Appendix G
Electric Vehicle Workgroup Report

Background[1]

The transportation sector currently produces 39.5 percent of New York State's combustion-based inventory of greenhouse gases (GHGs). The gasoline-fueled light-duty vehicle sector is responsible for the vast majority of those emissions. Plug-in electric vehicles (EVs), plug-in hybrid electric vehicles (PHEV), and fuel cell vehicles (FCVs) powered by hydrogen derived from electrolysis, offer the potential to displace a significant portion of this petroleum consumption by using electricity for all or portions of vehicle trips. If this electricity has a low- or near-zero carbon intensity, the carbon footprint from this segment could be nearly eliminated.

The New York Climate Action Council established five Technical Working Groups representing key sectors of the economy. Each Technical Work Group was tasked with providing technical analysis and developing policy options for GHG reductions in each sector. The GHG reduction potential of electrically powered vehicles will be influenced by the policies developed in three sectors: Transportation and Land Use; Power Supply and Delivery; and Residential, Commercial/Institutional, and Industrial Buildings and Infrastructure. The cross-sector Electric Vehicle Subgroup[2] was established to identify how transitioning to a high penetration of grid-powered vehicles would affect multiple economic sectors and to establish, where possible, a consensus on a comprehensive transition strategy for all sectors.

The Approach

The Cross-Sector subgroup consisted of members from the Transportation and Land Use, Power Supply and Delivery, and Residential, Commercial/Institutional, and Industrial Technical Work Groups. The approach used was: (1) segment the flow of electricity from source to vehicle into five stages; (2) identify the questions and issues in each segment that need to be addressed to achieve significant market penetration of plug-in vehicles with maximum GHG reductions; and (3) research the issues, establish findings, and describe strategies or approaches that address the issues. Where appropriate, the group made an attempt to identify mid- and long-term issues.

In addition to the individual sector perspective and expertise of the Technical Work Group members, the group invited participation and presentations from several outside sources. These included vehicle manufacturers Ford and Tesla and a manufacturer/supplier of charging station infrastructure.

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[1] This report was developed by representatives from the Climate Action Council's Transportation and Land Use (TLU), Power Supply and Delivery (PSD), and Residential Commercial/Institutional, and Industrial (RCI) Technical Working Groups. The report describes cross–sector issues and policies associated with a transition to electric-grid-powered vehicles.

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Summary

General: A top priority should be an in-depth analysis of the coincidental overlays of: EV-charging load profiles; future intermittent and non-dispatchable generation growth in New York State; and projected residential, commercial/institutional, and industrial electrical load growth in the state. The findings in this appendix are based on available analysis as referenced in the report.

Power Supply—Generation

- Through the mid-term (2025), New York State has adequate generation capacity to accommodate the maximum (30 percent) anticipated penetration of EVs and PHEVs.
- "Smart charging" to minimize grid impacts will be necessary.
- New York's current off-peak generation mix provides PHEVs significant GHG reductions, as compared to conventional vehicles. However, to maximize GHG reductions, the transmission grid will need to be near carbon-free.
- Through the mid-term (2025), the state's transmission grid has adequate capacity to accommodate the maximum (30 percent) anticipated penetration of EVs and PHEVs with smart charging.

Distribution

- Near to mid-term: Local distribution (transformer) upgrades are likely to be necessary.
- Longer term: The large number of EVs requiring quick charge may require local storage.
- Business models, policies, and regulatory actions encouraging smart charging and allowing third-party sale of electricity may be necessary.

Infrastructure

- Building codes addressing Level II and Level III charging in new residential and commercial garage construction will significantly reduce costs.
- Building codes that address garaging hydrogen-fueled vehicles should be part of the long-term solution.
- Policies and regulations should encourage the development of a variety of business models for charging/refueling (battery swap, etc.).

Vehicles

- PHEVs, EVs, and FCVs demonstrating acceptable performance are a reality.
- Vehicles deriving their fuel from the electric grid are likely to become a cost-effective means of achieving carbon-free mobility.

