NEW APPLICATION

0000109132

BEFORE THE ARIZONA CORPORATION COMMISSION

COMMISSIONERS

KRISTIN K. MAYES, Chairman
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E-01345A-10-0123

IN THE MATTER OF THE ARIZONA PUBLIC SERVICE COMPANY'S ELECTRIC VEHICLE FILING	DOCKET NO. E-01345A-10-_____ **NOTICE OF FILING**

With this filing, Arizona Public Service Company ("APS" or "Company") is providing a vehicle-to-grid feasibility and cost benefit study, in compliance with Arizona Corporation Commission Decision No. 71104.[1] In addition, the Company is providing an overview of its Electric Vehicle Readiness Development Program ("EV Readiness Program"), which outlines the approach that APS is undertaking to effectively prepare its customers and service territory for the availability of electric vehicles in the coming decade.

I. BACKGROUND

There has been much discussion regarding the potential of plug-in hybrid electric vehicles and other electric vehicles, including whether they will take a significant share of the automobile markets in the future, and their impact on air emissions. Development of these vehicles is currently underway, and many car manufacturers have plans to roll out electric vehicles in the future.[2]

The arrival of electric vehicles in Arizona is expected on a limited basis in the near future. In 2011, more than 1,000 Nissan LEAF electric vehicles may be available to Arizona consumers. Because these vehicles are fueled with electric power, the batteries will have to be recharged on a regular basis. Equipment for recharging vehicles at home, as well as in

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[1] Issued June 5, 2009.

[2] For a more detailed discussion, *see* APS Demand Response & Load Management Program Study at 51-54. The study was filed in Docket No. E-01345A-05-0816 (June 27, 2008) in compliance with Decision No. 69663.

public and commercial locations, will need to be installed to service these vehicles. Publically available charging stations, which will be selling electricity, pose policy questions in Arizona because of the constitutional issues related to public service corporations.

Also being discussed is the potential for electric vehicles to redeliver energy stored in these vehicles' batteries to provide consumers another option to power their homes and buildings. In the future, "vehicle-to-building" applications may provide a tool for consumers to better manage the cost of supplying energy to their homes and businesses from electric vehicle batteries during peak periods, and recharging the batteries during off-peak hours.

Another potential application in the more distant future is vehicle-to-grid ("V2G"). The two-way plug capability of electric vehicles may allow a utility to take advantage of the extra electrical storage capacity in the vehicle batteries to meet peak demand, provide grid support services, or respond to power outages. During periods where utilities face high power prices, it may be economical to pay commuters to plug their vehicles in while at work, and allow the utility to draw from their batteries during peak demand periods.

The United States Department of Energy ("DOE") has set ambitious targets for future research and development of electric vehicles. In August 2009, President Obama announced $2.4 billion in grants associated with electric vehicles and batteries. One of those grants provided $100 million to Electric Transportation Engineering Corporation ("eTec") of Arizona in partnership with Nissan to deploy approximately 4,700 LEAF electric vehicles and more than 10,000 chargers in five states, including Arizona, beginning in 2010. In addition, government and industry have planned advanced battery technology research activities.

Developing codes and standards for electric vehicles and charging facilities is underway. The Federal Energy Regulatory Commission ("FERC") has published a smart grid policy and action plan that includes specific codes, standards, and regulations for smart charging.[3] Ultimately, FERC expects that the smart grid will provide a wide array of advanced options for electric vehicle interaction with the grid. Eventually the demand for

[3] FERC, *Smart Grid Policy*, March 19, 2009, Docket No. PL09-4-000.

ancillary services from grid-connected electric vehicles will require electrical interconnection issues to be resolved and communications ability to be expanded.

II. THE ELECTRIC VEHICLE STUDY: KEY FINDINGS

In September 2009, APS retained Navigant Consulting, Inc. ("Navigant") to assess the likely adoption and impact of plug-in hybrid electric vehicles and other electric vehicles, including the potential of these vehicles to provide V2G energy services.[4] As part of this study, Navigant assessed the current and likely future state of electric vehicle technology, costs, and performance. Navigant also surveyed potential V2G energy storage approaches and current market barriers, and assessed the likely adoption of V2G and its impacts on the APS electric system. Navigant finalized its comprehensive *PHEV/EV and V2G Impacts and Valuation Study* ("EV Study") in March 2010. The EV Study is attached as Exhibit A.

Key findings from the EV Study include:

- Given the current trajectory of electric vehicle development, market penetration is likely to be gradual, especially within the next 15 years. Electric vehicles are likely to comprise about 2% of motor vehicle sales in the APS service territory by 2018. After 2025, sales are expected to increase significantly, and by 2035, electric vehicles could account for about 17% of sales, assuming that battery performance improves and costs decline.
- The initial costs of electric vehicles are expected to exceed the cost of conventional vehicles. In 2012, a plug-in hybrid electric vehicle with a 25-mile range is expected to cost approximately $10,000 more than a conventional vehicle, and an electric vehicle with a 100-mile range is expected to cost approximately $20,000 more, although federal and state tax credits of $5,800 and $7,500 respectively, will help offset a significant portion of these incremental costs. Tax credits will be key to customer economics in the short-

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[4] Plug-in electric vehicles operate as an electric-only vehicle for a limited range, and can switch to a conventional fuel when the battery charge declines. Many electric vehicles run exclusively on stored energy.

term, making the permanence of these credits an important determinant of the early success and customer adoption of electric vehicles.

- Current battery technology is limited and expensive, although a number of promising battery technologies are being developed. For electric vehicles to gain a significant share of vehicle sales, battery cost must decline and battery performance must improve.
- While the initial adoption rate of electric vehicles may be modest, investments in the utility's distribution system may be required in the near-term, where multiple electric vehicles may be on a single transformer or local line.[5] Feeder and substation transformer impacts are likely to occur as penetration grows.
- Impacts to system peak are expected to be small, even in 2035. Generation and transmission should require little investment because it is expected that customers will charge vehicles at night to take advantage of much lower off-peak electricity rates. In the APS service territory, electric vehicle charging is forecast to add only 6 – 15 megawatts to the APS load by 2015. This could increase to as much as 87 – 143 megawatts by 2025, and to 1,000 – 1,400 megawatts by 2035.
- The provision of electricity to the grid from electric vehicles is not likely to be viable or effective until 2025 and beyond. Near-term opportunities to use vehicles as storage devices to re-deliver electricity back to the electric grid are constrained by the numerous technological and developmental challenges, including a variety of code, standard and regulatory issues. One of the key hurdles is current battery technology; today's batteries do not readily support re-injecting power back into the grid, and using a battery for V2G services shortens its life cycle and degrades its performance. In fact, manufacturer

[5] Electric vehicles are expected to "cluster" in certain areas – a phenomenon seen today with hybrid vehicles and distributed solar generation. Because one vehicle can draw as much as 6.6 kilowatts in a residential setting, or roughly the equivalent of a typical 1,200 – 1,500 square foot home in metropolitan Phoenix, adding multiple vehicles on a single residential transformer may necessitate an upgrade.

warranties prohibit the discharge of batteries for vehicle-to-building and V2G purposes at this time. These limitations and the expected slow rate of electric vehicle market penetration make V2G uncertain as a meaningful source of power for the foreseeable future.

III. APS'S ELECTRIC VEHICLE READINESS DEVELOPMENT PROGRAM

APS is developing a comprehensive strategy to effectively prepare its customers and service territory for the availability of electric vehicles in the coming decade. There are a myriad of issues that will need to be addressed as the nascent technology develops into significant market share.

Based on the EV Study, APS believes that the impact of technology will develop in stages. In the earliest stage — and as early as 2011 for Arizona — electric vehicles will be introduced to consumers. While electric vehicles are likely to comprise only about 2% of motor vehicle sales in the APS service territory by 2018, there will be significant issues that must be considered as electric vehicles are developed and commercialized. Where will electric vehicle drivers recharge their batteries? How will they pay for electricity needed to recharge away from home? How will they be encouraged to charge their electric vehicles at night when demand on the electric system is low? Are APS's and the customers' local electric circuits of sufficient size to handle the additional load?

To support the development and acceptance of electric vehicles, it will be important to raise public awareness of their benefits, as well as to shape how electric vehicles will interface with the individual utility's electric system and the nation's power grid. In the near-term, APS is focusing its efforts on both of these primary areas.

APS does not expect that electric vehicles will provide a meaningful source of power to its electric system in the near future. V2G technologies, including battery technology, are currently in the research and development phase. V2G services are not forecast to be economical for customers or utilities, and significant net benefit from providing V2G services will not be realized until battery technology with improved performance is developed. This is critical in the desert climate, where the extreme heat poses substantial battery life challenges.

To address the near-term and long-range issues related to the development and implementation of electric vehicles and their impact on the electric system, APS has developed a multi-phased EV Readiness Program. This approach, which is outlined below, provides an effective means to focus on the many immediate issues while planning for a future when electric vehicles will have a more significant presence in the market.

A. Phase One

The initial phase of the Company's EV Readiness Program, which involves collaborating with the industry and stakeholders to address issues related to the implementation of electric vehicles and their impact on the electric grid, is currently underway. In fact, APS has a long history of working on the evolution of electric vehicles, including providing one of four test sites in the world to prepare the market for the first mass-produced electric vehicle, the General Motors EV 1.

The EV Study was a key component of Phase One; its purpose was to provide the research necessary for APS to develop a reasoned approach to the new technology. In addition, APS has partnered with eTec, the company that is developing electric vehicle infrastructure in Arizona. APS participates in eTec's Utility Stakeholder Group and their Phoenix Area Stakeholder Advisory Panel. APS is working together with these groups to develop electric vehicle infrastructure deployment guidelines, to educate stakeholders on infrastructure requirements, to develop a ten-year plan, and to develop a road map with specific locations for potential infrastructure.

APS is also engaged in discussions with multiple industry and trade associations to evaluate issues that must be resolved before wide-spread adoption of electric vehicles will occur. APS is working with the Edison Electric Institute, the Electric Drive Transportation Association, the Electric Power Research Institute, and the Department of Energy on these issues. APS has participated in the Utility Standards Board's efforts for developing payment and settlement options for electric vehicles. The Company is monitoring electric vehicle and infrastructure research and demonstrations, such as those currently underway with Southern California Edison, Pacific Gas and Electric, Duke Energy, Progress Energy, DTE Energy and

Southern Company. APS continues to examine the progress of car manufacturers in bringing electric vehicles to market, such as the Nissan LEAF and General Motor's Chevy Volt.

B. Phase Two

It is clear that APS must address several key topics in a proactive manner to effectively integrate electric vehicles. To that end, APS intends to engage key stakeholders during the summer of 2010 for assistance in vetting these concerns. The Company will be seeking stakeholder feedback on the following focus areas:

- **Impacts to the distribution system and future planning efforts**. What is the best strategy for managing concentrated deployments where multiple electric vehicles may be located on a single transformer or line? What impact will electric vehicle deployment have on feeder and substation components? What are the appropriate standardization requirements for chargers? Should the requirements be varied, depending on the chargers' location, such as residential, commercial, business or parking garages?
- **Review of electric rates for vehicle charging**. Do the current APS Time-of-Use rates adequately encourage off-peak charging? Should there be a special electric vehicle rate? If so, what is the best approach for developing an electric vehicle rate schedule to encourage charging of vehicles during off-peak hours? Should non-residential charging stations have special rates?
- **Demand response nexus — smart charging protocols**. What protocols and procedures must be developed to manage off-peak charging and to avoid the creation of a new peak period when numerous customers plug-in their vehicles to charge at the same time? What is the potential for vehicle-to-building inter-operability? What are the critical paths for national standards and technology availability?
- **Ownership of charging stations**. Are nationwide requirements necessary for consistency among charging stations across the country and the different entities (such as utilities, municipalities, third parties) that may own and

operate them? What are the implications of the different ownership options and approaches? How does a customer conveniently charge an electric vehicle at different charging stations owned by different entities? In other words, how does billing work for a customer who lives in one utility's service territory, but works and recharges in another utility's service territory?

- **Potential customer incentives for electric vehicle ownership**. What role should utilities play in the roll-out of electric vehicles? To encourage adoption and development of the infrastructure, should utilities provide financial incentives to owners of electric vehicles?

C. Phase Three

Taking into consideration the input from stakeholders as well as the developments in electric vehicle and battery technologies, APS will develop an appropriate EV program that is cost-effective and benefits both customers and the APS electric system. The Company plans on bringing that program to the Commission for approval during third quarter 2010. Because of the relatively long lead-time for wide-scale adoption forecast in the EV Study, APS is confident that there is adequate time to develop a comprehensive approach aimed at a successful integration of electric vehicles into society at large.

IV. POLICY CONSIDERATIONS

There are a variety of regulatory issues that will need to be addressed over time as electric vehicles become more integrated into the market. With the deployment of electric vehicles, a charging infrastructure will become essential, and electric utilities will have an important role in establishing that infrastructure, both as the provider and the distributor of electricity.

Publically-available charging stations, where electric vehicle drivers can refuel (much like a gas station for conventional vehicles) pose regulatory issues because these stations will be selling electricity. In Arizona, the regulatory question would be whether a charging station owned by a private third party, rather than a regulated electric utility, would be considered a public service corporation, as defined in the Arizona constitution.[6] Therefore, the Commission will be faced with determining whether these charging station providers satisfy the literal and textual definition of a public service corporation under the Arizona Constitution.

Other regulatory considerations include: the potential development of special time-of-use rates that will encourage charging during off-peak times; vehicle "roaming" (traveling outside the home-utility's service territory) and the billing and settlement process associated with the out-of-home area charges; and the allocation of costs associated with providing customers with in-home charging infrastructure.

V. CONCLUSION

Electric vehicles are making their entry into the marketplace. As with most new technologies, numerous development, implementation and regulatory challenges must be addressed. Issues related to electric vehicles are currently being discussed across the United States with no clear and consistent conclusions. APS believes that it is well positioned to take a leadership role as electric vehicles are developed and commercialized. The Company is committed to working closely with the Commission, the industry and stakeholders to assure that the necessary infrastructure is available to provide reliable service for this new technology.

RESPECTFULLY SUBMITTED this 1st day of April, 2010.

By: Deborah R. Scott
Deborah R. Scott
Linda J. Benally
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[6] "[a]ll corporations … engaged in furnishing … electricity for fuel, light or power." ARIZ.CONST.Art. 15 § 2.

ORIGINAL and thirteen (13) copies of the foregoing filed this 1st day of April, 2010, with:

Docket Control
ARIZONA CORPORATION COMMISSION
1200 West Washington Street
Phoenix, Arizona 85007

Stephanie Little
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EXHIBIT A

Exhibit A

NAVIGANT
CONSULTING

PHEV/EV AND V2G IMPACTS AND VALUATION STUDY

Presented to

Arizona Public Service Company

March 10, 2010

Presented by

Navigant Consulting, Inc.
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Exhibit A

NAVIGANT CONSULTING

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Executive Summary

Plug-in hybrid electric vehicles (PHEV) and other electric vehicles (EV) may be on the verge of taking a significant share of the automobile market, as many see them as a possible strategy to reduce urban air pollution, greenhouse gas emissions and fossil fuel dependence. Arizona Public Service (APS) asked Navigant Consulting, Inc. (NCI) to assess the potential for the emergence of a PHEV/EV fleet, and how it might affect utilities in general and APS in particular.

To develop its analysis, NCI reviewed the full spectrum of PHEV/EV technologies and key market drivers. These include: vehicle characteristics, initial cost premiums, operating efficiency and costs, and emission rates; current and future battery performance and costs; charger issues, such as the status of electrical codes and standard charger power levels; and government incentives and actions, such as federal tax credits and low/zero emission vehicle regulations. NCI applied these considerations across a variety of potential applications, including residential, light duty vehicle fleet, and large vehicle commercial use. NCI also examined the potential for using PHEV/EV as energy storage devices to redeliver energy in vehicle-to-grid (V2G) or vehicle-to-building (V2B) applications.

Some PHEV/EV proponents believe that a market shift from combustion-engine vehicles to PHEV/EV would yield substantial benefits, including reduced vehicle-generated air emissions in urban areas, and the ability to provide V2G and V2B applications at highly competitive prices which would save money for consumers and reduce capital investments by utilities. While the imminence of these benefits may be debated, the issue is not whether the technology is ready today; it is whether the technology will improve and be sufficiently scalable within 10 years to provide the anticipated benefits to the power grid.

PHEV/EV products are not yet viable enough to impact overall vehicle sales. However, the Federal government has taken actions to encourage the market. For example, the U.S. Department of Energy (DOE) has set ambitious performance and cost targets for EV-related technologies. Also, the American Recovery and Reinvestment Act of 2009 (ARRA) provides a large tax credit for vehicle battery purchase. If DOE's targets are achieved, ARRA is likely to motivate more people to adopt PHEV/EV technologies. NCI is cautiously optimistic that as technology evolves and significant investments are made by private industry and the Federal government, battery performance will improve and costs will decline, and PHEV/EV will make inroads into a variety of residential, fleet, and heavy commercial applications.

Among the numerous battery technologies being developed, lithium ion (LI-ion) holds the most promise. However, for PHEV/EV to gain a significant share of vehicle sales, battery costs, irrespective of the technology used, must decline, and battery performance—especially deep discharge cycle and calendar life performance in batteries suited for the Arizona climate and the climate of cities like Phoenix—must improve.

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Given the current trajectory of PHEV/EV development, market penetration is likely to be gradual, especially within the next 15 years. According to the U.S. Energy Information Agency's 2009 Annual Energy Outlook, nationwide electricity use for light-duty vehicles will grow from 190,000 MWh in 2009 to more than 6.4 million MWh in 2030 – increasing very little until 2025, when it ramps up sharply, yielding an annual growth rate over the entire period of about 18 percent. PHEV/EV are likely to comprise about 2 percent of motor vehicles sales in the APS service territory by 2018. After 2025, however, sales are expected to increase substantially, and by 2035, PHEV/EV could account for about 17 percent of sales, assuming that battery performance improves and costs decline as most analysts expect. Within APS service territory, NCI projects sales of about 29,000 EV and about 12,000 PHEV in 2035, for a total PHEV/EV population of about 174,000. This level of market penetration would save about 148 million gallons of conventional motor fuels annually.

Adoption rates will be affected by the initial cost of PHEV/EV vehicles, which is expected to exceed the initial cost of conventional vehicles through 2035, even with the tax credits discussed below. On the other hand, equivalent operating costs will be less than those of conventional vehicles, provided battery cycle life improves. As initial costs decline, the operating cost savings will begin to outweigh initial costs and customer acceptance is likely to increase.

PHEV/EV will be slow to penetrate the market due to the pace of technology improvements and the relative cost premium. By 2012, NCI expects a PHEV automobile or light truck with a 25 mile range to cost about $10,400 more per vehicle than an equivalent conventional vehicle. An EV automobile or light truck with a 100 mile range is expected to cost $20,900 more than an equivalent conventional vehicle. These costs will be partially offset by State and Federal tax incentives, including a $2,500 to $15,000 Federal battery tax credit for the first 200,000 PHEV/EV sold by each manufacturer nationwide, and a Federal charging infrastructure tax credit (that expires at the end of 2010) for 50 percent of the cost of PHEV/EV fleet charging equipment (up to $50,000) or $2,000 per residence. NCI bases its initial cost projections on assumptions of production-scale vehicle battery costs of $500 to $750/kWh, declining at six percent annually thereafter, and a deep discharge cycle robustness that allows a 10 year service life.

Our simulations indicate that tax credits are critical to customer economics in the short term, and thus the permanence of these credits will be an important determinant of the early success and adoption rates of PHEV/EV technology. Low/Zero Emission Vehicle (LEV/ZEV) regulations may also influence PHEV/EV adoption as some customers purchase PHEV/EV to help meet LEV/ZEV targets.

The assumptions driving these market adoption expectations include not only dozens of State and Federal incentives but, more importantly, the future prices of electricity and motor fuels. These prices are especially difficult to predict; therefore all long-term predictions and forecasts, including the ones in this report, are subject to high levels of uncertainty.

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While the initial adoption rate for PHEV/EV may be modest, it will require new investments in the local distribution system, where multiple PHEV/EV may be on a single transformer or local line. Broad adoption of faster chargers (Level 2 and 3 chargers) could increase these impacts. Feeder and substation transformer impacts are likely to occur only in later years, as penetration grows. Generation and transmission will require little if any investment, even in 2035, since most customers will charge their vehicles at night to take advantage of much lower off-peak electricity rates. In 2015, PHEV/EV charging is forecast to add only 6-15 MW of load. This will increase to as much as 87- 143 MW by 2025, and to 1,000-1,400 MW by 2035. These off-peak demands are relatively small compared to the APS system peak.

The case for vehicle to grid (V2G) services, which for purposes of this report consist of utility customers selling vehicle-stored power back to the grid, is less optimistic than the case for PHEV/EV market penetration. V2G is currently at the research and pilot stage, and none of the V2G concepts reviewed are at present commercially viable. Most pilot programs involve just a few vehicles, and some programs labeled "V2G" merely replicate functionality that is already offered by APS in its time-of-use rates. Since time-of-use rates push most vehicle charging into off-peak hours, the opportunities to apply traditional load management programs to reduce on-peak demand are limited.

Near-term opportunities to use vehicles as storage devices to redeliver electricity back to the grid are constrained by three factors. First, the utility must invest in preparing its system for V2G, including installing a considerable amount of equipment such as discharge ports, and resolve a variety of code, standard, and regulatory issues, such as the resale of electricity by non-utilities, cost allocation, possible special tariffs, and roaming charges. The problems presented by this are compounded because industry and government are still discussing the appropriate technical approaches to integrate PHEV/EV to the grid, including communication, safety, and control standards. Second, today's batteries do not readily support re-injecting power back into the grid, because the residual charge that remains after driving an EV is small, and is smaller still for a PHEV. Finally, using a battery for V2G services shortens its cycle life, degrades its performance and may present manufacturer warranty issues.

V2G services are not forecast to be economic for the utility, and consumers will not realize significant net benefit from providing these services (in fact, they may incur costs), until battery cycle life and affordability move much closer to DOE goals. These shortcomings, and the expected slow rate of PHEV/EV market penetration, make V2G too uncertain to depend on as a meaningful source of power for the next several years.

Vehicle-to-building (V2B) applications show somewhat more promise, although they, too, are likely to be very limited. By 2020, in-home charging stations are forecast to provide V2B capabilities at little incremental cost; however, workplace and commercial destinations may require new outlets to allow

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commuter vehicles to provide V2B services, and the cost of such retrofits is likely to be prohibitive. By 2035, our modeling shows that in the APS service territory about 67,000 workspace and commercial destination sites could be equipped with V2B capability, and approximately 10 percent of residential vehicles will be at home during on-peak periods and may be able to deliver V2B services. Since most commercial vehicles are expected to be on the road during on-peak hours, few if any will be able to deliver on-peak V2B services.

V2G/V2B will be adopted almost exclusively where the benefits exceed the costs of adding V2G/V2B infrastructure. This will limit V2G/V2B energy delivered to a small share of PHEV/EV energy use. V2G services will require more infrastructure investments than V2B, and are unlikely to yield significantly more revenues or avoid more costs. In many cases, the customer's own retail electric rates will provide more value for V2B services than wholesale rates will provide for V2G. Thus, vehicle based energy storage is expected to be primarily a V2B service opportunity.

