources Board show that from the FUDS [the current Federal urban driving cycle] to the LA-92 emissions are increased by 12.5% for VOC, by 50% for CO, and by 31.4% for NOx (Gammariello and Long, 1993). These emission differences are used to adjust Mobile5a-estimated FUDS emissions to LA-92 emissions.

Although it was difficult to determine how the authors used LA-92 test results reported by CARB,^{1***} the more significant concern is that CARB work is cited in support of *increasing* the emission factors produced by MOBILE5a when CARB's view is that MOBILE5a substantially overstates the emissions of late-model vehicles. In addition, the emissions for gasoline-fueled vehicles used throughout the report are based on the assumption that so-called "Tier 1" vehicles continue to be sold forever. As shown in Figures 1-3, the combined effect of these assumptions is enormous.

^{*}The DOE report computed the marginal emissions factor, EF_{MSE} (in lb/MWh), for the summer season only. The emission factor for average system emissions, EF_{ASE} , was available for all seasons. The marginal system emissions factor for other seasons was computed as follows:

$$EF_{MSE, season} = EF_{ASE, season} \frac{EF_{MSE, summer}}{EF_{ASE, summer}}$$

^{**}Report page B-90.

^{***}Superscripts denote references provided at the end of this document.

Figure 1

MOBILE5a vs. EMFAC7F Exhaust VOC Emission Rates

Figure 2

MOBILE5a vs. EMFAC7F Exhaust CO Emission Rates

Figure 3

MOBILE5a vs. EMFAC7F Exhaust NOx Emission Rates

Figures 1-3 show MOBILE5a predictions of emissions vs. mileage for passenger cars certified to Tier 1 standards compared to CARB's estimates for both Tier 1 and LEV vehicles using the EMFAC7F model.* As the figures show, MOBILE5a estimates are substantially higher than CARB's estimates for Tier 1 vehicles. The figures also show that substantial emission reductions will be associated with the use of NLEV vehicles. At the 50,000-mile point, MOBILE5a estimates for Tier 1 are higher than CARB's estimates for Low Emission Vehicles by 315% for HC, 193% for CO, and 116% for NOx. Although the authors of the report acknowledged the possibility that more stringent emission standards will apply in the future, they chose not to estimate their effect. As illustrated in Figures 1-3, this had a very large effect on the emissions projected for gasoline-fueled vehicles.

As mentioned previously, the authors further increased the MOBILE5a estimates for Tier 1 vehicles based on CARB's analysis of the difference between emissions on the standard driving cycle and the more representative driving cycle. Although the authors state a rationale for upwardly adjusting the MOBILE5a-based numbers, they completely ignore the fact that new certification requirements, referred to as the Supplemental Federal

*The MOBILE5a values shown in the figures are based on enhanced I/M with non-reformulated gasoline. EMFAC7F values are based on the 1990-1995 California I/M program and non-reformulated gasoline. The 1990-1995 California I/M program (BAR90) uses exhaust measurements at normal idle and high speed (2500 RPM) idle.

Test Procedure (SFTP), will provide substantially improved control of emissions during operation on more representative driving cycles, like the LA-92.

3. The summary results use misleading comparisons of Btu/mile for electric vehicles and conventional vehicles.

Although more meaningful comparisons of energy use appear in the body of the report, the Synopsis (page S-4) contains the following sentences:

The average energy efficiency of EVs (not accounting for electricity generation losses) is about 1150 Btu/mile. This is equivalent to 0.34 kWh/mile or 100 mpg.

One hundred miles per gallon is an impressive figure; it is also a gross misrepresentation of the true energy efficiency of EVs because it completely ignores the energy lost during the generation of the electricity required to recharge the vehicle. Based on results contained in the body of the report, it is clear that the real efficiency is less than 30 mpg equivalent.

4. Electric vehicles cannot replace conventional vehicles on a one-for-one basis as assumed in the DOE report.

The owner of a conventional vehicle purchases a vehicle that meets all of his or her requirements. This includes the ability to use the vehicle for extended trips, even if such trips are made only infrequently. The limited range available for electric vehicles means that they will be used as second cars or for limited fleet applications where daily range is short and daily recharging is available. Thus, the average electric vehicle cannot replace the average conventional vehicle. Owners who purchase electric vehicles as supplemental vehicles will retain their old vehicles for longer trips. When used on such trips, the older vehicles will have higher emissions than a new vehicle that could have been purchased in place of the electric vehicle. In addition, the old vehicle will continue to have evaporative emissions. Such emissions will not be reduced by the purchase of a supplemental electric vehicle.