- Near term: Incentives will likely be necessary to induce adoption. Gas may need to reach $4/gallon and research and development (R&D) will be needed to improve performance and reduce cost before EVs and PHEVs are economically compelling without incentives.[3]
- Near- and mid-term: Battery vehicles will predominate. The advantages of FCVs having greater range, performance, and quick fill together with lower vehicle cost may compel commercial fleets initially and later private vehicles to invest in localized hydrogen infrastructure based on electrolysis from off-peak carbon-free grid power.

Table G-1. Electric Grid Powered Vehicle—Climate Policy Issues by Category

A Generation	B Transmission	C Distribution	D Infrastructure (Buildings and Facilities)	E Vehicle + End-User
A-1: How much generation is needed to meet the new load? **A-2**: What CO_2e intensity is required to achieve 80 by 50? How do we achieve it? **A-3:** What is the desired load shape for EVs to minimize the carbon intensity of required generation?	**B-1:** Do we have sufficient transmission capacity to meet the new load? **B-2:** Does this new load create any major reliability issues (e.g., stability, thermal, voltage)? **B-3:** Are there transmission-level investments that would reduce the carbon intensity of an EV load?	**C-1:** Do we have sufficient distribution capacity to meet the new load? **C-2:** Does this new load create any major reliability or infrastructure cost issues (e.g., stability, thermal, voltage)? **C-3:** Are there legal, regulatory, or policy actions that could reduce transaction obstacles and accelerate a transition to electrified transportation? **C-4:** Who should pay for any required upgrades? The individual beneficiary or the rate base? **C-5:** Will fast-fill fueling require distribution-scale stationary energy storage (hydrogen or electric)?	**D-1:** What charging infrastructure/ strategy is needed? **D-2:** Are changes necessary in retail electricity rate structures? If so, how should they be changed? **D-3:** What kind of advanced metering is needed? **D-4:** What land-use issues need to be addressed? **D-5:** What kind of consumer education is needed? **D-6:** How do we bring upfront costs down for consumers? **D-7:** What codes and standards need to be created/updated?	**E-1:** What charging technologies are needed (e.g., smart charge)? **E-2:** What battery technologies are most suitable for this application? Are they available and cost-effective? **E-3:** What vehicle platform(s) seems the most viable? Can EVs meet driver needs, or will we need fuel cell or bio-PHEVs to meet range requirements? **E-4:** Who will service these vehicles? **E-5:** What is the rate of advanced low carbon vehicle introduction needed to meet 80 by 50? How do we get more cars "in the pipeline"? **E-6:** How do we bring upfront costs down for consumers? Are incentives required to overcome the high cost of electric vehicles?

80 by 50 = 80percent reduction in carbon from 1990 levels by 2050; CO_2 = carbon dioxide; EV = electric vehicle; PHEV = plug-in electric vehicle.

[3] *Transitions to Alternative Transportation Technologies*, National Academy of Sciences, 2010.

Strategies

A. Power Supply: Generation

A-1 How much new generation is needed?[4]

New York's electric supply is sufficient to meet electric vehicle megawatt (MW) requirements in the near-to-mid-term (2025). According to a National Renewable Energy Laboratory study, "a 50 percent penetration of PHEVs would increase the per capita electricity demand by around 5–10 percent, while increasing total electrical energy consumption (but without requiring additional generation capacity)." However, an increased proportion of low- or zero-carbon generation to displace traditional fossil plants must be brought on line to meet the 80 by 50 goal. This assumes that smart charging will be implemented as grid-fueled vehicle penetration grows. It may be necessary for public policy or rate structures to provide incentives and disincentives to implement adoption.

- Strategy: Near-term and long-term continued support of R&D for renewable technologies, as well as methods to reduce carbon from fossil sources; continued financial incentives/rate structure to encourage low-/zero-carbon generation and off-peak, valley filling charging.

A-2 What electric grid carbon dioxide (CO_2) intensity is required to achieve 80 by 50?[5]

The nation has experienced a significant increase in the carbon intensity of the grid over the past 20 years. Therefore, for the United States to achieve an 80 percent reduction in carbon from 1990 levels by 2050, the country must cut its current rate of 5.8 billion tons CO_2/year to 1 billion tons/year. This equates to approximately a 4 percent reduction each year for the next 40 years.