PHEV/EV holds promise for reducing vehicle emissions in urban areas. However, vehicle charging may increase off-peak power plant emissions, which would be compounded by storage and conversion losses. Since V2G and V2B applications are unlikely to be viable at any significant scale, no substantive changes in emissions are expected from V2G/V2B adoption.

Codes and standards are being developed rapidly for PHEV/EV chargers. The industry is settling on standardized charger sizes: Level 1 (approximately 1.5 kW), Level 2 (approximately 6.6 kW), and Level 3 (up to 200 kW). Some auto manufacturers will limit Level 2 chargers to 3.3 kW to reduce the electric system impacts of vehicles so equipped, reducing the maximum aggregate demand caused by these vehicles. Codes and standards are currently lagging for V2G/V2B infrastructure.

Overall, PHEV/EV will have relatively minor impacts on the APS system in the next 10 years with the exception of the local distribution system. Impacts in the next 20 to 30 years, although growing, will also be relatively minor. V2G/V2B services will play only a minor role within the next 20 to 30 years in providing energy services within the APS service territory.

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Section 1 - EV Technology and Markets

1.0 EV Technology and Markets

1.1 Key Findings

- PHEV/EV will make inroads for a variety of residential, fleet, and heavy commercial applications, provided that DOE performance and cost targets are achieved; however, PHEV/EV will be slow to penetrate the market due to technology and price.
- Battery technology is limited and expensive today although a number of promising battery technologies are being developed and Lithium Ion (Li-ion) batteries are thought to hold the most promise absent revolutionary technological breakthroughs. However, for PHEV/EV to gain a significant share of vehicle sales, battery cost must decline and battery performance must improve, especially deep discharge cycle and calendar life performance for batteries suited for the Arizona climate and the climate of cities like Phoenix.
- The industry is settling on three standardized charger sizes:
    - Level 1 (approximately 1.5 kW per charger)
    - Level 2 (approximately 6.6 kW)
        - Some auto manufacturers will impose an internal limit of 3.3 kW on Level 2 chargers which will reduce the electric system impacts of vehicles so equipped.
    - Level 3 (up to 200 kW).
    - Increased penetration of the larger Level 2 and 3 chargers could increase the impact on the APS system.
- Initial costs for PHEV/EV are expected to exceed the initial costs of conventional vehicles through 2035. Equivalent operating costs will be less than conventional vehicles, provided battery cycle life improves.
- Federal tax credits for PHEV/EV will be a significant driver of early adoption of PHEV/EV.
- PHEV/EV can help reduce local emissions in the Phoenix metropolitan area and other key cities throughout the APS service territory. Early demand for PHEV/EV will be driven in part by customers who purchase PHEV/EV to help meet LEV/ZEV targets.

Section 1 - EV Technology and Markets

1.2 Detailed Discussion of EV Technology and Markets

An electric vehicle is one that uses an electric motor for propulsion at least some of the time. Nearly every electric vehicle carries an on-board battery. If the battery is charged solely from the electrical grid, it is called a *plug-in electric vehicle* (EV). An EV is distinct from a *hybrid* electric vehicle (HEV) whose battery is recharged exclusively by energy from the combustion engine and energy recovered through dynamic braking. Typically, an HEV switches frequently back and forth between the electric and internal combustion motors, depending on driving conditions. A *plug-in hybrid* electric vehicle (PHEV) has the characteristics of both and EV and an HEV: it continually operates as an EV until its battery is sufficiently discharged so that it needs to revert to an internal combustion engine as does an HEV, rather than constantly switching between electric and gasoline operation. This study is concerned only with EVs and PHEVs, not HEVs. Nor is it concerned with electric buses, trains, and light-rail vehicles that derive power from overhead wires through on-board catenary poles.

The PHEV/EV market consists not only of the vehicles, but also of related technologies and applications. How the PHEV/EV market may grow will be affected by a variety of key drivers, including vehicle characteristics, battery performance and cost, battery charger issues, government incentives, tax credits, regulatory policies, and potential PHEV/EV applications. Market development will also be affected by the initial sales price of vehicles, their operating efficiency and operating cost reduction, and emission rates. NCI assessed these market components as well as the vehicle themselves.

Potential markets for EVs and PHEVs are vast and include vehicles of every size, from the smallest cars to the heaviest trucks. Several PHEV/EV applications are likely, including light-duty vehicles (automobiles and light trucks) and commercial vehicles up to 13 tons Gross Vehicle Weight Rating (GVWR) in individual and fleet applications.

According to the U.S. Department of Energy, Arizona is home to several electric vehicle recharging stations, although the current operational status of each station is unknown.[1] This number is set to grow dramatically due to a new DOE funded project, which aims to install up to 2,420 home, commercial, and public charging stations by 2012 in the Phoenix and Tucson metropolitan areas.[2] [3] In 2012, Arizona will adopt California Low Emission Vehicle (LEV) regulations that require vehicle manufacturers to sell Zero Emission Vehicles (ZEV) such as PHEV/EV. Key market features including customer acceptance, persistence of tax credits, vehicle turnover rates, and actual future cost and

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[1] U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center website, www.afdc.energy.gov. Retrieved Jan. 1, 2010.

[2] Ecotality Press Release, "The EV Project FAQs", Sept. 30, 2009.

[3] See http://www.evchargernews.com/regions/ch-az-all.htm

performance trajectories may limit early market adoption. Research to date indicates that incremental PHEV/EV costs will continue to decline while battery performance and life will continue to improve; both as incremental improvements are made to existing technologies and as new technologies are introduced. These improvements will strengthen the business case for EV and PHEV.

All PHEV/EV are equipped with certain components not found in conventional vehicles, including electric traction motors, on-vehicle charging systems, power electronics, and large battery packs with associated hardware, trays, and thermal management systems. PHEV also include components and systems found on conventional vehicles including combustion engines, exhaust systems, transmissions, and fuel tanks. Including the cost of batteries, an electric vehicle or plug-in hybrid electric vehicle today is considerably more expensive to purchase than an equivalent conventional vehicle.[4] Although batteries and electric-drive component cost are expected to decrease significantly in the coming years, PHEV/EV are not expected to achieve cost parity with conventional vehicles before 2035.[5]

HEV batteries are currently engineered for a ten-year life, although actual durability depends greatly on the number and depth of charging and discharging cycles during the life of the vehicle. Current PHEV/EV battery technologies are not durable enough for a ten-year life due to the deep discharge cycles required of them. Improving deep-discharge battery cycle life is a major task of PHEV/EV battery development, as described below. At the end of their life, electric vehicle batteries can be recycled.

1.2.1 Review of Energy Storage Systems

Two competing chemistries are seen as viable options for plug-in vehicle batteries: nickel metal hydride (NiMH) and lithium-ion (Li-ion), with different strengths and weaknesses. NiMH batteries are less expensive to produce and have a proven safety record; however, they are relatively heavy, and this limits their usefulness in plug-in vehicles. Lithium ion batteries have the potential to store significantly more electricity in lighter batteries; however, they are plagued by concerns about calendar life, cycle life, cost, and safety. Despite these trade-offs, most manufacturers have concluded that lithium ion batteries hold the most promise for the long term.[6]

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[4] Energy Information Administration, *Annual Energy Outlook 2009*, Washington, DC, 2009
[5] Anup Bandivadekar, Kristian Bodek, Lynette Cheah, Christopher Evans, Tiffany Groode, John Heywood, Emmanuel Kasseris, Matthew Kromer, Malcolm Weiss, "On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions", MIT Laboratory for Energy & the Environment, Cambridge, MA, July 2008.
[6] EIA 2009

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The U.S. Department of Energy is working with industry to improve battery performance and durability.[7] DOE has concluded that lithium ion batteries, with calendar life exceeding 10 years and cycle life exceeding 300,000 shallow discharge cycles, are ready for commercialization in HEV applications. Development of codes and standards and on-board battery management systems is underway to ensure the safety of electric vehicles and recharging equipment. Further improvements to lithium-ion battery durability, life expectancy, and cost are required for PHEV/EV applications. Also, PHEV batteries must be designed to offer the same high power output as EV batteries despite the PHEV batteries' smaller overall size and weight.

For instance, PHEV/EV battery deep-discharge cycle life must be improved. In HEV applications, batteries are neither charged to a level exceeding 70 percent of rated storage capacity nor discharged below 40 percent. By contrast, PHEV/EV batteries may repeatedly be charged to full capacity and discharged to 20 or 30 percent.[8] In addition to deep discharges in electric mode, PHEV batteries are subjected to frequent shallow cycles for power assist and regenerative braking in combustion mode.

Battery aging accelerates under high ambient temperatures. Current batteries are engineered for maximum operating temperature of 95° F. In order to maintain operating temperature in hot climates, batteries require cooling systems. Lithium-ion batteries can be optimized for either low-temperature or high-temperature climates, but it is difficult to ensure good performance across a wide range of temperatures and conditions.[9]

DOE has set near term battery performance targets that include 1,000 deep discharges for EV batteries and targets of 5,000 deep discharges plus 300,000 shallow discharges for PHEV batteries, along with a 15-year calendar life. PHEV battery targets are shown in Table 1 below. Lithium-ion batteries have achieved the 1,000 deep-discharge cycle durability target and a 3-year calendar life. PHEV batteries could achieve their cycle life targets by 2014.[10]

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[7] David Howell, "Battery R&D for Electric Drive Vehicles", presented at the Advanced Battery Manufacturing Conference, April 16, 2009.
[8] Ibid.
[9] Boston Consulting Group, "Batteries for Electric Cars: Challenges, Opportunities, and the Outlook to 2020", 2010. http://www.bcg.com/documents/file36615.pdf, last accessed Jan. 7, 2010.
[10] Howell, 2009.

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Table 1: U.S. DOE PHEV Battery Status and Development Targets[11]

Battery Attribute	High Power/Energy Ratio Battery	High Energy/Power Ratio Battery
Estimated range	10 miles	40 miles
Specific Energy	57 Wh/kg	97 Wh/kg
Energy Density	85 Wh/L	145 Wh/L
Shallow Discharge Cycle Life	5,000 cycles	5,000 cycles
Deep Discharge Cycle Life	300,000 cycles	300,000 cycles
Calendar Life	15 years	15 years
Maximum System Price	$500/kWh	$293/kWh

There is a range of different types and configurations of Lithium-ion batteries. These include Lithium Cobalt Oxide ($LiCoO_2$), Lithium Nickel Cobalt Aluminum (NCA), Lithium Nickel Manganese Cobalt (NMC), Lithium Manganese dioxide ($LiMn_2O_4$), and Lithium Iron Phosphate ($LiFePO_4$). These vary in terms of characteristics such as battery life, energy storage density, power, and abuse tolerance. Currently, no single battery provides class-leading performance in all categories. Research and development efforts are currently focused on improving Li-ion durability, energy density, power density, temperature sensitivity, recharge time, and cost. In the near term, the existing suite of lithium ion batteries, and a few other types, will be optimized and used in PHEVs and EVs. However in the longer term (e.g., after 2015), new battery chemistries with significantly higher-energy densities need to be developed to enable PHEVs and EVs with a longer all-electric range. It is expected that new chemistries will outperform existing chemistries by incorporating high capacity positive electrode materials, alloy electrodes, and electrolytes that are stable at 5 Volts.[12] The U.S. Dept. of Energy is currently supporting exploratory research on several new lithium-ion battery chemistries: Programs investigating Lithium alloy/high voltage positive, Li-Sulfur, and Li-metal/Li-ion Polymer are underway. Additional support for development of advanced batteries will likely speed their rates of improvement and help accelerate deployment.[13]

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[11] U.S. Department of Energy, *Energy Storage Research and Development: Annual Progress Report 2008*, Washington, DC, January 2009.

[12] IEA, 2009.

[13] Ibid.

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1.2.2 Review of Charging Infrastructure, Technologies and Information Systems

The Idaho National Laboratory has recently assessed PHEV/EV charging systems.[14] To help classify current PHEV/EV charging systems and facilitate discussion of these systems, the 1999 National Electric Code (NEC) formally classified three PHEV/EV charging levels: Level 1, Level 2, and Level 3.

Level 1 charging systems use a standard 120 VAC, 15 amp circuit providing a 12 amp continuous current, or a 20 amp circuit providing a 16 amp continuous current, typically provided over the branch circuit that is the lowest common voltage level found in both residential and commercial buildings in the United States. Level 1 charging systems provide between 1-2 kW of charging power. Because Level 1 charging systems provides a small amount of power, they can result in prolonged charge times, and are expected to be an initial approach used during the introduction of battery electric vehicles and not the ultimate charging solution. Level 1 charging equipment is typically installed on the vehicle and the 120 V AC power is routed to the vehicle through a plug and cord set.

Level 2 specifies a 220-VAC or 240-VAC, single-phase, 40-Amp branch circuit providing 32 amps of continuous power for a total of 6.6 to 7.7 kW or higher. Level 2 is typically described as the "primary" and "preferred" level for a battery electric vehicle charger for both private and public facilities and is expected to be the primary charging system adopted. Level 2 chargers employ special equipment to provide a higher level of safety required by the NEC. With power as high as 15 kW, typical charge time is 1-5 hours depending on battery size and initial state of charge. Historically, there have been two types of Level 2 equipment: "Conductive" and "Inductive." Conductive equipment uses "butt-type" or "pin and sleeve" type connection and is typically referred to as the electric vehicle supply equipment (EVSE) or power control station The inductive system has no metal-to-metal contact and inductively transfers energy to the vehicle. Each type of equipment requires a dedicated branch circuit for installation. It is not expected that inductive charging will be used for EV or PHEV charging.

Several PHEV/EV manufacturers have recently announced adopting on-board technology that limits charging to 3.3 kW. This charging level can also be accommodated using Level 2 plugs, wires, and appurtenant equipment. Designing the chargers for the market, several manufacturers will roll PHEV vehicles out initially with 3.3 kW charging limits. With experience in accommodating expanding PHEV/EV markets and improvements in battery technology, NCI expects that charging levels increase to full Level 2 levels, approximately 6.6 kW.

Level 3 features "Fast Charging" technology and provides up to 200 kW of power. It is generally intended for commercial and public applications. Level 3 typically uses an off vehicle charge system

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[14] Kevin Morrow, Donald Karner, James Francfort, *Plug-in Hybrid Electric Vehicle Charging Infrastructure Review*, Idaho National Laboratory, November 2008. Idaho Falls, ID, INL/EXT-08-15058.

serviced by a 480-VAC, three-phase circuit. In practice, Level 3 is intended to allow battery electric vehicles to achieve a 50% charge in 10 to 15 minutes.

Charging time is limited primarily by the capacity of the grid connection. A normal household outlet is about 1.5 kilowatts, which is enough for a Level 1 charger. A Level 1 charger provides reasonable charging times for today's PHEV/EV at minimal cost. As battery cost declines and EV range increases, demand for Level 2 and Level 3 charging equipment may rise to keep charging times low.

As an alternative to expensive private fast-charging equipment, future vehicles may feature easily removable battery packs, enabling a system of battery swapping stations that allow quick replacement of discharged battery packs with charged ones.[15] Public fast recharging stations offer the additional benefit of providing a medium for sharing capital costs over all the vehicles that utilize them for fast charging. On the other hand, a successful battery swapping system will need standardized compartments, interconnection, and terminations to ensure full compatibility between all batteries (at least for participating vehicles), and a means to ensure that swapped batteries have equal performance to those the driver gives up, and that initially come with the vehicle.

1.2.3 Review of Standards to Support Grid Charged Vehicles

As is the case with all new developments, the PHEV/EV industry is struggling to understand and address the numerous issues that have thus far presented themselves. New solutions will likely be developed even as PHEV/EV begin mass production early in the next decade.

Various Standards Development Organizations (SDOs) and user groups are investing considerable time to identify and develop standards that will be required for PHEV/EV, but much remains to be done. In recent months, The National Institute of Standards and Technology (NIST) has become a driving force behind standards for electrified transportation as part of its Smart Grid infrastructure work. [16]While NIST is not developing any new standards, it has organized a framework within which standards shall be developed. Its role is identifying and charging those SDOs best qualified to develop electrified transportation related standards with doing so.

The NIST effort is ongoing and has so far identified a number of 'use cases' through which it expects standards to be defined. The top level use cases describe modes of interaction between PHEV/EV customer and the utility as outlined in Table 2 below.

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[15] IEA, 2009.

[16] National Institute for Standards and Technology, *NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0 (Draft)*, Washington, DC, September, 2009.

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Table 2: SAE Top Level Use Case Descriptions

PEV0	Customer Attributes
PEV1	Utility Provides Services to PEV Customer
PEV2	Customer connects PEV to premise energy portal
PEV3	Customer enrolls in a PEV3 Demand Side Management Program

For example, NIST distinguishes circumstances where a utility provides services directly to the PHEV/EV customer from those where the PHEV/EV charging is accomplished through a customer energy portal or energy management system. Terminating charging in response to a utility demand management signal is another form of interaction that will require additional standards. Appendix B lists some additional detailed use cases for which standards will need to be devised. Each of these use cases is under development and will likely result in the development of corresponding standards for consideration by the industry. It is likely however that these standards will take some time to emerge and be adopted.

Standards are important because they allow different utilities, different vehicle and electrical equipment manufacturers all to build equipment and protocols that can be widely used. Rather than designing equipment to address a variety of utility programs, vehicle manufacturers can concentrate on a single set of equipment requirements, and where needed, communication and control protocols. Utilities can specify equipment to be used for PHEV/EV programs knowing that the equipment will be workable for a wide range of vehicles and not subject to early obsolescence. Plug, receptacle and coupling manufacturers will have a standard set of criteria to which to build their equipment[17]. Equipment will be interchangeable. Collectively, these concepts are grouped under the term 'interoperability'. Safety will also be assured as standards preventing unintentional back feed and personal shock are promulgated.[18]

Some standards have already been developed, such as those pertaining to the installation and functionality requirements of electric vehicle infrastructure as provided in the NEC Article 625, published by the National Fire Protection Association. Other associated use cases standards are listed in Appendix B and other associated standards are listed in Appendix F.

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[17] IEC 62196 - plugs, socket-outlets, vehicle couplers and vehicle inlets - conductive charging of electric vehicles

[18] NFPA 70 Article 625 - Electrical Vehicle Supply Equipment: EV coupler, cord and plug, interlock, automatic de-energization of cable, personal protection against electric shock, back feed, interactive systems, and ventilation.

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1.2.4 Applications

Vehicle technology, battery technology, codes and standards, and recharging and electricity infrastructure for plug-in vehicles are now under development, with pending solutions nearing commercialization. Figure 1 shows a possible commercialization timeline for EVs and PHEVs, including energy storage device, codes and standards, and charging infrastructure developments based on planned activities through 2035. This timeline shows some of the key data for NCI's market penetration forecast, discussed in the next section.

Currently, PHEV/EV are undergoing limited demonstrations but are not yet fully commercialized. No mass produced light-duty PHEV/EV models and only a few PHEV/EV commercial truck models are commercially available. This is expected to change between 2010 and 2012, with numerous vehicle introductions by major automakers and automotive startups. The U.S. government has awarded billions of dollars from the American Recovery & Reinvestment Act of 2009 to ramp up battery manufacturing and install vehicle charging infrastructure to accelerate the deployment of these vehicles.[19] A significant development is the U.S. Dept. of Energy sponsored Electric Vehicle (EV) Project. This project will result in the deployment of 10,950 Level 2 (220V) chargers, 260 Level 3 fast-chargers and 4,700 Nissan LEAF zero-emission electric vehicles in five states, including Arizona (Phoenix and Tucson areas), beginning in Fall 2010. [20]

The economic milestones for EV and PHEV operation are shown in Figure 1 . These show NCI's estimates of payback period through 2035. The payback period is the length of time required for the higher initial cost of the vehicles and infrastructure to equal the sum of cost savings due to decreased energy cost. In general, payback periods gradually decline due to decreasing vehicle and charging system costs as well as increasing gasoline and diesel costs. Payback periods increase briefly due to the expiration of tax credits in the early years. Payback periods greater than 10 years, as is the case today, suggest weak sales of PHEV/EV, since this period exceeds the typical useful life of a vehicle. Payback periods less than 5 years, which are shown after 2025 for most vehicle types, lead to strong sales. Due to the Federal Qualified Electric Drive Motor Vehicle Tax Credit available beginning in 2010, payback periods less than 5 years are seen in most vehicle types by 2018, several years earlier than otherwise would be expected. However, the tax credit is likely to expire soon after this (although its expiration is based on PHEV/EV sales by manufacturer, not a specific date) causing a spike in payback periods. More details about payback periods are provided in Section 2, Market Demand Forecast.

Meanwhile, government and industry have planned advanced battery technology research activities with measurable milestones as shown in Figure 1. The U.S. Advanced Battery Consortium (USABC)

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[19] Howell, 2009.

[20] Electric Transportation Engineering Corporation, "ECOtality's eTec Finalizes Contract for $100 Million Transportation Electrification Project with U.S. Department of Energy", Press Release, Phoenix/Scottsdale, AZ, October 1, 2009.

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and FreedomCAR Programs have published technical targets for EV batteries including cost, power density, and energy density goals for PHEV/EV-critical technologies like batteries, converters, and motors through 2020.[21] The Japanese government has published goals through 2030.[22] Figure 1 shows some of these published battery goals for 2015, 2020, and 2030. For instance, the USABC targets call for battery specific energy to increase from 40 Wh/kg in 2010 to 200 Wh/kg and for maximum operating temperature to increase from 95°F to 185°F by 2020, enabling electric vehicles in that year to travel longer distances with greater efficiency and with fewer hot weather durability impacts than is possible today. Meanwhile, battery costs are expected to decline significantly, with Japan targeting a cost 40 times lower than the 2008 level by 2030[23]. If this goal is achieved, along with cost reductions in motors and power electronics, PHEV/EV could be nearly cost competitive with conventional vehicles by 2030. However, NCI estimates future PHEV/EV battery costs declining at more conservative rate of 6 percent per year based on interviews with battery manufacturers and others.[24] Thus, battery cost targets shown in Figure 1 are expressed as ranges of possible values.

Codes, standards and regulatory development will focus on vehicle standards and smart charging as shown in Figure 1. The Federal Energy Regulatory Commission has published a Smart Grid policy and action plan with specific codes, standards, and regulations for smart charging.[25] Ultimately FERC expects that smart grid investments will eventually lead to a wide array of advanced options for electric vehicle interaction with the grid, including full vehicle to grid capabilities. In the near term, FERC calls for appropriate standards, or extensions to relevant existing standards, to provide at least the minimum communications and interoperability requirements that are necessary to permit some ability for distribution utilities to facilitate vehicle charging during off-peak load periods. For instance, the Society of Automotive Engineers (SAE) has developed two draft standards, SAE J2836 and SAE J2847, which address communications and price signals/demand response respectively. Eventually, the demand for ancillary services from grid-connected electric vehicles will require electrical interconnection issues to be resolved and communications ability to be expanded. FERC has urged SAE and the automobile industry to plan data communications systems between electric vehicles and the grid that are able to be upgraded. FERC has also suggested that electric vehicles be included in Distributed Energy Resource standards development. There are a variety of regulatory issues that need to be addressed to incorporate V2G including resale of electricity by non-utilities, cost allocation, possible special tariffs, and addressing roaming charges.