The DOE report assumed that electric vehicles would replace conventional vehicles that were purchased for low-mileage applications. The annual mileage for these vehicles was determined from data in the Nationwide Personal Transportation Survey (NPTS). The data for the average travel distance per trip, for trips that were 30 miles or less, were used as the average trip length. The DOE report determined the total daily mileage by multiplying the average trip length by the average number of trips per day. However, according to a footnote in Table B.4.8, the average number of trips per day was computed *excluding the vehicles that made no trips*. This would inflate the daily mileage figures used in the report. An inflated estimate of the annual mileage for the electric vehicles would increase the benefits of such vehicles. The DOE report estimated that the electric vehicles were used between 24.4 and 30.0 miles per day, seven days a week, in the various

urban areas considered. Using the report's assumption that vehicles are operated 365 days per year, this corresponds to an annual range of 8,906 to 10,950 miles. By properly accounting for "no-trip" days, the actual annual mileage for vehicles used only for short trips is likely to be much lower. For example, business fleet vehicles used five days per week would accumulate 29% fewer miles.

5. The analysis is based on the inappropriate assumption that electric vehicles have lower aerodynamic drag and lower rolling resistance than conventional vehicles.

The rolling resistance coefficient and aerodynamic drag coefficient assumed for electric vehicles are significantly lower than the values assumed for conventional vehicles. Although some electric vehicles have been designed with very low values for aerodynamic drag and rolling resistance (as compared to a conventional vehicle), these design characteristics have required compromises in the ride, handling, and space efficiency of the vehicles that need to be taken into account. A comparison of electric vehicles and conventional vehicles should, insofar as possible, compare vehicles with similar capabilities and design features such as low rolling resistance tires or aerodynamic body design. This would include interior space for a passenger car and load capacity for a van. This was not done in the DOE report.

In addition, the analysis of vehicle weights uses the following steps to obtain the weight of the electric vehicle: (1) the weight of the conventional vehicle is decreased by 20% to account for the removal of the engine, engine accessories, cooling system, exhaust system, and fuel storage system, and the addition of the motor controller; and (2) weight is added for the battery pack as required to meet the vehicle performance characteristics. The net effect of these two steps is to produce an electric vehicle that is heavier than the initial conventional vehicle. However, no additional weight is added to the electric vehicle to account for any structural changes that might be required by the added weight of the batteries. In addition, there is no discussion of any changes in the vehicle size to maintain the same interior space in the two vehicles that are being compared.

6. The efficiency of electric vehicles assumed in the report is unrealistically high.

Various tables in Appendix B provide the following data for the 2010 compact vehicle with sodium-sulfur batteries:

- Aerodynamic drag coefficient, $C_D = 0.20$
- Rolling friction coefficient, $f_R = 0.0045$
- Drivetrain efficiency = 92.5%

*For 2008-2010, the aerodynamic drag coefficient for an electric vehicle is assumed to be 0.20 as compared to 0.27 for a conventional vehicle; the rolling resistance coefficient is assumed to be 0.0045 for an electric vehicle as compared to 0.007 for a conventional vehicle.

- Motor efficiency = 92.5%
- Battery efficiency = 89%
- Charger efficiency = 90.0%
- Efficiency for transmission and distribution of electric power = 95%
- Efficiency of regenerative braking = 50%
- Battery weight = 803 pounds
- Curb weight without batteries = 2,034 pounds
- Payload weight = 225 pounds
- Total weight, $W = 3,062$ pounds

As discussed above, the aerodynamic drag and rolling resistance assumptions would result in reduced space efficiency and inferior ride and handling compared to conventional vehicles, which biases the results of the analysis. The analysis is further biased by the other assumptions.

The overall efficiency from the wall outlet to the rear wheels is the product of the individual efficiencies, which yield a net efficiency of 68.5% ($92.5\% \times 92.5\% \times 89\% \times 90\%$). With a transmission and distribution efficiency of 95%, the overall efficiency from power generated at the utility to the rear wheels of the electric vehicle is 65.1%. With this efficiency, the power generated by the utility would have to be $1/0.651$, or 1.54 times the tractive energy required at the rear wheels of the vehicle.

Based on a previous Sierra analysis² of EV efficiency, the overall efficiency for an EV using state-of-the-art components and advanced batteries would be 58.3%, which requires power generation to be 1.72 times the tractive energy requirement. Compared to our analysis, the assumptions used in the DOE report reduce the power plant energy demand by 10.5%.

It should also be noted that the analysis in the DOE report ignores the loss of battery charge that occurs during periods of inactivity. Self-discharge of EV batteries combined with the power consumption during periods when the vehicle is parked (e.g., to run a clock, maintain computer memory, etc.) are not insignificant. Based on our preliminary analysis, even if the loss of charge is 1% per day, the net effect is approximately another 10% increase in annual energy consumption.

References

1. Robert T. Gammariello and Jeffery R. Long, "An Emissions Comparison Between the Unified Cycle and the Federal Test Procedure," *The Emissions Inventory: Perception and Reality*, Proceedings of an International Specialty Conference, VIP-38, Air and Waste Management Association, 1994, pp. 535-548.
2. Thomas C. Austin and Laurence S. Caretto, "Powerplant Emissions and Energy Consumption Associated with Electric Vehicle Recharging," 5th CRC On-Road Vehicle Emissions Workshop, April 3, 1995.