The carbon intensity of the grid varies significantly as a function of grid load, with off-peak power having the lowest carbon footprint. In New York, the electric grid is responsible on average for approximately 800 pounds (lb) of CO_2 for every MW produced. At this level of intensity, an all-electric car typically produces approximately 0.3 lbs. of CO_2 per mile while a conventional vehicle getting 26 miles per gallon (MPG) produces 0.77 lbs. CO_2 per mile. Therefore, with today's generation mix, an electric vehicle provides on average a 61percent reduction in CO_2. With the current generation mix, New York State would be unable to achieve the 80 by 50 goal, even if elective vehicles were used for all travel. While off-peak power is less carbon intense and "smart (off-peak) charging" has the potential to provide some benefit in the near term, a high percentage of grid-powered vehicles and a near-zero carbon footprint from the electric grid will be required in order to achieve the 80 by 50 goal

- Strategy: (1) Develop technologies (energy storage, smart charging) and policies (EV electric rates) that promote vehicle charging at times when the carbon intensity of the grid is lowest

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[4] EPRI/NYSERDA, *Grid Impact of PHEVs*, 2010; NREL, *An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles*, Oct. 2006; PNNL, *Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids*, 2007.

[5] International Energy Agency, "CO_2 Emissions from Fuel Combustion - Highlights," 2009; U.S. DOE, *Annual Energy Review*, Table 12.2, 2009; CARB, *2050 Greenhouse Gas Emissions Analysis: Staff Modeling in Support of the Zero Emission Vehicle Regulation*, 2009.

(i.e., off-peak). (2) De-carbonize the grid to the greatest extent possible. Achieving more than a 60 percent reduction in vehicle-mile carbon intensity from EVs will require a grid with a much lower carbon footprint.

A-3 What is the desired load shape for EVs to minimize the carbon intensity of required generation?[6]

EV charging should move to off-peak charging. Conversely, charging immediately upon returning home (4-6 p.m.) should generally be avoided, as this could compete with other electrical loads. Furthermore, moving charging to overnight hours would correlate with the production profile of zero-carbon wind resources in New York (as well as base-loaded hydro and nuclear power).

- Strategy: Create an electricity rate structure with incentives for EV owners to charge during off-peak hours, with the highest incentives during overnight hours.

B. Transmission

B-1 Do we have sufficient transmission capacity to meet the new load?[7]

The transmission system will not require added capacity specifically for EV charging because PHEV vehicle adoption is not anticipated to seriously affect generation (MW of supply).

- Strategy: This assumes smart charging and other strategies to shift demand from peak hours. Otherwise, no specific strategy is required, assuming upgrades to the transmission system due to expected load growth outside of EV.

B-2 Does this new load create any major reliability issues (e.g., stability, thermal, voltage)?[8]

System reliability could be reduced as a result of a high utilization scenario, as less reserve capacity is available. With smart charging, reliability issues are not expected. With further advancements in vehicle-to-grid (V2G) technology, it is possible that vehicle storage may provide benefits to transmission system reliability. While it appears that PHEVs are much better suited to support short-term ancillary services, such as regulation and spinning reserve, a large fleet of PHEVs could replace a moderate percentage (perhaps up to 25 percent) of conventional low-capacity-factor (rarely used) generation used for periods of extreme demand or system emergencies. Overall, the ability to schedule both charging and very limited discharging of PHEVs could significantly increase power system utilization.

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[6] NYISO, "Alternate Route: Electrifying the Transportation Sector," June 2009.

[7] KEMA, *Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems*, report for ISO/RTO Council; PNNL, *Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids*, 2007. (Note: KEMA is not an acronym, it is the name of an international testing and certification company.)

[8] PNNL, *Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids*, 2007; NREL, *An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicle*s, Oct. 2006

- Strategy: Adopting "smart charging" systems that recognize grid emergencies could mitigate the extent and severity of these events. Continue R&D into V2G technology. Explore financial incentives for providing grid support.

B-3 Are there transmission-level investments that would reduce the carbon intensity of an EV load?