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[21] United States Advanced Battery Consortium, "USABC Goals for Advanced Batteries for EVs", www.uscar.org/commands/files_download.php?files_id=27, retrieved Jan. 1, 2010.

[22] IEA, 2009.

[23] Ibid.

[24] Battery cost assumptions are similar to findings of Boston Consulting Group, 2010.

[25] Federal Energy Regulatory Commission, Smart Grid Policy, Washington, DC, March 19, 2009. Docket No. PL09-4-000.

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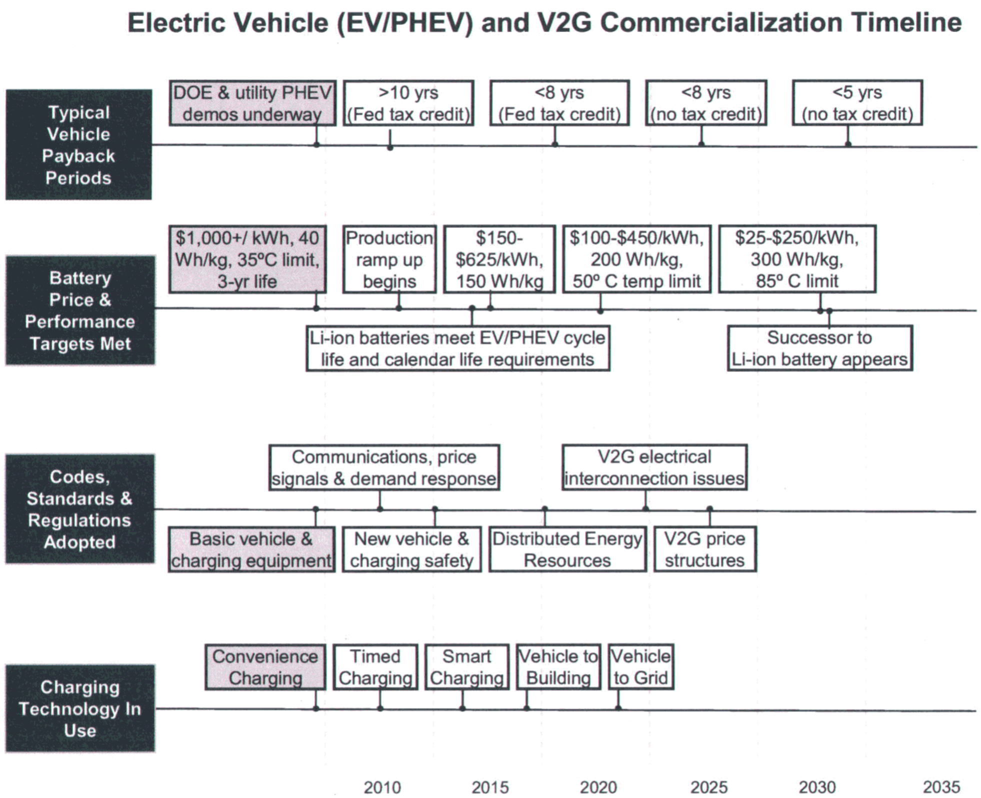
As the necessary codes, standards, regulations, and warranty assurances are finalized, the charging infrastructure will be upgraded with additional capabilities as shown in Figure 1. These capabilities are expected to roll out over time as requirements for issues such as fault protection, breaker reclosing intervals and trip settings, and communications are met. It is widely agreed that widespread V2G programs are unlikely to emerge before 2020. First, timed charging with the ability to delay charging to low-demand periods in response to preset times input by the user or price signals received from the utility will be available. Next, smart charging, i.e. the capability of the vehicle and grid to communicate in real time to control the charging rate, will be available. Finally, V2G technology will be available, allowing vehicles to discharge to the grid. Participation in V2G programs, even when fully available, may be limited due to high costs of battery storage, conversion and inversion losses, and potentially significant reductions in battery life due to increasing discharge depth or the costs of upgrades to utility infrastructure.

Section 1 - EV Technology and Markets

Figure 1: Electric Vehicle Technology



1.2.5 Vehicle Emissions Estimates

The need to reduce local emissions, especially in densely populated urban areas, will likely help drive policies supportive of PHEV/EV adoption. CO_2 emission reduction targets will also favor technologies like PHEV/EV with higher efficiencies, lower carbon intensities, and lower CO2 emissions than conventional vehicles. Reductions in PHEV/EV tailpipe emissions of smog precursors are also significant, reducing smog and ground level ozone within urban areas. Finally, PHEV/EV will help Arizona meet upcoming Low Emission Vehicle (LEV) standards.

Table 3 shows estimates of nationwide average fuel efficiency and emissions rates by owner type (passenger or commercial) for new model year 2007 vehicles based on results from the EPA MOBILE 6.2 model and other EPA guidance.[26] Passenger vehicles include all privately owned automobiles and light

[26] U.S. Environmental Protection Agency, MOBILE6 Vehicle Emission Modeling Software website, http://www.epa.gov/otaq/m6.htm, last accessed Feb. 12, 2010. Model year 2008 vehicles were subject to

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trucks, whereas commercial vehicles include all fleet vehicles, including fleet automobiles. Each group includes both diesel and gasoline vehicles based on EPA data.[27] For comparison, Table 3 also shows estimated emissions rates for PHEV/EV based on the 2008 APS electricity generation mix.[28] Because few data were available model year 2007 PHEV/EV, NCI made assumptions concerning typical EV efficiency and PHEV electric range.[29]

In Table 3, PHEV/EV are shown to have significantly lower average emissions rates of CO, VOC, and CO_2 than those of conventional vehicles for both groups, passenger and commercial. On the other hand, PHEV/EV are shown to have higher average PM, NO_x, Pb and Hg emission rates per vehicle mile than conventional vehicles for both groups. SO_2 emissions data were not included in the vehicle emissions modeling results because this is a trace pollutant for motor vehicles.

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the same emissions and fuel economy regulations as model year 2007 vehicles and thus are expected to have comparable emissions characteristics. Fleet owned vehicles make up 4.7 percent of light duty vehicles as determined using Arizona Department of Motor Vehicles data from 2006-2007. The figures shown are nationwide averages based on vehicles running on regular gasoline and diesel. For more complete data on Arizona emissions from the Western Regional Air Partnership see http://www.wrapair.org/forums/ef/UMSI/index.html.

[27] Vehicle market shares and diesel fractions were taken from Chris E. Lindhjem and Stella Shepard, *Development Work for Improved Heavy-Duty Vehicle Modeling Capability Data Mining – FHWA Datasets*, EPA/600/R-07/096, July 2007.

[28] 2008 Data provided by APS for utility-owned generation assets.

[29] EV average efficiency values (3.6 mi/kWh for light-duty, 1.7 for small commercial, and 1.4 for medium commercial) were based on IEA and NCI assumptions for vehicles operated in mild climates. PHEV electric range was assumed to be 25 miles, with 60 percent of all travel in electric mode for privately owned PHEVs and 28 percent for fleet owned and commercial PHEVs.

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Table 3: Recent Nationwide Average Vehicle Operation Emissions for Conventional Vehicles Compared to Estimated Arizona PHEV/EV Emissions (Lbs/1000 Miles)[30]

	Fuel Efficiency (mpg or mi/kWh)	Carbon Monoxide	Particulate Matter	Nitrogen Oxides	Sulfur Dioxide	Volatile Organic Comp. VOC	Carbon Dioxide	Lead	Mercury
Conventional Vehicle (Based on EPA MOBILE 6.2 model results for Model Year 2007)									
Passenger	19.9	3.34	0.008	0.11	None	0.28	970	None	None
Commercial	14.3	6.97	0.014	0.96	None	0.40	1,568	None	None
PHEV (Estimated based on conventional and EV rates)									
Passenger	NA	0.81	0.02	0.42	0.20	0.07	442	<0.000005	<0.000005
Commercial	NA	2.97	0.02	0.72	0.16	0.17	833	<0.000005	<0.000005
EV (Estimated based on 2008 APS electricity generation emissions and expected efficiency of EVs)									
Passenger	3.60	0.04	0.04	0.66	0.33	0.003	356	<0.000005	0.00001
Commercial	2.47	0.07	0.06	1.12	0.57	0.006	605	0.00001	0.00001

New vehicle emissions rates are declining due to increasingly stringent tailpipe emissions regulations. For instance, new emissions standards took effect in model year 2009 for U.S. light-duty cars and in 2010 for medium and heavy duty trucks and buses. Corporate Average Fuel Economy (CAFE) standards for light duty cars and trucks are on the rise, while the Energy Independence and Security Act of 2007 (EISA) has mandated the first fuel economy standards for commercial medium and heavy-duty trucks.[31]

Furthermore, the Arizona Department of Environmental Quality (ADEQ) has adopted California's LEV II vehicle emissions standards, including the Zero Emission Vehicle sales and greenhouse gas emissions requirements.[32] These regulations will apply to passenger cars, light-duty trucks and some commercial trucks beginning with model year 2012. Table 3 shows California LEV II standards maximum exhaust

[30] Environmental Protection Agency, Mobile 6.2 Emissions Factors, retrieved September 2008. Vehicle data are not adjusted for Arizona climate conditions, which tend to reduce fuel consumption and increase certain emissions rates.

[31] American Truck Dealers, "Medium And Heavy Duty Truck Fuel Economy", October, 2009.

[32] U.S. Department of Energy, Alternative Fuels and Advanced Vehicle Data Center, www.afdc.energy.gov/afdc/progs/view_ind.php/AZ/6503, retrieved Jan. 1, 2010.

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emissions for different emissions certification classes.[33] Table 4 also shows The California Air Resources Board (CARB) has approved regulations that, beginning with model year 2009, delimit greenhouse gas emissions from new vehicles for LEV II certification.[34] These regulations provide alternative compliance methods including credit generation from extra-clean and alternative fuel vehicles. These regulations will result in reduced average emissions for nearly every pollutant shown in Table 4 compared to the levels shown in Table 3.

Table 4: LEV Regulations (Not to Exceed Standards) for Zero Emission Vehicles (ZEV)[35]

	Carbon Monoxide (lbs/1000 mi)	Particulate Matter (lbs/1000 mi)	Nitrogen Oxides (lbs/1000 mi)	VOC (lbs/1000 mi)	GHG (lbs CO_2 equivalent/1000 mi)
Vehicles up to 8,500 lbs. GVWR	2.2 to 9.3	0.022	0.044 to 0.15	0.022 to 0.20	514 (cars); 796 (light duty trucks)
Vehicles 8,500 to 10,000 lbs. GVWR (chassis certified)	7.1 to 14	0.13 to 0.26	0.22 to 0.44	0.22 to 0.43	796
Vehicles with 10,000 to 14,000 lbs. GVWR (chassis certified)	8.2 to 16	0.13 to 0.26	0.44 to 0.88	0.12 to 0.23	796
Zero Emission Vehicle Requirements	12 percent (This requirement can be met with larger numbers of Super Low Emissions Vehicles certified to the lower emissions rate in each cell above)				

In addition to overall changes in emission rates, PHEV/EV operation has important consequences on the location of emissions. Table 3 includes both electrical power plant emissions and vehicle tailpipe emissions. EV has no tailpipe emissions, and thus it is likely to reduce smog and ozone within densely populated areas. PHEV/EV charging creates incremental energy generation, which can create incremental power plant emissions, although this incremental generation may be very small until PHEV/EV reaches a significant share of the overall vehicle population. The incremental power plant emissions that displace EV tailpipe emissions are remote and have a smaller impact on densely populated urban areas. While PHEV has both tailpipe and power plant emissions, it also displaces emissions from densely populated areas, but less than EV.

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[33] Trucks between 8,500 lbs. and 14,000 lbs. GVWR can be engine certified rather than chassis certified; only chassis-certified standards are shown in Table 4.

[34] California Air Resources Board, "Clean Car Standards - Pavley, Assembly Bill 1493", www.arb.ca.gov/cc/ccms/ccms.htm, retrieved Jan. 1, 2010. These regulations have been the subject of various lawsuits.

[35] California Code of Regulations Title 13, Section 1962.

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Because PHEV/EV are likely to reduce key emissions within densely populated areas most susceptible to ozone non-attainment and smog concerns, states like California consider EVs to be among the class of zero emission vehicles irrespective of power plant emissions associated with EV charging. PHEV/EV can help reduce local emissions in the Phoenix metropolitan area and other key cities throughout the APS service territory. Early demand for PHEV/EV will be driven in part by customers who purchase PHEV/EV to help meet LEV/ZEV targets.

NCI anticipates that PHEV/EV charging emissions profiles will improve over time, especially for off-peak charging and where nuclear, renewable resources and other low emission power plants are a higher proportion of the generation mix. On-peak charging emissions will depend on the exact charging profile; nonetheless, emissions during periods of above-average load may compare favorably with pollutants that would otherwise have been emitted even by efficient gasoline or diesel.

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2.0 Market Demand Forecast

2.1 Key Findings

- Electricity use nationwide for light-duty vehicles will grow from 190,000 MWh in 2009 to more than 6.4 million MWh in 2030.[36]
- PHEV/EV will be slow to penetrate the market due to technology and price. PHEV/EV are likely to comprise only about two percent of motor vehicles sales in the U.S. by 2018. After 2025, however, sales are expected to increase substantially, and by 2035, PHEV/EV could account for about 17 percent of sales, assuming that battery performance improves and costs decline as most analysts expect.
- Within APS service territory, NCI projects approximate sales of 29,000 EV and 12,000 PHEV in 2035 (about 17 percent of overall vehicle sales in APS service territory in the vehicle classes considered), and APS total population of EV to be nearly 117,000 vehicles and PHEV to be nearly 57,000 vehicles, for a total PHEV/EV population of about 174,000 units.
- Tax credits are key to customer economics in the short term. Thus the permanence of these credits is an important determinant of the early success and adoption rates of PHEV/EV technology.
- In 2012, light-duty PHEV with a 25 mile all electric range are expected to cost about $10,400 more per vehicle than an equivalent conventional vehicle, offset in part by $5,800 in State and Federal tax credits. Light-duty EV with a 100 mile range are expected to cost $20,900 more, offset in part by a $7,500 tax credit per vehicle.

2.2 Detailed Discussion of Market Demand Forecast

NCI's projections of PHEV and EV sales are based on ambitious DOE research targets including battery costs of $500/kWh to $750/kWh in 2012 and declining at six percent annually thereafter, and a deep-discharge cycle life that allows a 10-year service life by 2015. They do not rely on any previous PHEV/EV forecasts, but are consistent with nationwide forecasts such as the Electric Power Research Institute's (EPRI) recent forecast of PHEV/EV sales through 2030, shown in Figure 2.

[36] Source: U.S. Energy Information Agency's 2009 Annual Energy Outlook

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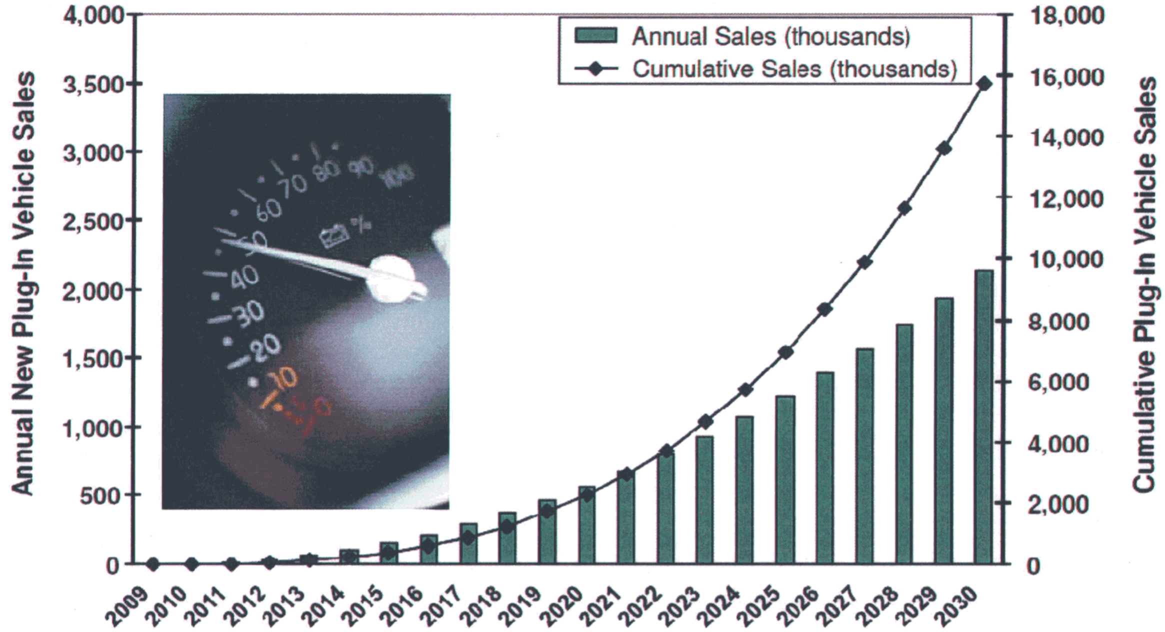
Figure 2: EPRI's nationwide forecast of plug-in electric drive vehicle sales through 2030. Copyright 2008 Electric Power Research Institute.[37]



EPRI's forecast shows annual new PHEV/EV sales of 500,000 by 2020, one million by 2024, and two million by 2030. EPRI expects cumulative U.S. sales of PHEV/EV to reach 16 million vehicles by 2030.

The projected market penetrations for EV and PHEV for APS service territory are shown in Table 5 and Table 6, respectively. By 2030, NCI predicts a total APS EV population of about 32,200 and a total PHEV population of nearly 19,600 vehicles, approximately 1.8 percent of the total vehicle population. By 2035, the model predicts a total EV population of nearly 117,000 vehicles and a total PHEV population of nearly 57,000 vehicles, about 6 percent of the total vehicle population. (See Appendix C for annual data.) This population is the cumulative result of sales that are expected to reach 29,000 units (EV) and 12,400 units (PHEV) annually by 2035.

[37] Mark Duvall, "Grid Integration of Plug-In Hybrid and Electric Vehicles", presented at PHEV Executive Summit, Jan. 26, 2009.

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Table 5: EV Market Penetration Estimates for APS – Vehicle Population

Year	Light Duty/ Privately Owned	Light Duty/ Privately Owned (Wealthy)	Light Duty/ Fleet Owned	Commercial (4-7 tons GVWR) /Fleet Owned	Commercial (7-13 tons GVWR) / Fleet Owned	Total
2015	133	41	161	93	41	**469**
2025	2,237	416	1,791	2,580	1,026	**8,050**
2035	60,227	9,267	17,819	21,989	7,798	**117,100**

Table 6: PHEV Market Penetration Estimates – Vehicle Population

Year	Light Duty/ Privately Owned	Light Duty/ Privately Owned (Wealthy)	Light Duty/ Fleet Owned	Commercial (4-7 tons GVWR) /Fleet Owned	Commercial (7-13 tons GVWR) / Fleet Owned	Total
2015	721	120	535	101	36	**1,513**
2025	4,638	709	1,695	1,164	436	**8,641**
2035	29,234	4,676	11,881	8,288	3,037	**57,116**

At the above levels of PHEV/EV market penetration, NCI expects about 148 million gallons of conventional motor fuels to be saved annually in APS service territory by 2035. Annual savings in 2025 and 2015 are expected to be about 16 million and 1.4 million gallons respectively.

The above results are illustrated in the following graphs.

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Figure 3: EV Expected Sales and Population in APS Service Territory by Vehicle/Owner Type, 2010-2035

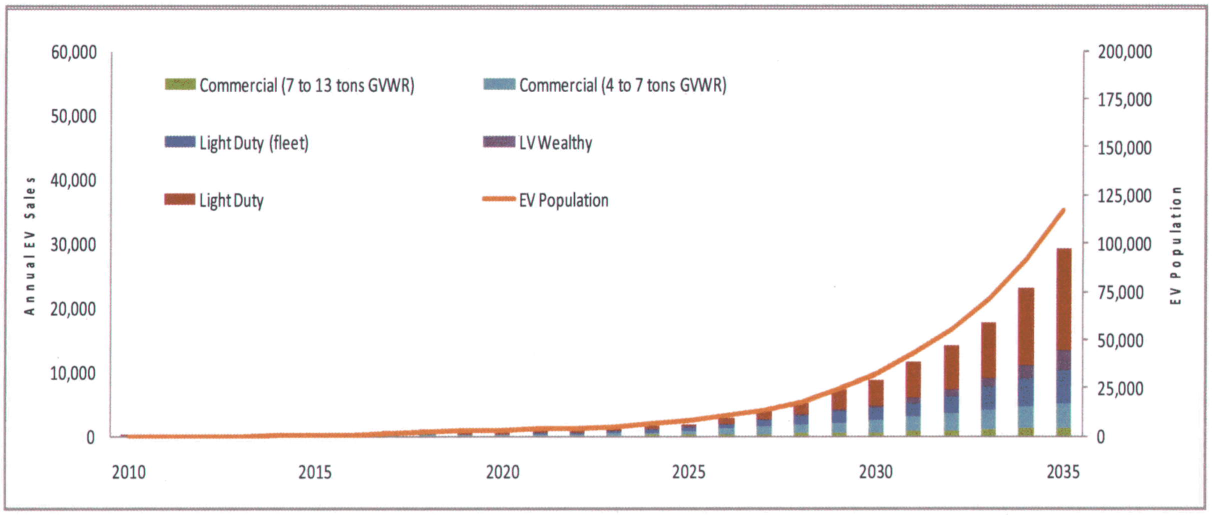

Figure 4: PHEV Expected Sales and Population in APS Service Territory by Vehicle/Owner Type, 2010-2035

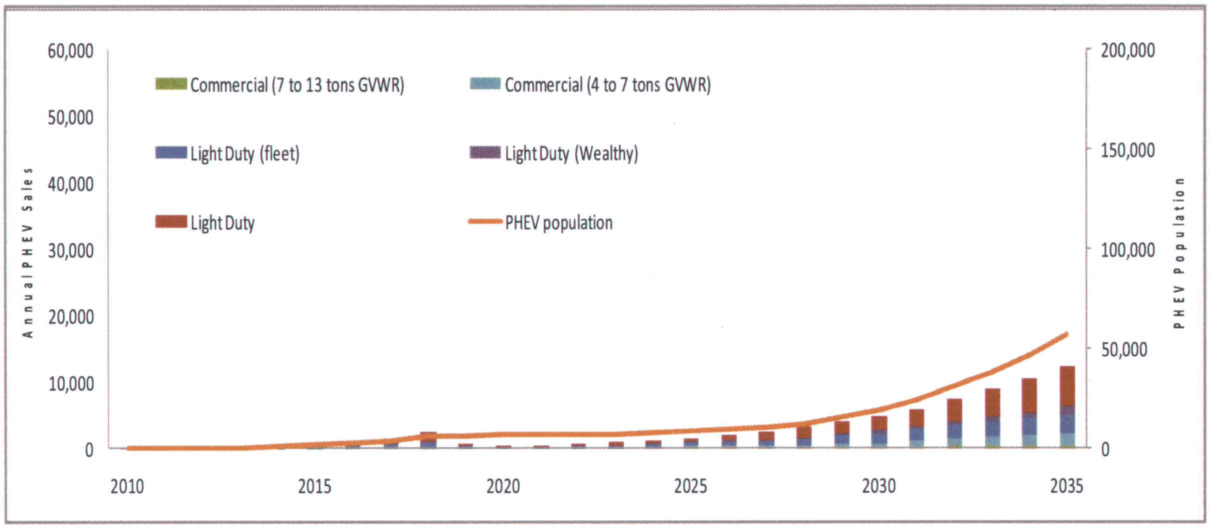

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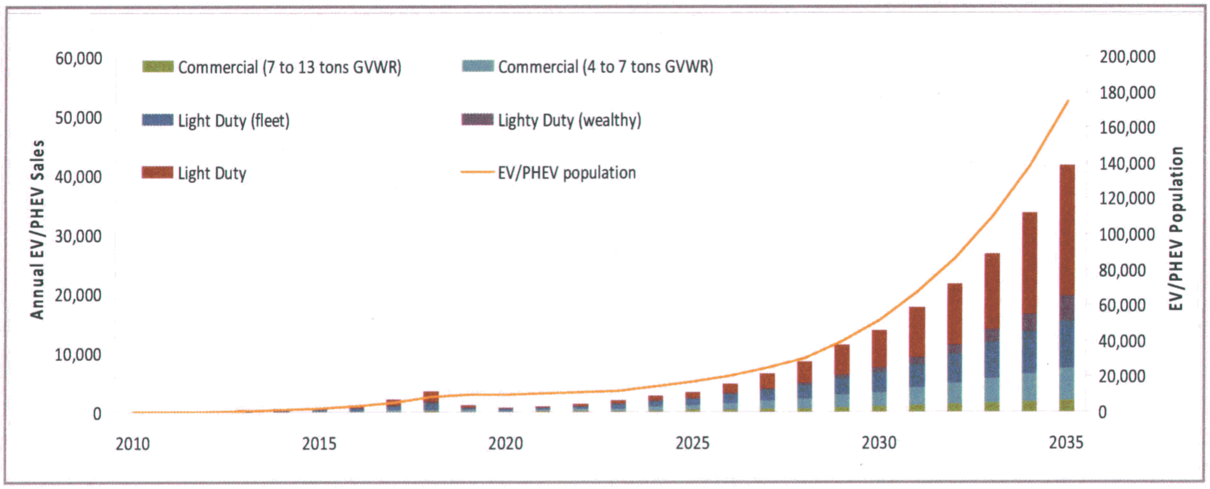
Figure 5: PHEV/EV Total Sales and Vehicle Population in APS Service Territory, 2010 to 2035



As displayed in the preceding graphs, NCI's market penetration modeling results show sales of EV and PHEV of all types increasing steadily but slowly through 2018, at its peak about 2 percent of all sales in APS territory of the types of vehicles considered in the forecast. NCI estimates the Federal Qualified Plug An Electric Drive Motor Vehicle Tax Credit of $2,500 to $15,000 will begin to phase out in 2019-2020.[38] This results in a cooling off period for PHEV/EV sales, which is not shown in the 2008 EPRI forecast as it was created before the Federal incentive was enacted. Sales rebound to 2 percent again in 2025 and increase from there to about 6 percent in 2035. In 2035, approximately 42,000 PHEV/EV would be sold, and the PHEV/EV population in APS service territory would reach about 174,000 vehicles. Full results are included in Appendix C.

The fleet and commercial EV/PHEV population grows more quickly at first than does the privately owned population. Privately owned vehicles account for approximately half of the EV/PHEV population in 2015 and 2025, but increase to about 60 percent by 2035. Residential vehicles include all privately owned automobiles and light trucks. Commercial vehicles include all fleet-owned automobiles and light trucks plus all commercial vehicles with Gross Vehicle Weight Rating (GVWR) from four to 13 tons.

Market penetration is likely to be gradual, especially within the next 15 years. According to the U.S. Energy Information Agency's 2009 Annual Energy Outlook, nationwide electricity use for light-duty vehicles will grow from 190,000 MWh in 2009 to more than 6.4 million MWh in 2030. PHEV/EV are likely to comprise only one percent of motor vehicles sales in the U.S. by 2020, and only two percent by 2025. After 2025, however, sales are expected to increase substantially, yielding about 18 percent per year

[38] Vehicle owners are assumed to receive full tax credits regardless of their tax liabilities.

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growth over the entire period. The forces driving these expectations include dozens of State and Federal incentives and, more importantly, the future prices of electricity, gasoline and diesel fuel. These driving factors are especially difficult to predict; therefore all long-term predictions and forecasts, including the ones in this report, are subject to high levels of uncertainty.

Considering vehicle stock and turnover rates, product availability, and customer demographics and income distribution, NCI estimated both the technological and economic potential of this technology. NCI identified a number of State and Federal tax incentives, and regulatory changes that are likely to influence customer adoption rates, including a $2,500 to $15,000 Federal tax credit for the first 200,000 PHEV/EV sold by each manufacturer nationwide, and a Federal charging infrastructure tax credit (that expires at the end of 2010) for 50 percent of the cost of PHEV/EV fleet charging equipment (up to $50,000) or $2,000 per residence. Our simulations indicate that tax credits are one of several key drivers to customer economics in the short term, and thus the persistence of these credits is an important determinant of the early success and adoption rates of this technology.

Using data from sources such as the International Energy Agency[39], U.S. Energy Information Administration[40] and Idaho National Laboratory[41], NCI estimated incremental vehicle first costs compared to standard vehicles in 2012. The incremental cost associated with electric traction motors, on-vehicle charging systems, large battery packs and associated hardware, and thermal management system, regenerative brakes, etc. will be approximately $10,400 ($4,600 net of State and Federal tax credits) for a PHEV automobile with a 12 kWh Li-ion battery and approximately $20,900 ($13,400 net of State and Federal tax credits) for an EV automobile with a 43 kWh Li-ion battery in 2012. Incremental vehicle cost for commercial trucks from 7 to 13 tons GVWR will be approximately $25,000 ($10,000 net of State and Federal tax credits) for a PHEV truck with a 30 kWh Li-ion battery and $46,000 ($31,000 net of State and Federal tax credits) for an EV truck with a 100 kWh Li-ion battery in 2012. NCI estimates that gross customer charger and associated customer infrastructure costs would range from about $800 to about $1,800 per charger in 2012. Provided that the technology and cost roughly tracks DOE estimates, incremental vehicle and infrastructure costs will decline at a rate of three to six percent per year as battery costs and infrastructure hardware costs decline.

To determine technology penetration, NCI used a Fisher-Pry modeling technique as shown in Figure 6 below. Five separate vehicle/owner types were considered:

- Light-duty/privately owned
- Light-duty/privately owned by wealthy households (annual income greater than $100K)
- Light-duty/fleet owned

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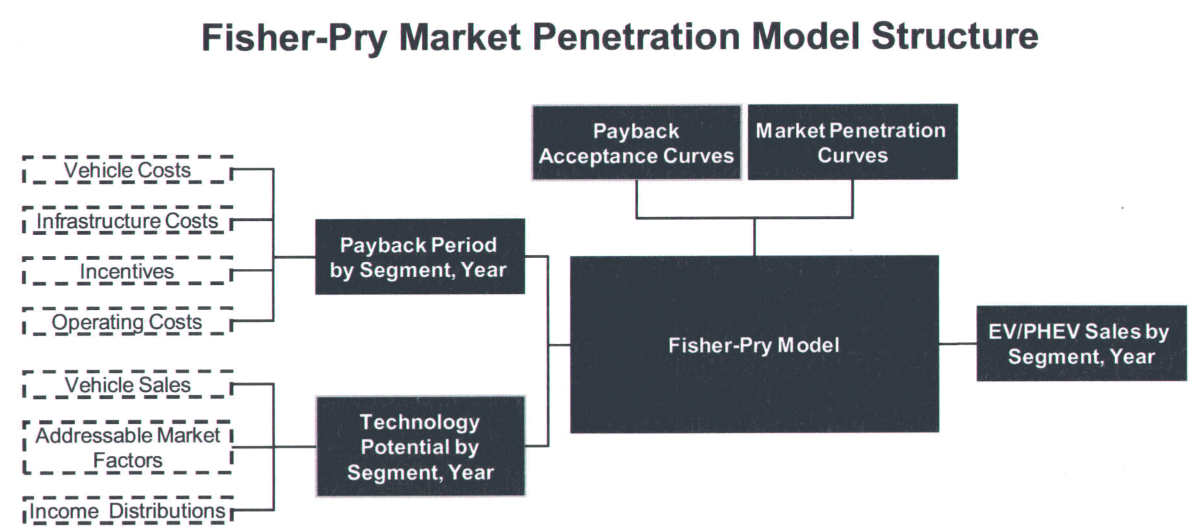
[39] IEA, 2009.
[40] EIA, 2009.
[41] Morrow, Karner, and Francfort, 2008.

- Commercial truck (four to seven tons GVWR)/fleet owned
- Commercial truck (seven to 13 tons GVWR)/fleet owned.

Figure 6 shows the structure of the model, with various inputs and outputs of annual PHEV/EV sales in APS service territory.

Figure 6: Fisher-Pry Market Penetration Model Structure



A key assumption is that the Federal Qualified Plug In Electric Drive Motor Vehicle Tax Credit will begin to phase out per the legislation's existing unit sale milestone of 200,000 per manufacturer, which is estimated to occur in 2018, with complete phase out by 2020. This tax credit, which is designed to reduce the payback period, applies to all PHEV/EV up to seven tons gross vehicular weight acquired after December 31, 2009.[42] NCI does not expect the tax credit to be extended because improvements in battery cost and vehicle efficiency will shorten the payback period for most vehicle types to less than five years by 2025.

2.2.1 Fuel Supply and Demand (Fossil and Bio fuels)

The volume and type of motor vehicle fuel used by PHEV/EV and displaced by these technologies as conventional vehicles are replaced defines the fuel supply and demand impacts of these technologies. Conventional vehicles displaced are assumed to be fueled by gasoline-only, diesel-only or gasoline/bio

[42] U.S. Department of Energy, Alternative Fuels and Advanced Vehicle Data Center, www.afdc.energy.gov/afdc/progs/view_ind_fed.php/afdc/409/0, Retrieved Jan. 1, 2010

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fuel or diesel/bio fuel blends or to a smaller extent, bio fuel only. Generally gasoline demand will increase world-wide putting upward pressure on prices.

For the purpose of determining market penetration in this study, annual mileage is assumed to be 10,500 to 14,000 for privately owned vehicles and 23,000 for all commercial vehicles. For all vehicle types, PHEV all-electric range is assumed to be 25 miles. After operating for 25 miles in all-electric mode, the vehicle switches to charge-sustaining mode and operates like an HEV. Overall, the share of miles driven in electric mode is assumed to be 60 percent for privately owned vehicles and 28 percent for commercial vehicles due to their higher annual mileage.[43] Fuel impacts are assessed against a typical conventional vehicle in each year operating in Arizona. For an expected 2035 PHEV/EV population of 174,000 vehicles in APS service territory, NCI estimates annual fuel savings of about 66 million gallons of gasoline and 82 million gallons of diesel. In 2025, the savings are estimated at 6.0 million gallons of gasoline and 10 million gallons of diesel annually. In 2015, 940,000 gallons of gasoline and 490,000 gallons of diesel are expected to be saved annually.[44]

2.2.2 Existing Vehicle Retirement

Each year a share of the total vehicle stock is retired as the aggregate vehicle population ages. Generally, as vehicle life lengthens, vehicle retirement rates decrease. Where new car sales increase faster than vehicle retirement, the total vehicle stock increases. Vehicle turnover is a small proportion of vehicle stock. For example, if the average life of a vehicle is 10 years and the age of the stock was evenly distributed, approximately 10% of the stock would turn over each year. The turnover rate is important because it limits the speed at which new vehicle technology is likely to be adopted. NCI assumed the

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[43] Based on NCI's review of several U.S. government sources, including EPA's MOBILE 6 modeling tool and USDOT's Omnibus Household Survey Federal Highway Statistics, that show new automobiles and light trucks travel at least 14,000 miles per year and new commercial trucks, at least 23,000 miles per year nationwide (Arizona vehicle travel measures are very close to nationwide averages). The USDOT survey in particular shows that approximately 60 percent of all roundtrip commutes are 25 miles or fewer in length; NCI assumed this number would also represent the total number of miles driven in all-electric mode by a typical driver of a privately owned PHEV with 25 miles electric range. NCI assumed that fleet owned autos and light trucks and all commercial vehicles would be available to recharge each weekday evening, so their share (28 percent) is the maximum number of all-electric miles afforded by such a recharging schedule.

[44] Fuel savings are calculated based on the required fleet average fuel economy of conventional vehicles in each year, the increased efficiency of PHEVs in combustion mode (70 percent greater than conventional), and EPA data concerning fleet mixes of different vehicles classes. Also, NCI assumed that all privately owned and fleet operated EV/PHEV autos and light trucks would displace only gasoline powered conventional vehicles traveling an equivalent number of miles per year and that all commercial EV/PHEV trucks would replace only diesel vehicles.

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PHEV/EV purchases as replacement vehicles would be at the end of the existing life of those vehicles. NCI used the number of vehicles scrapped each year as a percentage of new cars sold to estimate how many new vehicle purchases might be PHEV/EV. Vehicles sold as new elsewhere and subsequently added to roads in APS service territory were not considered. NCI assumed that turnover would be once every 10 years for passenger and most commercial vehicles except for fleet-owned light vehicles, whose turnover was assumed every 5 years. Annual new vehicle sales growth was assumed to be 2.4 percent. Vehicle scrappage was assumed to be 72 percent of new vehicle registrations annually, based on an analysis of 2002-2008 nationwide scrappage rate data published by the National Automobile Dealers Association.[45]

2.2.3 New EV Availability and General Automotive Market Conditions

For this study, NCI considered the vehicles of interest to be light-duty privately owned vehicles, light-duty fleet owned vehicles, and fleet owned trucks (4 to 13 tons GVWR). These were chosen for their high potential sales and large battery capacity compared to those of other vehicles such as 2 and 3 wheel vehicles (e.g., motorcycles), large trucks and buses (greater than 13 tons GVWR), off-road vehicles, lawn equipment, and others.

For the purpose of determining technology market penetration, enough vehicles in the categories of interest are assumed to be available in each year of the forecast period to satisfy the driving requirements of every PHEV/EV buyer in APS service territory. Although current PHEV/EV product availability is limited, NCI expects that supply will meet demand in the 2015 - 2035. The literature review shows dozens of plug-in vehicles in each category projected over the next few years and in some cases available now.[46]

2.2.4 Service Area Demographics

Customer characteristics and demographics are important in determining PHEV/EV adoption rates. Demographics are considered in assessing the technical and economic potential of PHEV/EV. Technical potential is limited by the number of applications in which the technology meets certain minimum customer utility requirements, while the economic potential considers both the technical potential and customer economics. Some data are taken from the 2005-2007 U.S. Census disaggregated by county in APS territory. The most important demographic data include the following:

- Household income by county
- Income distribution by county
- Vehicle population by county
- Vehicle registration growth trend
- Household growth trends
- Percent of households within APS service territory by county

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45 National Automobile Dealers Association, "NADA Data 2009", www.nada.org/nadadata.

46 Plug-in America, "Plug-in Vehicle Tracker", www.pluginamerica.org/vehicles/

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- Number of SUVs and trucks used by construction and agricultural workers
- Vehicles with more than 20 percent of trips with five or more occupants
- SUVs owned by high income households with two or more children
- Single-vehicle households with at least one monthly trip over 80 miles
- Vehicles in a multiple-vehicle household with at least one monthly trip over 80 miles

The most important demographic data for this analysis include the following:

- Number of units per house/structure
- Number of vehicles per household
- Commute types, income levels
- Population
- Growth in housing units

In addition, vehicle survey data are taken from the Arizona Department of Transportation,[47] National Automobile Dealers Association publications[48] and the National Household Transportation Survey[49]. The most relevant vehicle survey data include the following:

- Numbers of private, fleet, and commercial vehicles
- Vehicle sales
- Vehicle scrappage rates

2.2.5 Governmental Incentives, Laws and Regulations

Federal tax credits are a primary driver of the expected near term adoption of PHEV/EV. Other tax credits and incentives are also likely to support PHEV/EV adoption but have smaller impacts than federal tax credits. Several different types of Federal and State incentives currently apply to PHEV/EV, including the following[50]:

- Federal income tax credits for PHEV/EV purchase
- Federal plug-in electric vehicle conversion tax credits
- Federal charging equipment tax credits
- Arizona state EV equipment tax credits

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[47] Arizona Department of Transportation, www.azdot.gov/mvd/statistics/registeredVehicles.asp, retrieved Oct. 1, 2009.

[48] National Automobile Dealers Association, NADA Data 2009, www.nada.org/nadadata, retrieved Oct. 1, 2009.

[49] National Household Transportation Survey, nhts.ornl.gov, retrieved Oct. 1, 2009.

[50] U.S. Department of Energy, Alternative Fuels and Advanced Vehicle Data Center, www.afdc.energy.gov/afdc/incentives_laws.html, retrieved Oct. 1, 2009.

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- Arizona high occupancy vehicle (HOV) lane exemptions and alternative fuel vehicle parking incentives

The main PHEV/EV purchase incentive is the Federal Qualified Plug In Electric Drive Motor Vehicle Tax Credit. It provides to vehicle owners who place PHEV/EV in service after December 31, 2009 $2,500 plus $417 for each kWh of battery capacity over 4 kWh, limited to $7,500 total for light-duty vehicles. Owners may receive larger amounts for larger vehicles, up to $15,000. It is available for light-duty vehicles and trucks up to 4 tons GVWR. The credit expires when the manufacturer reaches 200,000 vehicles produced. NCI assumes persistence of this tax credit until each manufacturer reaches its 200,000 vehicle production limit, this is assumed to occur in 2018 and be consistent with 2018 sales and vehicle population levels. Repeal of the Federal tax credit prior to 2018 would likely have significantly adverse impacts on PHEV/EV adoption. A complete list with descriptions of Federal and State incentives applicable to electric drive vehicles are shown in the Appendix D.

On September 15, 2009, the U.S. Environmental Protection Agency (EPA) and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) issued a joint proposal to establish a national program consisting of new federal vehicle standards for greenhouse gas (GHG) emissions and improved fuel economy. The standards would apply to model year 2012 through 2016 passenger cars, light-duty trucks, and medium-duty passenger vehicles, and are expected to increase average fuel economy by approximately 5% per year. The proposed standards would create the first federal limits on vehicle GHG emissions. In addition, NHTSA has been directed to set medium and heavy-duty truck MPG standards at the "maximum feasible" levels based on forthcoming National Academy of Sciences studies, but the exact standards levels had not been announced by early 2010.

2.2.6 Customer Economics and Acceptance

The important aspects of customer economics and acceptance are captured in two key parameters, simple payback period and technical potential. Simple payback period is defined as the number of years required for total operating cost savings to equal the incremental first cost of PHEV/EV technology, including vehicles, batteries, and charging systems. The simple payback period analysis uses input data including vehicle costs, infrastructure costs, incentives, and operating costs for electric and conventional vehicles in each segment.

Technical potential is defined as the number of new vehicles sales in each year that could be captured by PHEV/EV. The technical potential analysis uses input data including new vehicle sales, addressable market factors, and income distribution by county.

The Fisher-Pry model uses the results of payback period and technical potential analyses in conjunction with payback acceptance and market penetration curves. These curves are based on the historical penetration rates of many different energy efficiency technologies (not necessarily vehicle technologies) and are used here without modification.

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For the purpose of determining technology penetration, five vehicle/owner categories are considered:

- Light-duty vehicles/privately owned
- Light-duty vehicles/privately owned by wealthy households
- Light-duty/fleet owned
- Commercial truck (4 to 7 tons)/fleet owned
- Commercial truck (7 to 13 tons)/fleet owned.

Other vehicles and owner types are not considered in the technology penetration model. Data sources and assumptions for payback period and technical potential analyses are listed in Appendix E.

2.2.7 Operating Cost

Annual fuel and electricity costs are based on vehicle fuel efficiency and mileage assumptions as well as on gasoline, diesel and electricity price forecasts. No alternative fuel besides electricity is considered in these analyses. For the initial analysis, APS off-peak electricity price was assumed to be $0.052/kWh (2010$) throughout the forecast period. PHEV/EV maintenance costs are assumed to be equivalent to conventional gasoline or diesel vehicles with batteries assumed to last for the life of the vehicle (5 years for light-duty fleet vehicles and 10 years for all others).

Vehicle efficiency and mileage vary for each vehicle/owner type. Privately owned light-duty vehicles are assumed to travel 14,000 miles per year or 10,500 miles per year if owned by wealthy households most likely to use the vehicle as a low-mileage second or third car. All fleet vehicles are assumed to travel 23,000 miles per year. Conventional light-duty vehicle efficiency is based on announced Corporate Average Fuel Economy standards. The standards are discounted by 20 percent to better represent actual fuel economy. Conventional truck efficiency is based on actual 2007 fuel consumption figures for single-unit trucks, remaining unchanged throughout the forecast period.[51]

PHEV/EV efficiency is characterized by electric energy consumption in all-electric mode and, for PHEV, gasoline or diesel fuel consumption in combustion mode. PHEV combustion mode fuel use is assumed to be 70 percent of that of conventional vehicles for similar miles traveled. PHEV are assumed to offer 25 miles of all-electric range and to travel either 28 percent (fleet owned) or 60 percent (privately owned) of total miles without activating the combustion engine.

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[51] The National Highway Traffic Safety Administration has been directed to set medium and heavy truck fuel economy standards, but the levels have not been announced..

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Finally, all fuel efficiency values, which are measured for a typical U.S. climate and do not include air conditioning loads typical of Arizona summer months,[52] are adjusted down to reflect the impact of Arizona air conditioning loads during summer months. For all vehicles, fuel economy is expected to decrease by about 20 percent for seven months per year for an average annual decrease of about 11.7 percent[53].

Gasoline and diesel price assumptions were taken from the U.S. Energy Information Administration's nationwide 2009 Annual Energy Outlook (AEO) baseline forecast[54], as shown in Figure 7. From 2015 to 2030, it shows gasoline and diesel prices to be similar, with less than one percent difference. However, future fuel price is highly uncertain, with up to 50 percent differences between baseline price and high or low price for both gasoline and diesel in some years. Gasoline and diesel prices are significant drivers of the relative economics of PHEV/EV and conventional vehicles, and higher gasoline and diesel prices contribute to quicker customer payback periods and larger adoption rates. This figure illustrates that expected future gasoline and diesel prices expressed in 2010 $ are likely to contribute to PHEV/EV economics provided that gasoline and diesel prices roughly track these DOE forecasts.

[52] For a full discussion of air conditioning load impacts on emissions and fuel consumption see EPA Publications EPA420-R-01-055 and EPA420-R-01-054.
[53] The full 20 percent fuel economy deduction is taken for 7 months per year that average daytime temperatures in the Phoenix area exceed 80 degrees Fahrenheit, with no deduction taken for the other 5 months. Each month is weighted equally for a yearly average deduction of 11.7 percent.
[54] EIA, 2009.