The issues of vehicle range, fueling infrastructure, and cost will be challenging. Quick-charge (Level III) electric charging may require stationary storage or other upgrades. Range issues can be overcome with FCVs; however, quick-fill public hydrogen infrastructure would require a major investment. A third option, hybrid bio-PHEV, may be the easiest pathway on the vehicle side; however, low-carbon cellulosic ethanol is not yet a proven option.

- Strategy: All of the above options should be developed; all may be needed to meet the variety of duty cycles, first cost versus operating cost constraints, and user needs. In all cases, continuous improvements in vehicle technology will be needed, together with significant long-term infrastructure investment. Public policy should be technology-neutral and, in the near term, focus on low-carbon vehicle incentives, such as feebates for low-carbon vehicles and tax credits and buy-downs for fueling infrastructure.

C. Distribution

C-1 Do we have sufficient distribution capacity to meet the new load?[9]

To achieve the penetration rates required by the 80 by 50 target, some distribution system upgrades will undoubtedly be needed. Because of clustering and a slower penetration rate of pure battery versus PHEV, current analysis indicates that upgrades involving distribution transformers and customer service – not primary feeders or transformers – will be needed at a local level. Impacts can vary greatly from system to system. Some distribution systems have a ratio of customers to service transformers as low as 2 to 1, while others, such as Rochester Gas and Electric, have ratios of 9 to 1. This will result in different impacts on the distribution systems in different distribution systems. In systems that are largely underground, there is some potential for underground cables and transformers to have inadequate cool-down periods at night, should significant load be shifted to off-peak nighttime periods on feeders that are highly loaded during the day. So, although the load growth rate is generally expected to be within the normal bounds of planning activities and load growth, there will be situations requiring special consideration and study.

- Strategies: Smart charging, load shifting, and stationary storage all have the potential to mitigate most of the anticipated problems for the next decade.

[9] EPRI/NYSERDA, *Analysis of Grid Impact of PHEVs in New York State,* 2010; Quanta Technology, "Thoughts and Opinions on the Impact of Plug-in Hybrid Electric Vehicles," 2008.

C-2 Does this new load create any major reliability or infrastructure cost issues (e.g., stability, thermal, voltage)?

As noted in B-2, (transmission), distribution reliability issues are not expected with smart charging. With further advancements in V2G technology, it is possible that vehicle storage may actually provide benefits to distribution system reliability.

- Strategies: Financial incentives for desired market transformation and disincentives for unwanted behavior will be necessary to accelerate low-carbon vehicle market penetration. Infrastructure investment will also be a necessary element and may require adjustments in public policy and public investment.

C-3 Are there legal, regulatory, or policy actions that could reduce transaction obstacles and accelerate a transition to electrified transportation?

- Strategy: Consider revised tariffs in New York that would allow charging infrastructure providers to resell the electricity they purchase from utilities.

C-4 Who should pay for any required upgrades? The individual beneficiary or the rate base?

It could be argued that the advent of PHEVs is similar to the widespread adoption of air conditioning in the 1960s. The utilities incorporated this new load as a part of their normal planning process, and the cost was added to the rate base.

- Strategy: Costs should not be borne by individual customers. A preferred alternative is to use revenue derived from a broader base to cover the cost of upgrades specific to the supply of electricity for plug-in vehicle charging.

C-5 Will fast-fill fueling require distribution-scale stationary energy storage (hydrogen or electric)?

- Strategy: Since fast-fill charging is likely to be required by a user at a time other than off-peak hours, purchase of the stationary electrical storage may be necessary to minimize negative grid impacts and allow the utilization of excess renewable electricity generated in off-peak times.

D. Infrastructure (Buildings and Facilities)

D-1 What charging infrastructure/strategy is needed?

It seems generally accepted (and reinforced with surveys, PlaNYC, Electric Power Research Institute, etc.) that the most important locations for charging infrastructure are those facilities where vehicles are parked routinely for extended periods, such as home garages or places of work. New business models together with communication and transaction protocols will need to be standardized to allow smart charging that benefits the grid and consumer.