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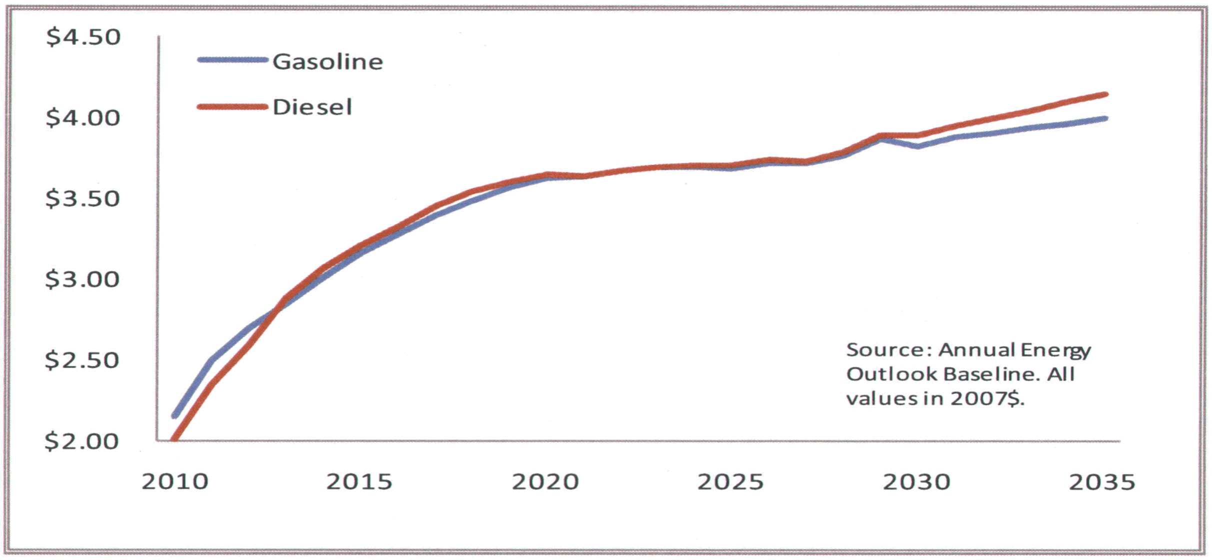
Figure 7: Expected Nationwide Gasoline and Diesel Prices, 2010 through 2035, according to 2009 Annual Energy Outlook.



2.2.8 Rate Structure and Customer Operating Costs

To understand how rate structure and selection of charging strategy might influence operating cost, NCI explored existing APS rate structures and found that off-peak charging strategies were most economic, especially for those customers that were on a two part rate that included both energy and demand charges. Charging duration also played a factor in customer economics with demand charge impacts highest for quick charging (Level 2 & 3) approaches. Residential customers that adopt PHEV/EV and are currently using APS inclining block flat rate structure are likely to face an increase in prices as PHEV/EV energy use triggers the use of a higher block price. Thus, the APS inclining block rate structure will influence most customers to adopt time of use (TOU) rates, i.e. on-peak and off-peak pricing, although a smaller share will adopt voluntary TOU plus demand charge rates. Over 50 percent of APS residential customers are currently on TOU rates, one of the highest shares of residential customers in the nation. These rates allow for on and off-peak pricing for PHEV/EV without the large expense that separate PHEV/EV metering might entail, an issue faced by utilities elsewhere. APS experience shows that residential customers on TOU rates will most often defer charging until the beginning of the off-peak rate period. Use of off-peak rates will reduce residential charging cost to between $0.05/kWh and $0.07/kWh.

To understand the relationship between electric rates and consumer economics and gasoline prices, one of the chief exogenous variables, NCI developed and expanded on an equivalent dollar per gallon metric used in prior studies. NCI calculated the energy, incremental capital and maintenance costs per mile for various PHEV/EV alternatives and compared these to the costs for average conventional new vehicles.

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NCI showed what the cost of a gallon of gasoline would have to be for a conventional vehicle to have the same cost per mile as a PHEV.

The costs per gallon-equivalent for residential and commercial PHEV that pay a demand charge are different for different charging durations. A PHEV with electric storage of 12 kWh charged evenly over an 6 hour period will create an average demand of 2 kW, while the same vehicle charged over a 2 hour period would result in 6 kW of incremental demand. A Level 2 charger could charge the vehicle in 1-2 hours, while a Level 3 charger could charge the vehicle in 15-30 minutes. Where PHEV/EV demand is coincident with the customer's peak demand and the customer pays demand charges, demand charges dominate for shorter charging periods. For example, gasoline might have to exceed about $11/gallon for 15-minute on-peak and about $6/gallon for 30 minute on-peak charging to be cost effective under a residential rate with about a $12/kW-month demand charge. NCI expects that direct 15-minute and 30-minute charging will be cost prohibitive, although some mechanisms for indirect charging through another storage medium may be developed.

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Figure 8: Gasoline Price at which PHEV Becomes Economic Relative to Average New Vehicle - Residential Time of Use Rate w/o Demand Charge (ET1) 2015 with and without Federal tax Credit.

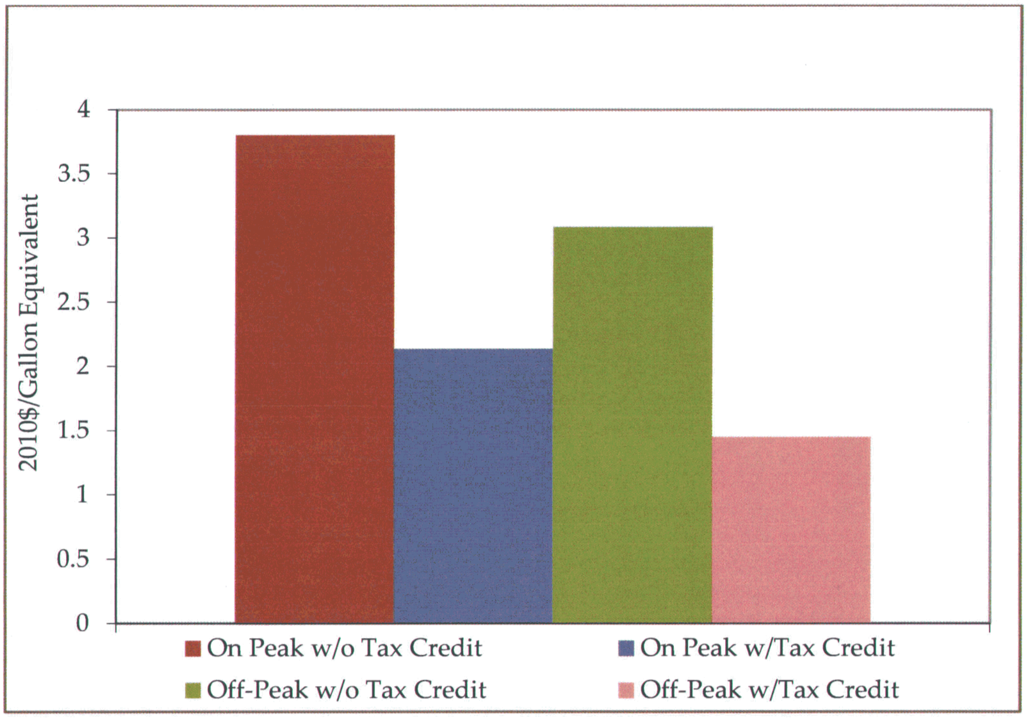


Figure 8 shows the equivalent cost on- and off-peak for APS residential TOU rates (ET1). With tax credits, PHEV would be cost effective under the off-peak rate of ET1, the most commonly used TOU rate, for gasoline prices above about $1.45/gallon-equivalent. The on-peak price with tax credits is $2.14/gallon. Facing a nearly $0.70/gallon-equivalent price savings when charging off peak, NCI expects that residential consumers with PHEV/EV will adopt TOU rates and opt off-peak charging. Figure 8 illustrates that near term customer economics for PHEV are favorable relative to average new vehicles. An equivalent cost of $1.45/gallon for PHEV counting both operating cost and incremental fixed cost shows that PHEV can be economic relative to average new vehicles; at even relatively low gasoline prices. These near term economics are driven in part by Federal Tax credits, target battery life, and projected battery life cycle costs.

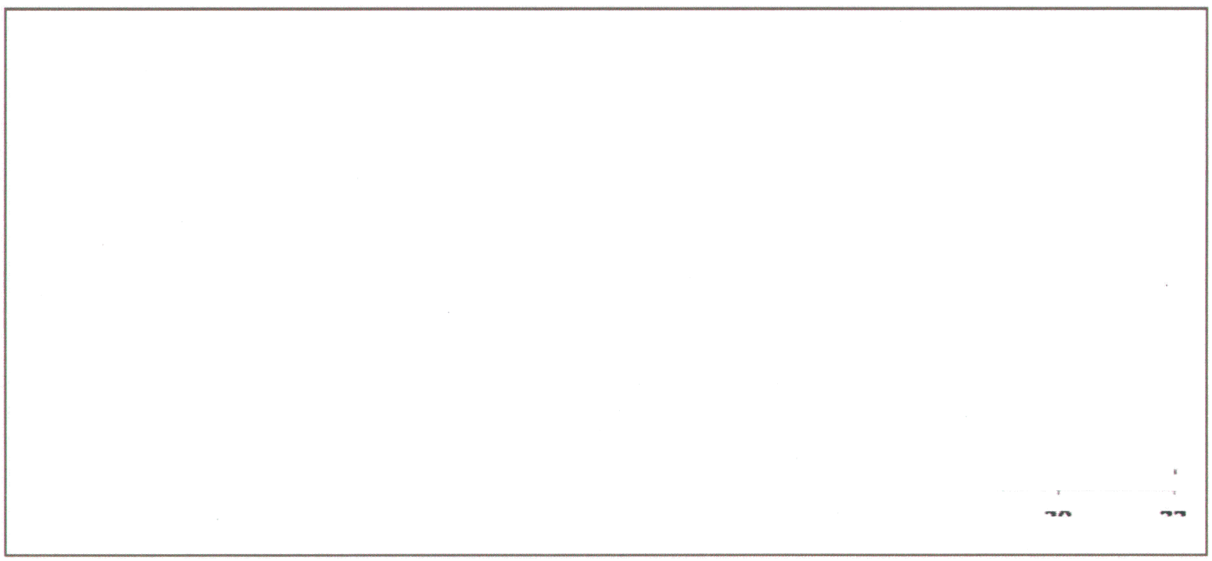
2.2.9 Tax Credits and Customer Operating Costs

The relationship between equivalent cost and Federal tax credits as shown in Figure 8 illustrates that absent Federal tax credits, PHEV becomes economic relative to an average new vehicle at a gasoline price above a $3.80/gallon-equivalent for on-peak charging under the residential TOU rate ET1 and above a $3.10/gallon-equivalent for off-peak charging. ET1- Residential Time of Use Rates has a constant equivalent cost across the range of charging durations because this rate does not include a demand charge component that increases the customer cost as charging duration decreases.

2.2.10 Battery Life Cycle Cost and Customer Operating Costs

NCI based its 2012 battery costs on IEA estimates of $500/kWh for EVs and $750/kWh for PHEVs dropping by 6 percent per year and a battery life equal to the vehicle life. In addition battery cost increases with the ratio of discharge power to stored energy. The higher this ratio, the faster the vehicle can accelerate in electric mode. Doubling the power to energy ratio would increase 2012 NI-MH battery costs to about $1,100/kWh[55]. Battery life also features prominently in the equivalent cost. Figure 9 shows cost as a function of battery life for a fast discharge versus standard discharge battery for various hypothetical battery lives. In 2015, absent the tax credit, nearly $2.09/gallon-equivalent of the operating cost of a PHEV is from battery costs. The shorter battery life associated with current battery technology significantly increases the gasoline price at which PHEV becomes economic although Federal tax credits for PHEV/EV batteries obscure some of these effects.

Figure 9: Battery Cost contribution by Battery Life to PHEV equivalent Gasoline Cost



[55] See NREL Cost-Benefit Analysis of Plug-In Hybrid Electric Vehicle Technology, Conference Paper NREL/CP-540-40485, November 2006 (page 7) for a discussion of battery cost versus power to energy ratio.

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2.2.11 Charging Infrastructure Including Cost, Availability, and Management

Three types of charging systems are currently available and are characterized by their charging power: Level 1, Level 2, and Level 3. These are described in detail in Section 1 - EV Technology and Markets.

For the purpose of determining technology penetration in this study, infrastructure costs from an Idaho National Lab study were used[56]. Each privately owned light-duty vehicle is assumed to use a Level 1 charger at an installed cost of $878 per charger in 2009$ with hardware costs declining by 3 percent per year. Each fleet-owned light-duty vehicle is assumed to use its own Level 2 charger at a 2009 cost of $1,852 per charger with hardware costs declining by 30 percent per year. All fleet-owned trucks are assumed to share a limited number of Level 3 charging systems at a cost of $1,872 per vehicle with costs declining at the same rate as Level 2 chargers. Nevertheless, any vehicle could use a public charging station, with users assumed to pay only the retail cost of electricity used.

2.2.12 Geographic Environmental Factors That Impact Vehicle Performance

Extreme climates are known to be a limiting factor for EV battery range (cold) and power and durability (hot). Also, air conditioning loads on vehicles can be significant in hot climates, reducing efficiency and range. Recently, progress has been made with active thermal management systems that control battery temperature in parked PHEV/EV. These systems are integrated with the battery to maintain a steady temperature. In the coming years, advances in battery technology are expected to raise the operating temperature of Li-ion batteries so these systems can be downsized.

For the purpose of determining technology penetration, all vehicles are assumed to include an active thermal management system that minimizes the effects of the Arizona climate on battery range and durability. The price of the thermal management system is assumed to be included in the incremental vehicle cost.

Batteries are sized for summer driving conditions, when efficiency is decreased due to air conditioning loads. In the future, the impact of climate on air conditioning loads may be reduced through increased use of new solar reflective glass technology and other vehicle efficiency improving technologies.

2.2.13 Carbon Tax on Fuels and Grid Energy

A carbon tax is assessed on the quantity of carbon dioxide emissions generated through the production or use of a product. A carbon tax is one proposed change to the motor fuels excise tax structure in Arizona and other states. Currently, road user fees are collected through motor fuels excise taxes assessed on the basis of the volume of fuel dispensed. In the case of vehicles powered by grid electricity, no road user fees are currently collected through an excise tax. In order to stabilize State road projects as road users increasingly power their vehicles with grid electricity, the motor fuels excise tax may be replaced with a broad excise tax applied to all motor fuels and electricity used for vehicle charging. The tax could

[56] Morrow, Karner, and Francfort, 2009

be assessed on the basis of carbon emissions associated with the volume of fuel dispensed or amount of electricity used for vehicle charging.

For the purpose of determining technology penetration in this study, no change to the excise tax structure currently in place in Arizona has been assumed.

2.2.14 EV Utility Programs and EV Markets in Other States

Utilities across the U.S. are currently evaluating their response to the impending arrival of electric vehicles. Many of the larger utilities (such as Duke, Dominion and AEP) are actively engaging with the various Standards Development Organizations and NIST in an effort to ensure that the operational and customer impacts that will accompany electric vehicles are taken into adequate consideration. However, utilities have so far not been as successful as technology vendors in communicating the significant impact that PHEV/EV will have on their business operations.

There are several regulatory issues that will need to be addressed before utilities are able to fully align themselves with other industry stakeholders. One relates the resale of electricity by non-utilities, which is not presently allowed under federal law and may not be allowed under state law, but will need to be addressed if a robust non-utility public charging infrastructure is to be developed. A second relates to how costs associated with providing customers with in-home charging infrastructure will be allocated and whether a separate revenue grade meter will be required for in home EV charging. A third relates to the development of special tariffs for EV customers to incentivize adoption and/or encourage charging during non-peak times. A fourth issue is that of vehicle roaming and the billing and settlement process associated with out of home-area charges. Each of these involves a highly complex series of issues, questions and legal factors, none of which will be straightforward to resolve, with many requiring both Federal and State involvement.

Coupled with the yet to be defined standards associated with vehicle charging and discharging and the yet to be defined adoption rates of electric vehicles and the assumption that at least initially, adoption will not be uniformly dispersed across the U.S.; utilities, in general, have not yet committed to anything other than very limited vehicle charging pilot programs and participation in various PHEV/EV trials.

2.2.15 Distributed Generation

Small generation facilities often on the customer side of the meter, such as solar panels or customer sited cogeneration are known as distributed generation. NCI did not consider the relative cost of power generated by customer sited cogeneration, but does not believe the relative cost is a significant factor that would increase PHEV/EV penetration. NCI's customer adoption model is keyed to simple payback periods. Distributed solar electricity continues to be significantly more expensive than APS electricity costs, although the gap may narrow somewhat in the future. Given the cost of distributed solar electric power relative to APS rates, NCI does not believe that the possibility of combining solar electric power with PHEV/EV will be a significant factor in improving PHEV/EV penetration. As described in more

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detail in Section 3, relying on distributed generation for PHEV/EV charging will not necessarily reduce utility infrastructure costs if the traditionally high standards of reliability are maintained.

Section 3 - Impacts of Electric Vehicle Charging on APS

3.0 Impacts of Electric Vehicle Charging on APS

3.1 Key Findings

- Overall electric demand from PHEV/EV charging will have a minor impact on the APS system by 2015, on the order of 6-15 MW of added load. This will increase to roughly 87-143 MW of new load by 2025, and to about 1,000-1,400 MW by 2035.
- APS existing time of use rates will encourage off-peak usage, and demand increases from PHEV/EV will be almost exclusively off-peak and relatively small compared to the APS system peak.
- PHEV/EV will reduce emissions of air pollutants in urban areas, although remote stationary emissions may increase due to increases in generation to charge vehicles.
- PHEV/EV will require additional investment in the local distribution system where multiple PHEV/EV may be on a single transformer or local line. Feeder and substation transformer impacts are likely to occur only at higher penetrations due to the off-peak nature of PHEV/EV charging. Broad adoption of faster chargers (Level 2 and 3 chargers) could increase these impacts.

3.2 Detailed Discussion on Impacts of Electric Vehicle Charging on APS Infrastructure

To assess the impacts of electric vehicle charging on APS, projecting the expected pattern of PHEV/EV charging is equally important as projecting PHEV/EV stock. Both residential and commercial charging patterns will vary depending on electric rate structure, as well as customer driving patterns. Utility impacts are driven largely by the PHEV/EV impacts on load, whether those impacts are coincident or non-coincident with other loads on that part of the system, and the costs of addressing those increases in coincident and non-coincident peak loads. The timing of the peak for different elements of the distribution system can vary, as the coincident peak demand of the substation may be different than individual feeders, line taps, distribution transformers, and the system as a whole. Customer charging costs are driven by the customer's energy rates and, for customers that pay a demand charge, the increase in the customer's monthly maximum demand.

NCI reviewed several sources to predict PHEV/EV load shape. We adopted estimates from a recent study at Xcel Energy, modified for differences in Arizona and Colorado load.

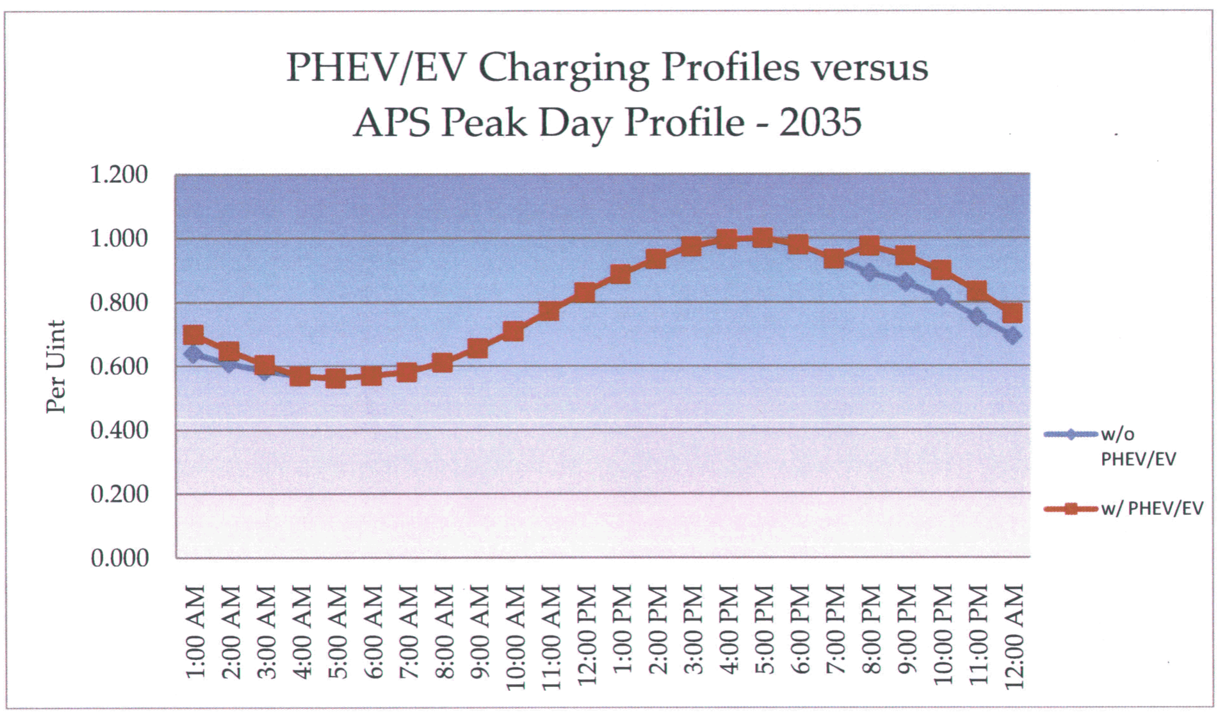
Section 3 - Impacts of Electric Vehicle Charging on APS

Residential customers with PHEV/EV will likely adopt Time-of-Use (TOU) rates and begin charging at the start of the off-peak rate period, thereby maximizing demand with little diversity at the beginning of the off-peak period. Commercial and industrial demand and relatively high on-peak rates place a premium on charging during high demand periods, and these factors are likely to influence fleet owners to adopt an off-peak charging strategy, especially for Level 2 or 3 charging demand.

Between 1998 and 2008, the APS coincident peak increased from 5,072 MW to 7,026 MW. During these years, net of depreciation, APS added (in equivalent 2010 $) an average of about $1.8 B in distribution plant, $1.2 B in generation plant, and $0.7 B in transmission plant. Off-peak PHEV/EV load growth will require distribution investments; however, historic investment levels will not be needed to address long-term increases in PHEV/EV demand since PHEV/EV can rely in part on existing infrastructure and PHEV/EV impacts are unlikely to be coincident with the peak demand on various distribution elements. Short term impacts are expected to be much lower due to modest PHEV/EV penetration and are expected to concentrate in local distribution infrastructure, where multiple PHEV/EV may be served by a single street level transformer or local distribution line.

The impact of PHEV/EV on peak-day load in 2035 is illustrated in Figure 10.

Figure 10: Impact of PHEV/EV Charging on APS Peak Day Profile per Unit of APS Peak Load – 2035



Section 3 - Impacts of Electric Vehicle Charging on APS

3.2.1 Load Impacts

To assess the impacts of electric vehicle charging on APS energy delivery infrastructure projections for PHEV/EV stock and the expected PHEV/EV charging patterns are critical. Charging patterns will vary according to rate structure and the driving patterns of PHEV/EV owners. Utility impacts are driven by PHEV/EV demand coincident and non-coincident with APS distribution and the composite system peaks, and the costs of mitigating the increase in coincident peak demand, where applicable. Customer PHEV/EV charging costs are driven by coincidence with the customer's maximum demand, where demand charges apply, and the cost of electricity during the charging interval.

3.2.2 PHEV/EV Charging Patterns

NCI reviewed several sources to predict PHEV/EV load shapes. Currently, PHEV/EV penetration is low and representative actual load shape data is sparse. PHEV/EV load shapes also depend on local utility electric rates and rate structures. For APS, NCI used PHEV charging load shape estimates from a recent study at Xcel Energy[57] (Colorado), modified for differences between Arizona and Colorado[58]. Xcel Energy also conducted field tests for vehicles in operation, although these tests were conducted on a limited number of vehicles.

Potential PHEV charging patterns for a large population of vehicles is presented in Figure 11 for a variety of charging strategies, including: unconstrained charging, opportunity charging, and off-peak charging. The charging intervals include a 7 PM start, 9 PM start and optimized off-peak charging. The off-peak charging period of APS current residential TOU rate begins at 9 PM for existing customers and 7 PM for new customers. The 9 AM to 9 PM peak period rate became effective 1982 and is frozen; the 12 PM – 7 PM rate became effective in 2006.

Figure 11 highlights the maximum charging intervals for a 100 vehicle sample, expressed as a per unit share of the aggregate demand, that is, as if all vehicles charged at 100 percent of their charger's capacity[59]. The actual charging pattern will vary depending on the electric rates and rate structures. For example, off-peak charging scenarios are more likely where on-peak charging costs are prohibitively high; when PHEV/EV on-peak demand charges contribute a high share of PHEV/EV charging costs or where customers place a high premium on the savings that off-peak TOU rates provide. Unconstrained charging is more likely under flat rate structures where customer charging costs are independent of the time at which they charge. Given the typical driving range of PHEV/EV, unconstrained charging is likely to begin when customers return from work in the early evening. Opportunity charging represents a deliberate strategy by customers to ensure the vehicle is fully charged by plugging the vehicle in whenever it is not in use.

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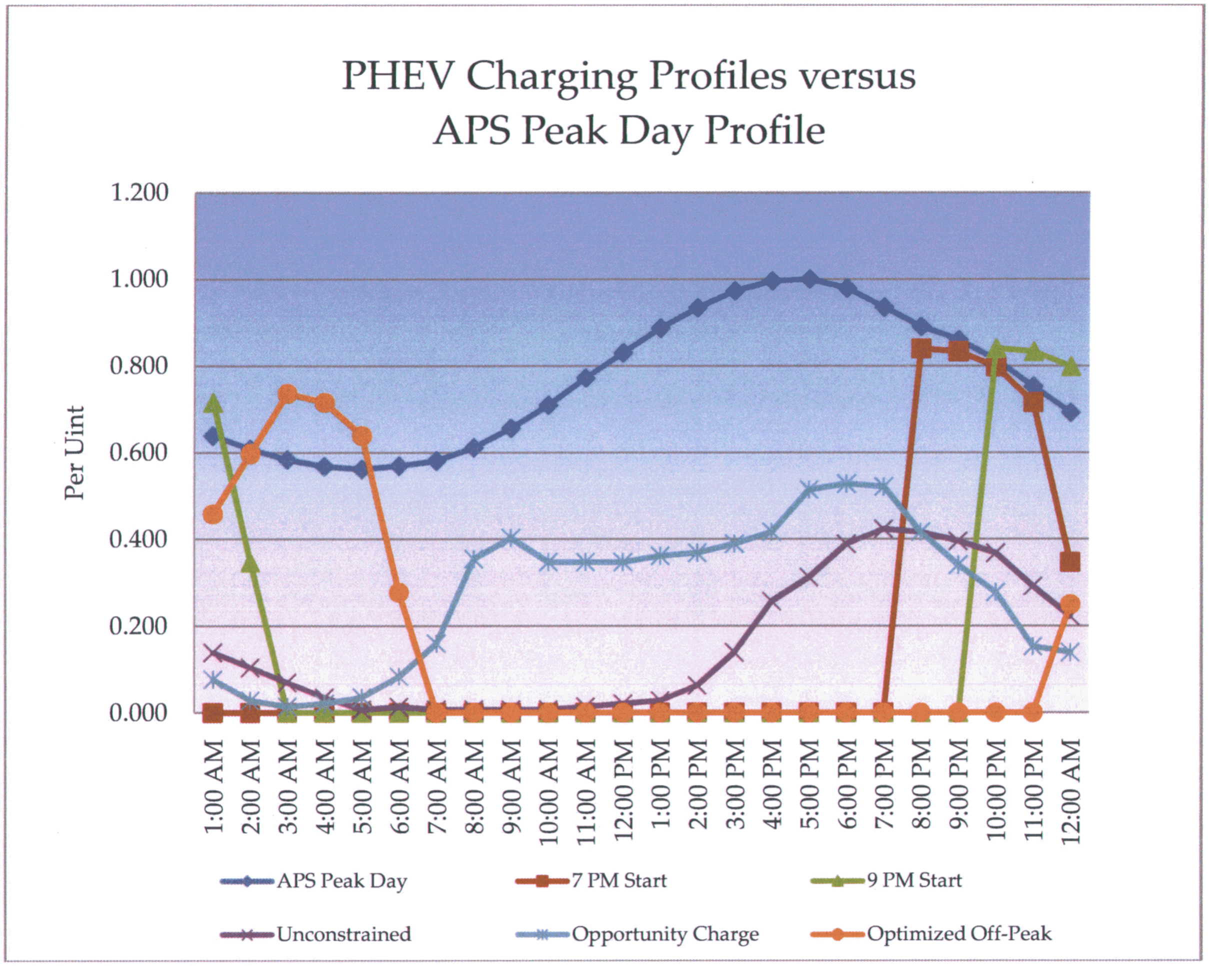
[57] Field Testing Plug-In Hybrid Electric Vehicles with Charge Control Technology in the Xcel Energy Network, Markel, Bennion, Bryan, Giedd, Kramer, May 29, 2009.

[58] For example, APS has two sets of time of use rates, the off-peak period of which begins at 7 PM and 9 PM, respectively.

[59] For example, the maximum of 100 vehicles charging at Level 1 (1.44 kW apiece) would be 144 kW.

Section 3 - Impacts of Electric Vehicle Charging on APS

Figure 11 – PHEV Charging vs., APS Load Profile per Unit of Maximum Aggregate PHEV/EV Demand



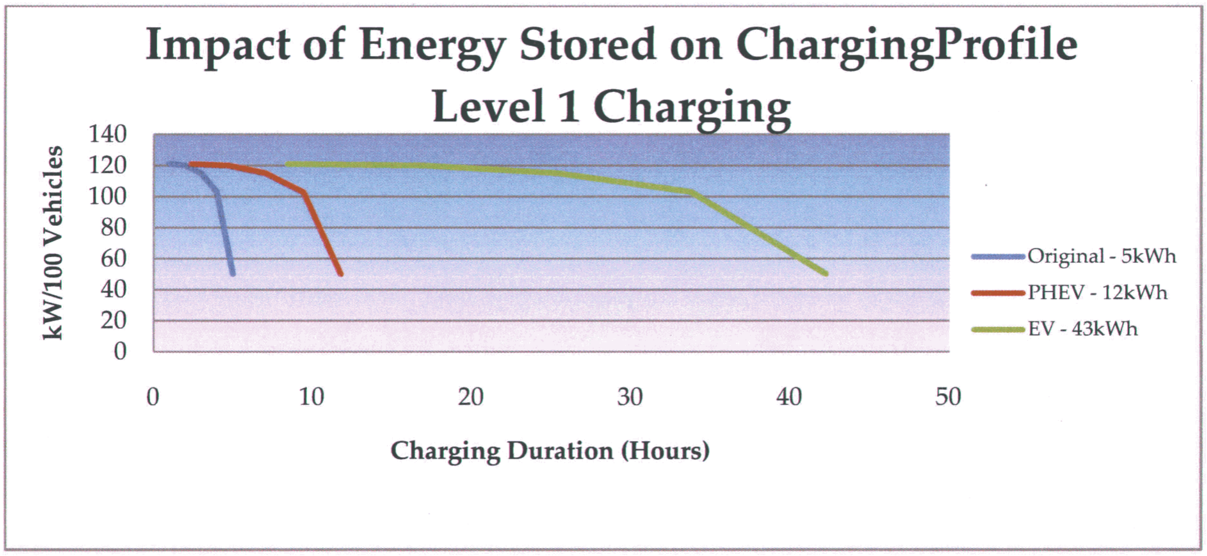
Unconstrained and Opportunity Charging strategies have a relatively high degree of coincidence with the average APS daily system peak. The 7 PM Start and 9 PM Start strategies are likely to avoid an increase in the APS system peak. In contrast, there can be a high degree of coincidence at the distribution level among vehicle owners who simultaneously begin their charging cycle at a particular time, e.g. 7:00 PM or 9:00 PM. In this case, the maximum PHEV charging demand is higher than it would be if customers were to follow an unconstrained charging strategy.

Using similar assumptions for vehicles beginning charging in each hour, NCI modified the Xcel charging load shape based on the energy required and the maximum charging rate. To store more energy for a given charging rate, charging duration must increase beyond the 5 kWh storage assumed in the Xcel Study. The initial Xcel load shapes were developed assuming an approximately 5 kWh of storage and a Level 1 charging infrastructure. Figure 12 illustrates how the residential vehicle charging profile might

Section 3 - Impacts of Electric Vehicle Charging on APS

vary as the energy to be stored increases at a constant Level 1 charging capability. Accordingly, APS PHEV and EV energy storage are likely to be significantly higher than values for Colorado, largely because of driving range requirements and reduced energy efficiency attributable to increased air conditioning loads in Arizona and increased charge requirements for EV technology. NCI simulated APS PHEV and EV requirements at 12 kWh and 43 kWh respectively. Figure 12 shows charging duration and profiles for a PHEV and EV compared to the original Xcel 5 kWh profile. Figure 12 also illustrates that EV would need over 24 hours to charge with a Level 1 charger. Accordingly, charging would be unacceptably long for daily use. However, Level 1 charging would be suitable for overnight charging of a PHEV.

Figure 12 - Impact of Energy Stored on Charging Profile – Level 1 Charging



A similar graph is presented for a Level 2 charger and for a Level 2 charger limited to 3.3 kW in Figure 13 and Figure 14. While a Level 2 charger limited to 3.3 kW may be workable for PHEV, EV may require unlimited Level 2 charging to fully charge batteries within a reasonable number of overnight hours.

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Figure 13 - Impact of Energy Stored on Charging Profile – Level 2 Charging Limited to 3.3 kW

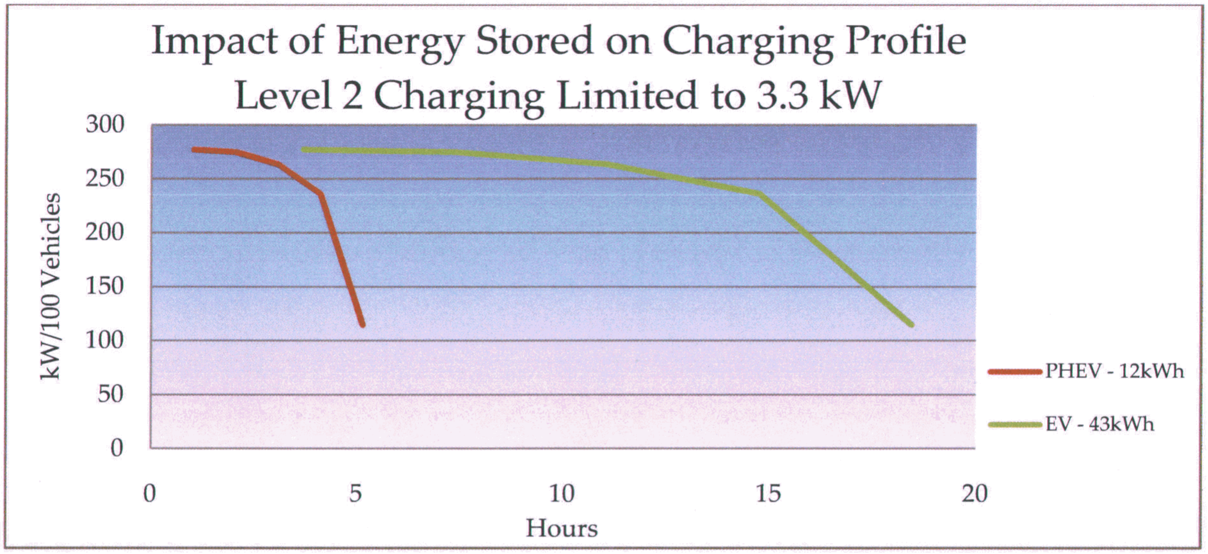

Figure 14 - Impact of Energy Stored on Charging Profile – Level 2 Charging

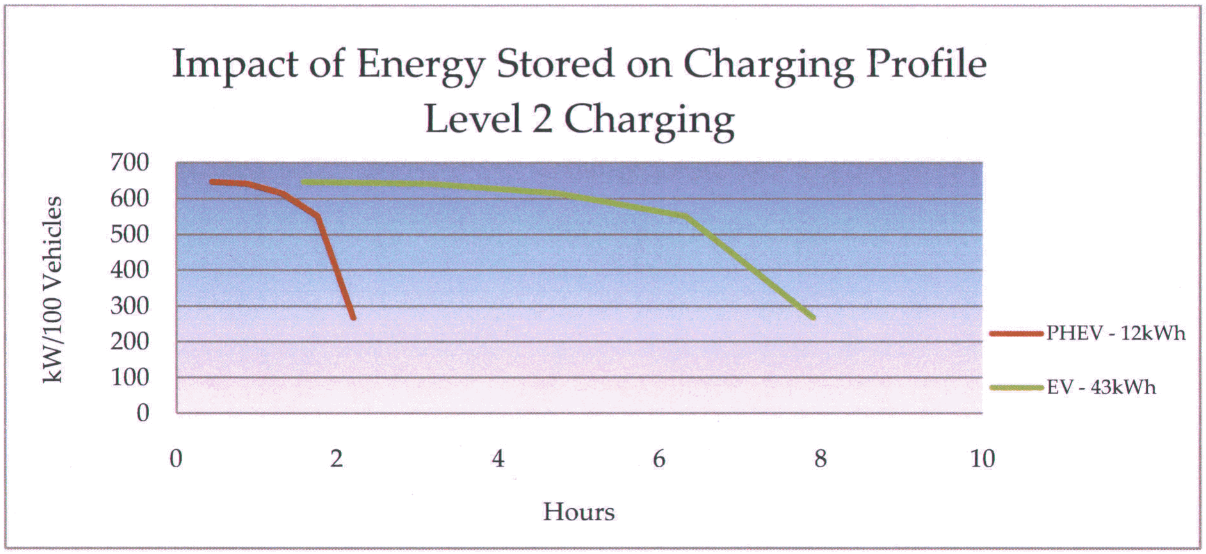

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Figure 15 illustrates that increasing PHEV/EV charging to 12 kWh also impacts the 'Unconstrained' charging load shape, assuming the same number of customers begin to charge in each hour as the 5 kWh case. The increased charging time extends the overlap in charging periods of various customers, and thus shifts and increases the magnitude of the diversified peak.

Figure 15 – Impacts of Increasing Storage to 12 kWh on Unconstrained Load Shape with Level 1 Charging

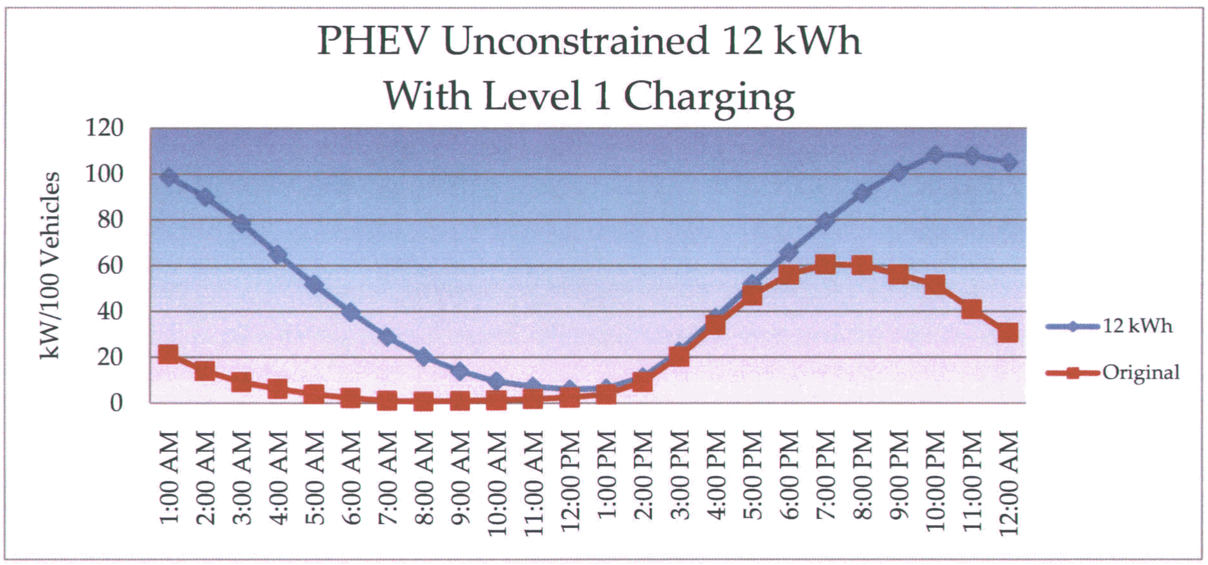

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Figure 16 - Impacts of Increasing Storage to 12 kWh on Unconstrained Load Shape with Level 2 Charging Limited to 3.3 kW

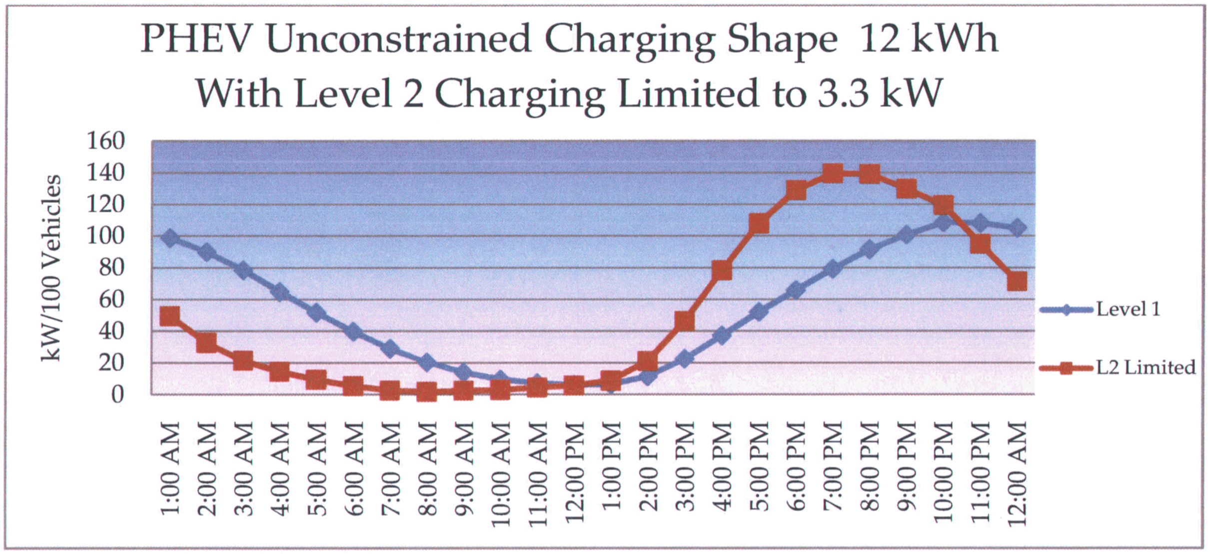
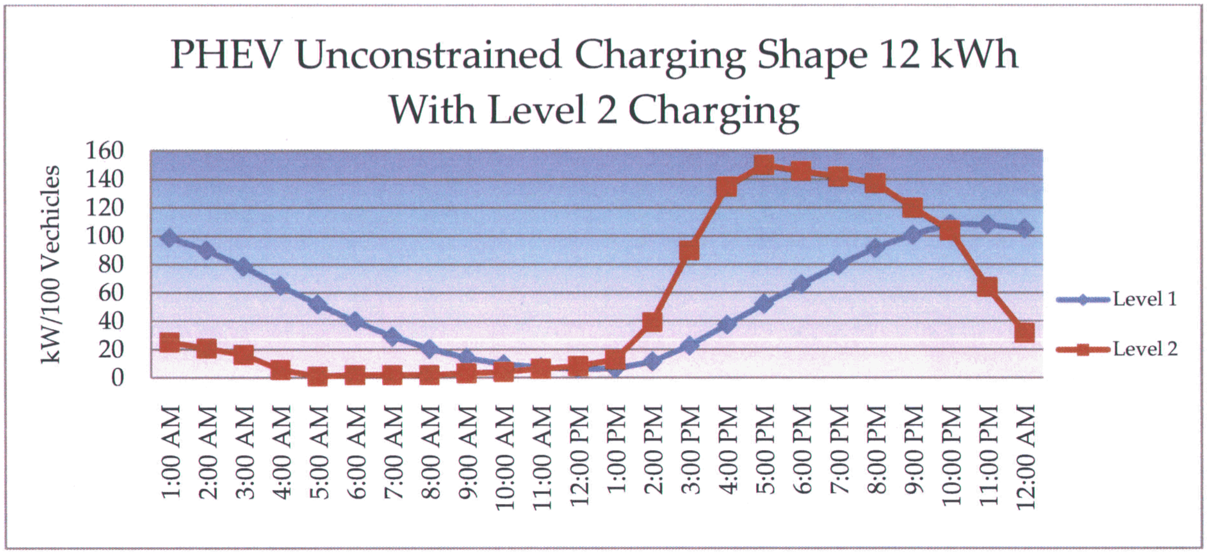


Figure 17 - Impacts of Increasing Storage to 12 kWh on Unconstrained Load Shape with Level 2 Charging



The above figures illustrate that limiting Level 2 charging to 3.3 kW helps delay and reduces the charging peak for both the 7 PM start and the unconstrained charging scenarios, thereby reducing the magnitude of the increase in coincident with the APS system peak. Further, NCI assumes that PHEV would employ Level 2 charging limited to 3.3 kW while EV will require and use Level 2 charging of at least 6.6 kW.