There are potential legal and regulatory barriers or policy choices related to the introduction of electric vehicle charging facilities on private premises and for public use. Under current New York law, all sellers of electricity to end users are electric corporations subject to Public Service Commission (PSC) regulation over rates and practices. New York has three overall options: (1) New York state could exercise this jurisdiction to set prices for EV charging that encourage electric car consumption and ensure off-peak charging to minimize grid impact (the Michigan approach); (2) the state could lightly regulate or forbear from regulating EV charging, to encourage new entrants and competition (the California approach); or (3) the state could amend its laws to deregulate entirely the sale of electricity as a motor vehicle fuel (to open the EV charging market completely, without any governmental oversight as to price and conditions, while safety and reliability restrictions would remain). Each approach has its own advantages, costs, and risks, and the policy and legal discussion is ongoing.

- Strategies: *First priority:* Standardize physical interconnections (plugs, voltages, etc.) and communications protocols. *Second priority:* Pursue public policy and regulatory actions that support the development of business models that allow the sale of electricity by third parties (non-utility), aggregation of loads for business transactions, private and public investment in publicly accessible vehicle charging, and development and deployment of standardized quick-charge (Level III) technology.

D-2 Are changes necessary in retail electricity rate structures? If so, how should they be changed?[10]

California's Public Utilities Commission has established special rates for EV charging and off-peak use. Remote-controlled charging could also occur by allowing customers to charge their vehicles at any location and be billed for the energy at a rate determined by the location of the vehicle, rather than at a residential rate.

- Strategy: Establish EV electric rates that encourage vehicle charging load growth that is consistent with minimized negative impact on the grid and that provides positive economic incentives to consumers. PHEV-specific dynamic pricing may be one way to introduce dynamic pricing to consumers while minimizing adverse customer reaction with regard to existing retail loads.

D-3 What kind of advanced metering is needed?

Using advanced meters, vehicle charging would be one of several home energy uses that could be managed through automation. Even simple time-of-use residential meters could provide customers with the incentive and the ability to manage their energy use for charging PHEVs.

- Strategy: Advanced metering will be required to enable consumers to benefit from favorable electric rate structures. Utility specifications and business models will determine meter specifications. PSC tariffs allowing rate-base recovery of additional costs specific to EV charging as opposed to unique customer cost may be helpful.

D-4 What land use issues need to be addressed?

- Strategy: Provide preferential parking, high-occupancy vehicle lanes, and lower tolls for low-carbon vehicles.

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[10] KEMA, *Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems*, report for ISO/RTO Council.

D-5 What kind of consumer education is needed?

- Strategy: Produce television, newspaper, and web site information for consumers similar to the current New York State Energy Research and Development Authority media campaign promoting change-out of incandescent lighting to compact fluorescent lamps.

D-6 How do we bring upfront costs down for consumers?

- Strategy: See D-2 and D-3.

D-7 What codes and standards need to be created/updated?

Vehicle charging communications has received some support from automakers because it could allow for a single industry standard for recharging mechanisms to meet the needs of the electric utility system. Automakers would prefer to see a single vehicle standard that could be universally implemented, as opposed to a patchwork of standards and technologies across state boundaries or utility service territories.

The addition of Level II charging infrastructure to an existing building can typically cost $3,000, which can be an impediment to sales. When charging infrastructure is incorporated in new construction, the cost is $300.

- Strategy: Develop standards that are compatible with smart-grid/smart-charging Level III and building codes that require conforming circuitry in both residential and commercial new garage construction. This will enable lower-cost market penetration and safer/more reliable service. Policy and regulations should encourage standardization of vehicle charging interfaces at the regulated utility level and with vehicle manufacturers.

E. Vehicle (End User) Strategies[11]

E-1 What charging technologies are needed (e.g., smart charge)?

Smart charging will be needed as grid-fueled vehicle penetration grows. Shifting the vehicle charging load to off-peak time may be the biggest long-term issue. It may be necessary for public policy or rate structures to provide incentives and disincentives to implement adoption. Society of Automotive Engineers and Institute of Electrical and Electronics Engineers standards are under development, and there are several technical approaches that will enable vehicle-grid-building communication and smart charging. Energy storage technology will likely be necessary to mitigate large quantities of on-peak or fast-charging use in the future.