3.2.3 Coincident Peak Demand

As described in Sections 1 and 2, NCI expects residential customers purchasing either PHEV or EV to adopt time of use rates. Currently, about 12.5 percent of existing residential customers are eligible to use time of use rates with an off-peak period starting at 7 PM. (New customers must use a 7:00 PM TOU start time). Currently, 38.3 percent of customers use time of use rates with an off-peak start time of 9 PM. As the former category applies to new time of use customers, NCI expects that long term PHEV/EV load growth will be primarily in the former category, or '7 PM Start'. Thus, NCI uses the '7 PM Start' Level 2 load shape for EV, and '7 PM Start' Level 2 limited to 3.3 kW for PHEV loads to simulate these loads. NCI scaled EV load shape in proportion to energy stored to reflect the charging demand of commercial vehicles, light and medium trucks. Table 7 summarizes these findings and shows the maximum impact of a large number of vehicles (diversified demand) expressed in kW per kWh stored. As shown in Figure 11, the maximum of the diversified demand will occur at 7 PM or 9 PM, depending on the time of use rate in use. While the allowed start time is 7 PM or 9 PM, most but not all vehicles will be charging during the starting hour, and the maximum diversified demand is smaller than the sum of the charging demand over all vehicles. The effect of diversity is more pronounced for the unconstrained charging shape where residential customers begin to charge when they return home.

Table 7: Demand for Each Unit of Daily Charging Energy

Charging Strategy	Diversified–Demand (kW/kWh)	Demand Coincident with System Peak (kW/kWh)
	Level 2 – Limited to 3.3kW	
PHEV 7 PM Start	0.231	0.000
PHEV 9 PM Start	0.231	0.000
PHEV Unconstrained	0.113	0.087
	Level 2	
EV 7 PM Start	.150	0.00
EV 9 PM Start	.150	0.00
EV Unconstrained	0.104	0.060

3.2.4 Aggregate Demand and Energy Impacts Associated with Expected PHEV/EV Adoption

The incremental electricity energy use associated with projected PHEV/EV adoption is presented for commercial and residential vehicles by daily charging cycle in Table 8 and by year in Table 9. By 2035, NCI expects incremental energy use to increase by about 7,100 MWh per daily charging cycle or about 1,850 GWh per year assuming 260 deep charging cycles each year. NCI expects PHEV/EV energy growth to occur mostly toward the end of the study period as the stock of PHEV/EV increases with prolonged and robust PHEV/EV sales. Early term impacts are likely to be relatively minor compared to impact of APS native load growth.

Table 8: Total PHEV&EV Electric Energy Use (MWh/Daily Charging Cycle)

Year	Residential	Commercial	Total MWH
2015	17	28	***45***
2025	178	446	***624***
2035	3,395	3,729	***7,124***

Table 9: Total PHEV&EV Electric Energy Use (GWh/Year)

Year	Residential	Commercial	Total MWH
2015	5	7	***12***
2025	46	116	***162***
2035	883	970	***1,853***

Table 10 shows that off-peak demand increases by about 1,000-1,400 MW or about 9 percent of the expected 2035 peak load. This off-peak load growth is not enough to cause off-peak load to exceed on-peak load. Again, the impacts are weighted most heavily toward the end of the study period. Optimizing off-peak charging demand or staggering start times can decrease peak load impacts. NCI shows a range of demand levels that depend on the charger size and coincidence of the beginning of the charging period. The highest demand occurs when all customers use Level 2 charging and simultaneously begin off-peak charging. The lower levels of demand would occur if PHEV/EV customers were split among those customers using TOU rates that begin at 9:00 PM versus those with TOU rates that begin at 7:00 PM. Some limited share of customers may not use time of use rates or wait for off-peak charging, and this could also reduce the diversity of the load impact. Thus, while NCI uses the higher impact estimate associated with all customers using a single off-peak period, a lower value associated with a more diverse rate selection is also presented.

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Table 10: Total PHEV/EV Off-Peak Demand Impacts (MW)

Year	Residential	Commercial	Total MW
2015	2-7	4-8	6-15
2025	23-52	64-91	87-143
2035	489-676	538-734	1,027-1,410

The combined impacts of the PHEV and EV load shapes on APS 2035 peak day load shape is summarized in Figure 10. Although PHEV/EV is likely to increase aggregate maximum off-peak demand and may require a second ramp up period, PHEV/EV load growth alone is unlikely to create a secondary peak. NCI believes that unconstrained charging is unlikely in APS service territory given APS inclining block rate structure and significantly reduced rates for off-peak charging. Table 11 shows what the maximum non-coincident demand associated with unconstrained charging would be if all PHEV/EV charging were to take the unconstrained load shape, and Table 12 shows the coincident demand. The table illustrates the adverse on-peak consequences that could occur absent strong incentives for off-peak charging such as incentives provided by APS time of use rates. Although the maximum non-coincident demand is lower for unconstrained charging than for off-peak charging starting at 7 PM or 9 PM, unconstrained charging would create significantly more on-peak demand. Annual results are shown in Appendix I.

Table 11: Total PHEV/EV Maximum Non-Coincident Demand Impacts (MW) of Unconstrained Charging If All PHEV/EV Charging Were to Be Unconstrained

Year	Residential	Commercial	Maximum MW
2015	2	3	5
2025	19	47	66
2035	357	392	749

Table 12: Total PHEV/EV Coincident Demand Impacts (MW) of Unconstrained Charging If All PHEV/EV Charging Were to Be Unconstrained

Year	Residential	Commercial	Maximum MW
2015	1	2	3
2025	12	28	40
2035	215	235	450

3.2.5 Broad Implications of Increased APS Load from PHEV/EV

To predict the impact of PHEV/EV charging on APS power delivery infrastructure, NCI identified functional portions of the system most sensitive to load growth. An initial review of APS FERC Form 1 from 1998 to 2008 indicates APS peak load grew from 5072 MW to 7026 MW, an average increase of about 3.3 percent (195MW) per year. NCI then compared load growth over this period to the average real dollar growth of capital investments net of depreciation expenses in three functional categories defined in the following FERC Form 1 Accounts: Distribution Plant, Transmission Plant, and Production Plant. Distribution Plant includes assets such as distribution substation equipment, poles and fixtures, overhead conductors, etc. Transmission Plant includes high voltage towers, conductors, and transmission substation equipment. Production Plant includes generation equipment.

While these broad indices do not provide an indication of all potential incremental cost impacts of PHEV/EV, they do indicate the rough relative magnitude of these investments and their dependence on coincident system peak load growth, among other factors. Net of depreciation, APS added in equivalent 2010 $ an average of about $1.8 B in distribution plant, $1.2 B in generation production plant, $0.7 B in transmission. While a portion of the net plant was added to serve new customers and equipment replacement, load growth required greater distribution investment than generation or transmission investments. NCI expects little or no incremental transmission or generation investment due to the largely off-peak PHEV/EV load. Even with predominately off-peak charging, PHEV/EV load growth will require additional capital investments in the local distribution system. While there may be existing capacity off-peak at the distribution feeder and substation level, secondary line and service transformer upgrades are likely even for relatively low PHEV/EV adoption levels, as these impacts are localized

Previously, NCI showed that coincident system peak impacts are most likely from customers that pay flat electric rates versus those with demand billing or time of use rates. Consequentially, the increase in coincident system peak may be relatively minor compared to the increase and impact of off-peak demand. Incremental PHEV/EV charging demand is likely to have a greater impact on local distribution investment. While the initial adoption rate for PHEV/EV will be modest, it will require new investments in the local distribution system, where multiple PHEV/EV may be on a single transformer or local line. Feeder and substation transformers may require upgrades for higher PHEV/EV adoption. For most levels of PHEV/EV adoption, existing transmission and generation capacity likely will accommodate much of the non-coincident load growth and small levels of coincident load growth.

3.2.6 Distribution System Impacts of Increased APS Load Due to PHEV/EV

The near term impacts of PHEV/EV are driven primarily by increases in local distribution capacity requirements. NCI estimated about 6-15 MW of diversified PHEV/EV demand by 2015, growing to about 1,000-1,400 MW of diversified demand by 2035 with relatively minor increases in coincident peak demand in the short term. The 6-15 MW of diversified demand in 2015 are fairly nominal, and unless highly localized growth occurs, these amounts are likely to have a minor impact on short term distribution capacity requirements.

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3.2.7 Distribution Feeder and Substation Impacts of PHEV/EV Load

APS distribution feeders typically are rated 10 to 12 MVA, and substations from 20 to 40 MVA. APS has approximately 1,240 feeders and 340 substations with large amounts of composite aggregate capacity. Accordingly, the impact of 6-15 MW of incremental demand of PHEV/EV by 2015 will have a minor impact on feeder and substation loadings. At most, short-term incremental PHEV/EV load might accelerate need dates of one to two feeders and one substation by one year. At an industry average cost of about $1 million per feeder and $5 million per substation (and annual carrying charge of 15 percent), the impact of 6-15 MW would be about $1.0 million, or $100/kW. There can and will be wide variations depending on the location. Over the longer term where the installation of hundreds of MWs of PHEV/EV is expected by 2025 and above 1,000 MW by 2035, APS planners will need to incorporate PHEV/EV impacts into long-term capacity plans.

The relationship between spending for capacity and load growth can be projected over the long term on a $/kW basis. However, APS will need to adjust this relationship to reflect the impact of on-peak and off-peak PHEV/EV charging. The level of charging and start intervals has a significant impact on feeder and substation loadings, as many experience early evening peaks. An example of the impact of PHEV/EV charging on a typical substation and distribution feeders is highlighted for the sample substation. The sample substation is equipped with two transformers, each rated 40 MVA and 7 feeders rated between 10 and 12 MVA. Assuming Level 1 and Level 2 charging and an average residential customer peak demand of 7 kW, the maximum number of vehicles and the number of years capacity upgrades must be advanced can be predicted based on current loading and projected growth.

If one assumes 90 percent loading as the trigger for capacity upgrades, the remaining available capacity can be derived. Assuming some average growth and average coincident PHEV/EV loadings, the number of years before upgrades are needed can be determined. The impact of Level 2 devices with 7:00 PM charging is presented in Figure 18 and Figure 19 for the two station transformers at a sample location. Notably, the addition of PHEV/EV shifts the peak for each station into later evening hours. However, the shift from unconstrained charging to 7 PM start charging significantly mitigates the impact of PHEV/EV installation on the substation coincident peak: approximately five to seven MWs can be added without any increase on the substation coincident peak.

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Figure 18: Sample Transformer Loading Scenarios – Sample Transformer 3 – 7 PM Start

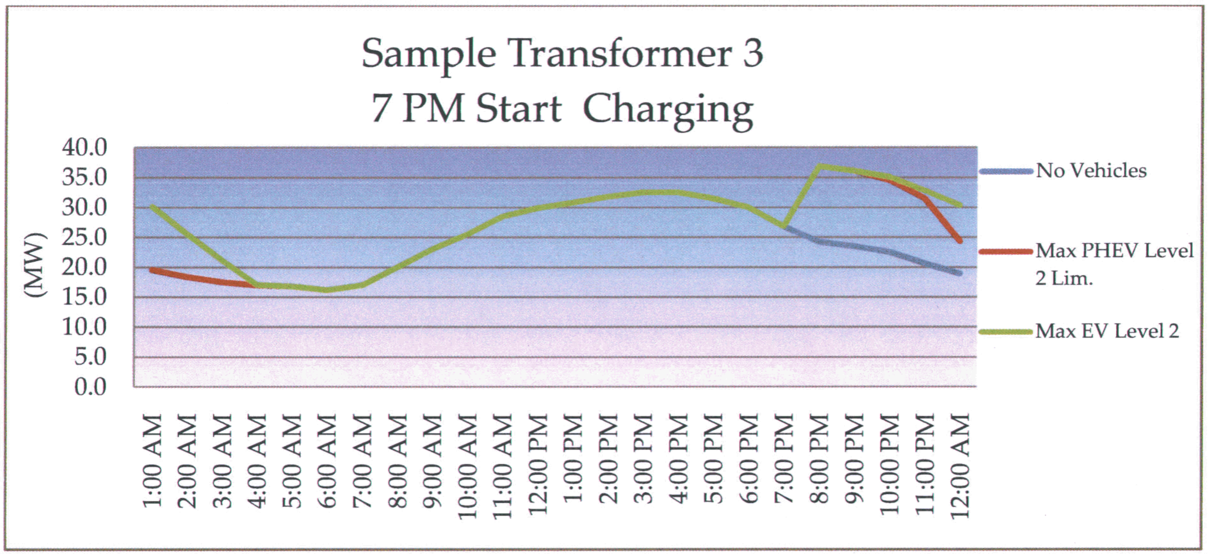
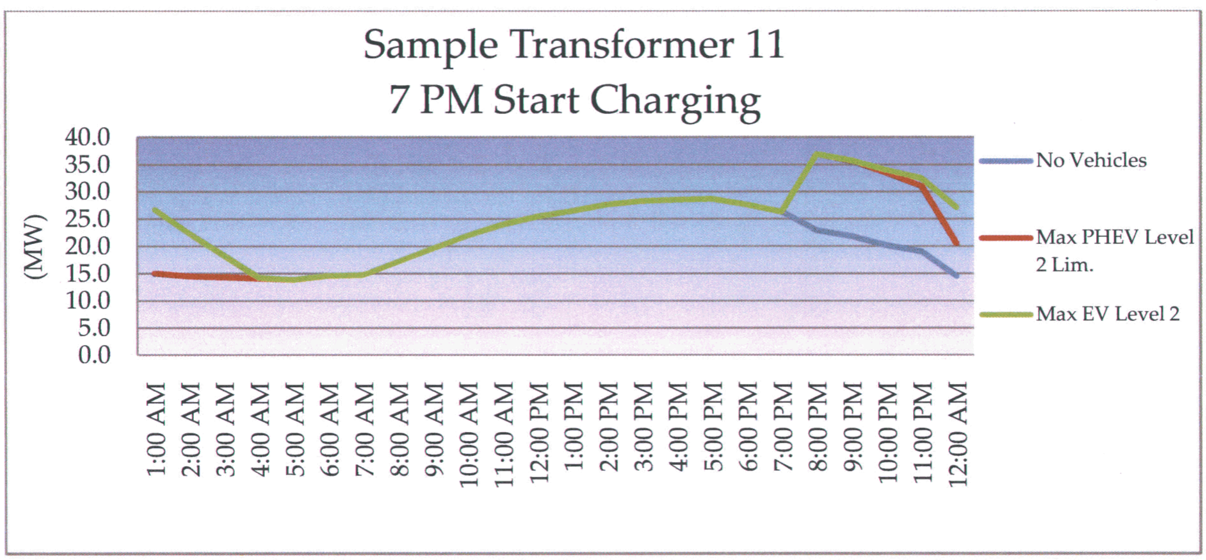


Figure 19: Sample Transformer Loading Scenarios – Sample Transformer 11 – 7 PM Start



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The current peak loads of about 28 MVA and 33 MVA of the sample substation transformers indicate 8 MVA and 3 MVA of available capacity remains for each device. For the unconstrained, 7:00 PM start and 9:00 PM start scenarios, the number of vehicles the two transformers and seven feeders can accommodate before exceeding loading limits can be estimated. Similarly, the number of vehicles each feeder can accommodate assuming a 90 percent upgrade trigger can be estimated as well. The feeder charts displayed illustrate the amount of PHEV/EV that can be accommodated by the remaining feeder capacity for three of the sample feeders. Similar to the substation peak, the shift from unconstrained to 7:00 PM charging start times mitigates the impact of PHEV/EV installation on the coincident peak for the sample substation and Feeders 13 and 14; Feeder 12 has a flatter evening load profile and PHEV/EV additions will have a more significant impact, even for the 9:00 PM charging start time. We expect this phenomena also exists on other parts of the APS system. Some feeders and substations in parts of the APS system likely experience early afternoon peaks. In these locations, the amount of PHEV/EV that can be accommodated will be proportionately higher.

Figure 20: - Sample Feeder Loading Scenarios – Sample Feeder 12 – 7 PM Start

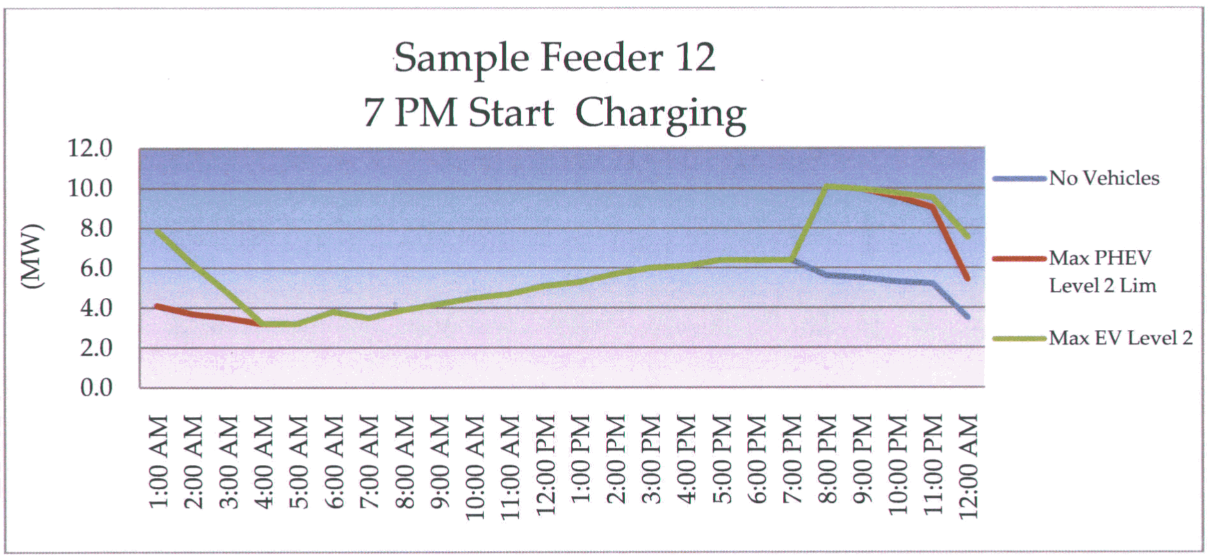

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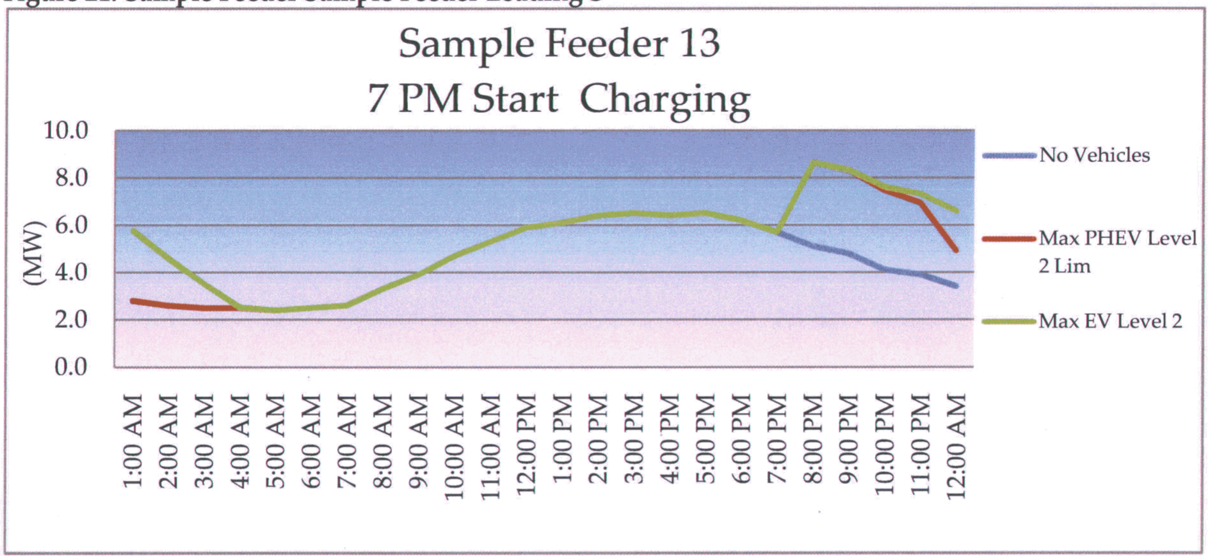
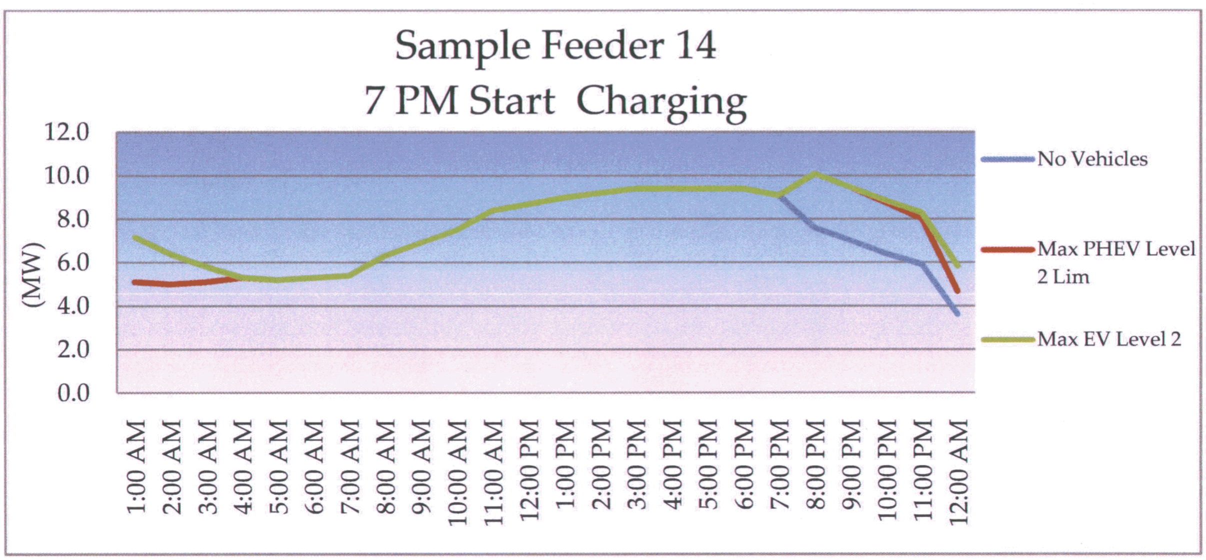
Figure 21: Sample Feeder Sample Feeder Loading S



cenarios – Sample Feeder 13 – 7 PM Start

Figure 22: Sample Feeder Sample Feeder Loading Scenarios – Sample Feeder 14 – 7 PM Start



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The above example illustrates how the diversity of feeder peak loadings can limit the number of vehicles that can be added before distribution capacity upgrades are needed. The need dates for new capacity can be further delayed by employing a control strategy that limits the number of vehicles allowed to simultaneously charge; advances in SmartGrid control technology may be more prevalent in the later years where PHEV/EV penetration is projected to be much higher than the modest levels projected over the next five years.

The process illustrated above can be repeated for all feeders at the sample location under different charge start times. Results are summarized in Table 13 for Level 2 charging.