- Strategy: *Near term:* Encourage demonstrations of technical options, monitor performance, and explore behavioral influences of rate structures and public policy. *Long term:* Enact appropriate rate adjustments and incentives to mitigate grid problems, and conduct R&D of

[11] National Academy of Sciences, *Transitions to Alternative Transportation Technologies—Plug-in Hybrid Electric Vehicles*, 2009; The Electrification Coalition, *Electrification Roadmap*, 2009 (200 million EVs by 2050); CARB, *2050 Greenhouse Gas Emissions Analysis: Staff Modeling in Support of the Zero Emission Vehicle Regulation*, 2009; David L. Greene *and* Andreas Schafer, *Reducing Greenhouse Gas Emissions from U.S. Transportation*, prepared for Pew Center on Global Climate Change, 2003.

energy storage technologies that can utilize large quantities of excess power generated from renewable sources and baseload nuclear power (which are difficult to turn down) for on-demand and Level III quick-charge vehicle charging.

E-2 What battery technologies are most suitable for this application? Are they available and cost-effective?

Continued advances are required in battery technology and manufacturing. Significant cost reductions will be required to allow grid-charged vehicles to compete with petroleum at anything less than $4/gallon. This may be difficult with lithium-ion technology, because of the currently low labor costs and as-of-yet undetermined sources of cheaper materials.

- Strategy: Continue R&D into the next generation of battery chemistry and explore innovative business models (battery leasing, battery change out, etc.).

E-3 What vehicle platform(s) seems the most viable? Can EVs meet driver needs, or will we need fuel cell or bio-PHEVs to meet range requirements?

The issues of vehicle range, fueling infrastructure, and cost will be challenging. Quick-charge (Level III) electric charging may require stationary storage or other upgrades. Range issues can be overcome with FCVs. However, quick fill public hydrogen infrastructure would require a major investment. Hydrogen only provides significant GHG benefits over conventional hybrids when the hydrogen is produced through electrolysis or via thermo-nuclear means. Therefore, hydrogen is a long-term option that can provide benefits if and when there is adequate (or an excess of) zero-carbon electricity. A third option, hybrid bio-PHEV, may be the easiest pathway on the vehicle side. However, low-carbon cellulosic ethanol is not a proven option.

- Strategies: None of the above options should be abandoned. All may be needed to meet the variety of duty cycles, first cost versus operating cost constraints, and user needs. In all cases, continuous improvements in vehicle technology will be needed together with significant long-term infrastructure investment. Public policy should be technology-neutral and in the near term should focus on low-carbon vehicle incentives, such as feebates for low-carbon vehicles, a low-carbon fuel standard and tax credits, and buy-downs for fueling infrastructure.

E-4 Who will service these vehicles?

- Strategies: To build the skilled workforce needed, adopt public policy and financial support for educational and workforce development programs at community colleges and the Board of Cooperative Education Services and other publicly supported schools and provide tuition assistance for these programs.

E-5 What is the rate of advanced low-carbon vehicle introduction needed to meet 80 by 50? How do we get more cars "in the pipeline"?

Over 90 percent of vehicle miles are traveled with vehicles less than 15 years old. Therefore, to achieve a near total transition to low-carbon travel by 2050, nearly all vehicles sold after 2030 would need to be low carbon.

- Strategies: Offer financial incentives for desired market transformation and disincentives for unwanted behavior to accelerate low-carbon vehicle market penetration. Fund infrastructure investments, which may require adjustments in public policy and public investment.

E-6 How do we bring upfront costs down for consumers? Are incentives required to overcome the high cost of electric vehicles?

- Strategy: Manufacturer competition may be the most cost-effective way to reduce vehicle cost, with battery manufacturing capacity and supply-demand being dominant factors. A robust market can be encouraged through incentives, adequate charging infrastructure, and education. A low-carbon fuel standard, vehicle purchase feebate, or other carbon pricing mechanism will be needed for EVs/PHEVs to be economically competitive in the near term.