Table 13: Sample – Number of Vehicles per Charging Starting Intervals

Sample Feeder/Transformer - Maximum Number of PHEV/EV Vehicles before Triggering Upgrade									
Charging Scenario	XFMR 11	XFMR 3	Fdr 1	Fdr 2	Fdr 3	Fdr 4	Fdr 5	Fdr 6	Fdr 7
Unconstrained	2,652	2,008	202	724	921	1,589	744	558	438
9 PM Start	2,597	2,226	569	702	739	1,155	819	538	661
7 PM Start	2,164	1,963	383	547	692	1,108	726	414	556

The results derived above can be extrapolated by identifying representative substations and feeders that can serve as a proxy for the entire APS system. The mix of substations and feeders should include rural, suburban and urban feeders with the most common capacity ratings and loadings. It also should include diversified feeder and substation peaks; although early evening peaking feeders may be predominant on the APS system, the collective impact of PHEV/EV should be weighted for those locations where charging impacts are less, such as feeders and substation that peak in the early afternoon. Once derived, the average number of years that feeder and substation will be accelerated can be predicted for different charging levels and start scenarios.

Demographics and the location and concentration of PHEV/EV purchased should also be considered. Generally, hundreds or thousands of vehicles can be accommodated at a single substation without triggering an immediate feeder or substation transformer upgrade due to the predominately off-peak nature of PHEV/EV charging. While dividing the number of PHEV/EV likely to be in service across all of the feeders and substation transformers on the system would yield relatively few vehicles per feeder or substation transformer, PHEV/EV concentration may vary from location to location. While it is premature to predict how PHEV/EV concentrations will be distributed, some factors may include the share of residential versus commercial customers, average customer income, share of new versus existing customers and other factors.

3.2.8 Localized Distribution System Impacts of PHEV/EV Load

The PHEV/EV charging scenarios outlined above can impact equipment located at or near customer premises, in some cases to a higher degree than main line feeder and substation capacity. For example, low voltage secondary conductor and line transformers could become overloaded if charging intervals coincide with periods of maximum demand, particularly for older equipment that has become increasingly loaded due to higher electronic and air conditioning load.[60] For example, if a customer with unconstrained Level 2 charging load of 7 kW was added to a 25 kVA transformer serving 4 customers with a coincident peak demand of 20 kVA, the transformer would need to be replaced. The average cost of a replacement device is approximately $3,500 to $5,500, depending on whether the transformer is overhead or pad mount. In this example, the incremental cost to the utility ranges from $500 to $800/kW of PHEV/EV installed. If unconstrained charging or 7:00 PM start times are employed, up to 10 percent of APS line transformers may need to be replaced. The average APS system impact would be approximately $20 to $40/kW per PHEV/EV installation. However, later start times and use of Level 1 charging likely would limit line transformer change-outs to less than three to five percent of those that service customers with PHEV/EV.

The impact of PHEV/EV charging is more difficult to predict for service cables and wires, as utilities asset record systems often do not include low voltage lines – field inspections may be needed in some locations to verify the capacity of these wires and cables. Typically, secondary conductors have sufficient reserve capacity to serve higher future demand; for example, sufficient existing capacity is available to serve new load such as electronic devices and Level 1 PHEV/EV. A reasonable assumption suggests about five percent of Level 2 charging would require service upgrades at an average cost impact of $3 to $5/kW per PHEV/EV installation.

Over the long-term, where PHEV/EV penetration will increase into the hundreds of MWs APS distribution design and planning personnel likely will increase low voltage equipment and transformer capacity design ratings for new subdivisions and services to accommodate higher expected loadings caused by PHEV/EV. Such an approach is justified as the incremental cost of higher rated equipment is expected to be modest compared to change-outs due to overloads. For current or future customers utilizing existing facilities, the increased penetration of PHEV/EV on line transformers will likely cause a greater number of line transformer replacements for PHEV/EV owners that adopt early evening or unconstrained charging. A reasonable estimate of these impacts is to double the cost of replacements to $40 to $80 for each kW of installed PHEV/EV for these charging scenarios.

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[60] APS current design standards provide greater surplus capacity for line transformers, particularly in areas with highest cooling loads.

Section 4 - Vehicle to Grid

4.0 Vehicle to Grid

4.1 Key Findings

- V2G is currently in the research and pilot phase. No commercial programs to allow PHEV/EV owners to discharge to the grid currently exist, and utility test programs where they exist are limited to a small number of vehicles.

- Codes and standards are lagging for V2G/V2B infrastructure. Significant standardization and code development must occur for V2G/V2B to be viable; standards organizations are only beginning to address these issues. NCI projects that such codes and standards will not be available prior to 2020.

- V2G/V2B reduce battery life by increasing deep discharge cycling and may raise warranty issues. The climate in cities like Phoenix poses additional battery life challenges. Meeting DOE deep discharge cycle life and calendar life targets for batteries operating in the Arizona climate and resolving warranty issues will be essential before vehicles can provide V2G/V2B services cost effectively.

- Even with technological improvements, EV has very limited energy storage potential for V2G/V2B, and PHEV has even less. Stored energy available for V2G/V2B is small compared to total PHEV/EV electric storage capacity, once driving needs and 'spare tank' capacity are considered. This significantly limits how much energy PHEV/EV can store off peak to inject into the building or grid on peak.

- APS residential time-of-use rates would provide a significant incentive to store energy off peak to deliver to the building on peak even after conversion, storage, and inversion losses are considered once battery cost penalties associated with deep discharge are addressed. Retail rates will provide better incentive than wholesale rates, and customers will focus on providing V2B services.

- If implemented, V2G/V2B might be expected to have positive emissions attributes as off-peak emissions, often from gas-fired combined cycle units, displace less efficient on-peak often gas-fired combustion turbine generation; however, battery storage and conversion losses largely negate these gains, and some pollutants may increase as a result. The overall impacts are small due to low V2G/V2B energy injections.

- Although the on-peak to off-peak rate differentials exceed battery storage and conversion losses, costly battery life reductions associated with today's lithium ion batteries will likely be cost prohibitive for regular deep discharge use. By 2020, advanced lithium ion batteries with significantly improved durability and increased cycle life in all climates may be available, and vehicle owners may be able to provide energy to the building or grid without significantly sacrificing battery life.

4.2 Detailed Discussion of Vehicle to Grid

Many utilities across the U.S. are currently evaluating their response to the impending arrival of electric vehicles. Many of the larger utilities (such as SoCal Ed, Duke, Dominion, and AEP) are actively engaging with the various Standards Development Organizations and the National Institute of Standards and Technology (NIST) in an effort to ensure that the operational and customer impacts that will accompany electric vehicles are taken into adequate consideration.

Despite certain press reports (such as the Tesla announcement that it is working with PGE on a V2G program[61]) no V2G programs have emerged to serve as a starting point for this review. Several groups including EPRI, EEI, the Utility Standards Board, Department of Energy and numerous other government agencies, user groups and industry consortia are considering vehicle to grid programs at a conceptual and early technical level. They are exploring V2G technical potential and are at a very early stage of identifying required technologies and their potential.

The electric transportation industry is currently focused on issues relating to PHEV/EV charging and first generation electric vehicle technologies, and widespread V2G programs are unlikely to emerge before 2020. However, there are some issues and technologies which are currently being explored which, once considered and resolved, will provide a number of foundational building blocks upon which such programs will be constructed. These include the following:

- Safety concerns – battery safety and building codes
- Charging/discharging equipment – home, business and public infrastructure
- Participation processes – value propositions and program designs
- Manufacturer acceptance and participation – standards development and adoption
- Standards for equipment, system communications, security, etc. - standards development and adoption
- Vehicle energy storage system impact (including travel range and battery life) – technologies and grid integration
- Environmental impact of V2G supply compared to incremental peaking power energy and capacity requirements – generation and distribution system impacts

[61] http://www.teslamotors.com/media/press_room.php?id=667 – Press release notes that the program is focused on 'smart charging' NOT battery discharge to the grid.

- Impact of discharging on drivers' travel requirements – travel patterns and range awareness
- Price needed to make V2G program attractive to vehicle owners – incentives and program design
- Billing and information system requirements – billing, settlement and 'roaming'
- Other barriers affecting vehicle owners' participation in V2G program
- Management of environmental attributes (REC's, carbon credits, White tags)

Additionally, there are a number of threshold customer cost issues that will likely prevent V2G/V2B programs from being a cost-effective means for regular energy storage use. These include battery storage, conversion and inversion losses, potentially significant reductions in battery life due to increasing discharge depth, and warranty issues. Once warranty issues, V2G/V2B business models, costs, and codes and standards and other issues are addressed, there may be some commercial potential.

The Mid-Atlantic Grid Interactive Cars Consortium, a group including the University of Delaware, Comverge, PHI and PJM, provides a simple definition of a Vehicle-to-Grid (V2G) program:

> *"V2G allows electric-gasoline hybrids or fully-electric vehicles to provide power back to the grid. V2G technology utilizes the stored energy in electric vehicle batteries to contribute electricity back to the grid when the grid operators request it.*
>
> *The key to realizing economic value from V2G is making the power available without compromising driving requirements of any one vehicle owner, yet having the aggregate of vehicles meet the time-critical "dispatch" needed by the electric distribution system.*
>
> *With a plug-in car, you are driving an electrical storage system. The cost of such storage can be shared between the electrical system and the transportation system, making it economically more efficient. The average U.S. car is driven one hour per day, and the electric system could make good use of it the other 23 hours. Using IP or broadcast protocols, utilities grid operators can "talk" to plugged-in cars, buying electricity from car owners when it is needed, and selling it back when demand is lower."*[62]

They argue that V2G requires the following:

1. *"A plug-in car - Either a plug-in hybrid or pure electric.*
2. *Control Signal from the electric grid - In most areas of the US, the Independent System Operator (ISO) provides an electronic signal to request frequency regulation, reserves, and other forms of fast-response, high value power. Additionally, a local utility may want to signal for other V2G services, such as peak load shedding or relief on targeted parts of the distribution system.*
3. *Computing to mediate driver and grid needs - There must be intelligent mediation between driver needs and grid operator needs."*[63]

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[62] Mid-Atlantic Grid Interactive Cars Consortium

[63] ibid

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In its "Smart Grid Charette Report"[64], December 2008, the Rocky Mountain Institute outlines six ways in which an electric vehicle might interact with the grid:

1. V0G (Convenience charging): vehicle starts to charge as soon as it is plugged in, like a typical appliance.
2. TC (Timed charging): vehicle does not charge until a given time (from an installed program or a signal from the utility) when rates and grid load are low.
3. V1G (Smart Charging): vehicle communicates with the grid in real time, and charges exactly when the grid needs it to. The vehicle also can provide ancillary services for extra revenue.
4. V2B (Vehicle-to-Building): like V2G, except the electrified vehicle does not communicate with the grid but instead with an individual building's energy management system.
5. V2G (Vehicle-to-Grid): like V1G, except the car can discharge, allowing a wider range of grid services as well as storage and back-up power.
6. V2G Next Generation Utility (NGU): V2G but in the future, when the grid has become smarter and more reliant on renewables, efficiency, etc.

These scenarios follow a logical chronology and underscore that the industry in 2010 is still wrestling with the first item, convenience charging, and as such, all the issues related to V2G are some years away from being fully identified, let alone addressed and resolved.

While it is impossible to provide definitive 'answers' to how the industry will address these issues – since doing so would require the industry to be much more developed than it currently is - the sections that follow provide insight into the activities and thinking of various organizations and companies who are currently engaged in this evolving space.

4.3 Alternative Utility Programs and PHEV/EV Treatments/Concepts

Utilities across the U.S. are currently evaluating their response to the impending arrival of electric vehicles. Many of the larger utilities (such as SoCal Ed, Duke, Dominion and AEP) are actively engaging with the various Standards Development Organizations and The National Institute of Standards and Technology (NIST) in an effort to ensure that the operational and customer impacts that will accompany electric vehicles are taken into adequate consideration. However, utilities so far have not been as successful as technology vendors in communicating the significant impact that PHEV/EV will have on their business operations.

[64] Rocky Mountain Institute "Smart Grid Charette Report", v2.0, December 2008

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Utilities are aware that their leadership will be required to facilitate the growth of the electric vehicle market; however, the costs associated with over-investing in this still emerging and highly immature market could far outweigh any benefits. Utilities are aware that while the auto makers will produce electric vehicles, consumers may expect that utilities will be responsible for ensuring that they are able to charge and use their vehicles reliably and affordably. This is uncharted territory for most utility companies and will not be easy to navigate.

With significant regulatory, technical, structural, and financial issues still unresolved, utilities are in the main adopting an engaged yet circumspect position with regard to electric transportation as they continue to monitor and evaluate emerging technology. In light of undefined vehicle charging and discharging standards and unknown, and potentially non-uniform adoption rates, utilities are seeking to understand PHEV/EV technologies and how best to support PHEV/EV in their service territories. As yet, none have committed to anything other than limited vehicle charging pilot programs and participation in various PHEV/EV trials.

Appendix G contains several brief profiles that summarize the PHEV/EV program efforts of several utilities in the U.S. and are indicative of the general approach being adopted by the more pro-active utilities across the nation.

APS joins these utilities in evaluating the potential for PHEV/EV in its service territories and has been very active in the electric vehicle space for over 40-years:

- 1967: APS Purchases MARS II EV and drives cross country back to Phoenix.
- 1979: DOE Awards APS EV Testing Contract as a "Site Operator".
- 1979 - 1991: APS uses Jet Industries Battery Electric Vehicle (BEV) in daily operations (meter reading, maintenance, pool cars). APS purchased about 25 vehicles.
- 1989: APS purchases Battery Electric Ford Escorts (EVcorts) BEV.
- 1991: APS wins the Solar & Electric 500 car race at Phoenix International Raceway (PIR) with the APS/SCE Honda CRX conversion powered by a Zinc-Air/NiCad Battery hybrid vehicle. APS won the race going 106 miles during the 2 hour race. APS receives national recognition in magazines and newspapers.
- 1992: APS competes in the Second Solar & Electric 500 at PIR with the Zinc-Air powered race cars. The Honda CRX and Saturn SC. The Saturn drive train was developed by APS/Motorola R&D and could accelerate the BEV to 60 mph in 4.7 seconds, with a top speed of 120 mph. The PIR race was terminated at lap 86 when another race vehicle using a Zinc Bromine battery developed an electrolyte leak.
- 1992: APS participates at the first SAE & Institute of Electrical and Electronic Engineers (IEEE) join conference (Convergence) in Dearborn MI. The APS Saturn with other OEM prototype BEVs were available for Ride & Drives at Ford's Proving Ground. The Saturn demonstrated significantly higher power (150 kW) and higher performance with its advanced variable speed

drive using IGBT's. Proving higher performance than the GM Impact. Five VP's from GM rode in this APS Race Car, which demonstrated that EV could outperform gasoline power car when the weight to horsepower ratio were the same.

- APS Sponsors High School BEV Racing & University BEV Racing (there were thousands of Arizona High School students who participated in these Races).
- APS Sponsorship causes other Utilities to sponsor high schools in their respective states.

- 1993: APS converts a 1986 Lola (Indy Car) to electric. The EV 11 was powered with a 100 kW DC direct drive system and had a top speed of 117 mph.
- 1993: APS wins a competitive solicitation to test Battery Electric Vehicles (BEV) for the U.S. DOE; and secures several BEV for testing.
- 1994: APS is selected as one of 10 sites in the nation for the GM PrEView Drive Program. Through this program APS was provided 10 GM "Impact" electric vehicles to test and evaluate with 40 APS customers including residential charging installation, electric load data collection, etc.
- 1994: APS creates "EV America" which is a formal invitation supported by the 12 largest electric utilities and the DOE for BEV. Specifications were developed and vehicle testing was performed under APS direction at Phoenix Area Proving Grounds.
- 1994: APS creates the EV-12 electric race car with Motorola R&D. Using a 1987 Lola chassis, low drag carbon fiber body, advanced NiCad Fiber Batteries (DOD), and a 300 kW advanced drive train developed by Motorola; the EV-12 could accelerate to 60 mph in 3.2 seconds and had a top speed of 220 mph.
- 1994: APS begin Fast Charge Testing on BEV.
- 1994: APS creates the Specifications for a 30 kW bi-directional Fast Charger.
- 1995: APS & AeroVironment set BEV 24 hour distance record on HYW 210 in Los Angles traveling 1058 miles in 24 hours with its Saturn and Fast Charge.
- 1996: Arizona is chosen as one of four sites in the nation for the sale of the new GM EV1 electric vehicle. APS installs 15 public charging stations, helps with legislation for EV travel in HOV lanes, and legislation for State incentive on EVs.
- 1996: APS receives Valley Forward Crescordia Award for its EV Program.
- 1997: APS begin installing public charge stations in Arizona.
- 1997: APS enter into a contract with Southwest Airlines (SWA) to provide Fast Charging and Batteries for their airport ground support operations. Over a 4 year period APS provides these services to Southwest Airline in Phoenix, San Diego, LA, Orange County, Sacramento, Tulsa, Dallas, Houston, and Chicago. SWA purchased all of the APS equipment in 2001demonstrating that Fast Charge electric power ground equipment was viable.

- 1997: APS working with ITT creates the 400 amp Fast Charge plug and connector for Airport Ground Operations.
- 1998: APS enters into a contract with DaimlerChrysler to provide Fast Charge infrastructure for their BEV Electric Powered Intra City Commuter (EPIC), in California, Arizona, and Michigan (including the Los Angeles Airport cab service where the EPIC's travels over 350 miles per day).
- 2001: APS installs Public Fast Charger at Goodyear and Fountain Hills for Neighborhood Electric Vehicle (NEV) charging.
- 2003: APS files first Charger Patent.
- 2008: APS begins deployment of hybrid electric vehicles as the standard for all passenger vehicles.
- 2008: APS begins testing hybrid electric line truck.
- 2009-ongoing: APS participating in EPRI EV working group.
- 2009: APS deploys first hybrid line truck.
- 2009: APS sponsors Utility Standards Board White Paper on EV Billing and Settlement Issues.
- 2010: APS commits to all hybrid electric lines trucks where feasible.

APS has been, and remains, committed to the evaluation of PHEV/EV technologies and is one of the more active U.S. utilities in this arena - as evidenced by the list of activities provided above.

4.4 V2G Equipment Requirements

4.4.1 Charging/Discharging Equipment

Electric Vehicle charging options will depend on the rate at which the user wishes to charge their vehicle. The desired charging rate will dictate the type of charging equipment they will need to use: Level 1, Level 2 or Level 3. It is likely that Federal and State requirements will change as the PHEV/EV market and associated technologies evolve. However, at present, and based on the assumption that in-home charging will not exceed Level 2 type charging, the following basic charging circuit requirements/components likely will be required for owners of light duty vehicles (in accordance with Federal and State electrical safety codes)[65]:

- Circuit Breaker:
  1. Level 1 - Either a 15- or 20-amp single-pole breaker;
  2. Level 2 - A 40-amp, two-pole breaker.
- Electric Vehicle Supply Equipment (EVSE):

[65] Southern California Edison

1. Level 1 - A 15- or 20-amp standard residential wall plug and receptacle for 120-volt charging;
2. Level 2 - According to the National Electrical Code (NEC), in 240-volt electric vehicle charging equipment installations, the supply equipment should be wired permanently to the electrical supply circuit. The supply equipment may vary in design depending on the manufacturer and vehicle type, but it must meet specifications set forth in the NEC. These specifications include:
   - Equipment that is listed and labeled;
   - Ground fault protection;
   - Diagnostic capability to prohibit charging from taking place when the batteries or the vehicle is damaged or an unsafe condition exists; and
   - An interlock that de-energizes the charging cable when the vehicle is disconnected from the charging equipment, or if excessive strain is placed on the cable/cord.

The charging equipment and permitting requirements of public charge stations, commercial enterprises and heavy-duty transportation concerns will be significantly more complex and are still evolving depending on the business model of the owner and other stakeholders. For example, Better Place[66], which focuses on vehicle battery replacement as opposed to in situ charging, will need to navigate hurdles associated with battery quality standards (since drivers would be leaving the facility with a different battery than that with which they arrived) as well as vehicle safety and warranty issues; this is in addition to a charging infrastructure that would allow them to charge numerous batteries simultaneously.

Coulomb, with its 'park and charge' model, might be able to leverage industrial versions of more simple Level 2 chargers but would, of course, need to add some additional load management tools to their chargers and, of course, billing and settlement tools.

For V2G, the same charging equipment would be used. However, from a battery discharge perspective, required functionalities would need to be addressed in addition to other issues, including those outlined in the following sections.

4.4.2 Vehicle Equipment Required to Enable V2G

The equipment needed to enable vehicles to deliver power to the electric grid varies according to the complexity of delivery options and pricing mechanisms employed by the utility. Three scenarios, each with increasing levels of discharge capability, flexibility and customer/utility benefits, are evaluated below.

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[66] Better Place is a U.S. based startup which is focused on developing EV related products and services. The company advocates battery switching (as an alternative to charging) allowing drivers to exchange their car's depleted battery pack for a fully recharged one in under a minute. The first prototype battery switch station demonstrated in Yokohama, Japan on May 14, 2009.

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Scenario 1 assumes the least amount of equipment would be added to enable V2G discharge. All PHEV/EV grid discharges would be controlled by the customer (i.e., passive control of discharge intervals versus direct utility control), who would receive billing credits or payments based on time-of-use pricing intervals. It also provides the lowest level of customer and utility benefits.

Scenario 2 assumes charging would allow the utility to actively control the time and length of vehicle discharge using two-way communications and controls. Customers would receive higher credits or payments as the utility would discharge V2G when costs are highest.

Scenario 3 is the most complex, and assumes utility control of V2G from locations other than the customer's premises, such as charging stations within and possibly outside of the utility's service territory. Each are described in greater detail below, including the infrastructure, hardware/software, and business process changes needed to enable V2G discharge. It also highlights the monitoring, control, metering, billing energy management, settlement and energy delivery system upgrades or additions needed to provide required functionality.

Scenario 1 – Passive Charging

At its simplest form, V2G can be accomplished using existing time-of-use (TOU) meters. Minimal, if any additional equipment is needed beyond those described previously to meet safety and Institute of Electrical and Electronic Engineers (IEEE) 1547 requirements.[67] The customer would receive credits equal to the time-of-use pricing in effect at the hour of vehicle discharge. This assumes customers will enable vehicle discharge during hours of maximum pricing and would make informed decisions about hours of desired discharge versus expected vehicle usage. A single meter would be used to record on- and off-peak electric usage. It is possible that on-peak V2G discharge would exceed customer electric usage, in which case the customer might receive a monthly carry-over credit or direct payment, depending on the rate design. A variation of this option is to limit vehicle discharge to peak hours using inexpensive TOU meters with relays or contacts that would open the single or double pole switch during off-peak hours; thus, enabling the customer to discharge only during peak load hours.

Scenario 2 – Active Utility V2G Control

Scenario 2 employs sophisticated monitoring and control systems that enable the utility to discharge the vehicle while parked at the customer premise. The vehicle control system would need to be equipped with 2-way communications to enable the utility to monitor the following vehicle status indicators:

- Remaining level of battery charge;

[67] All V2G options assume vehicles will be equipped with controls that will allow customers to operate the vehicle in charge or discharge mode while stationary. The vehicle would have visual displays to indicate level of charge available for discharge, number or hours discharge is available and maximum energy that can be discharged.

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- Discharge mode (e.g. discharge rating);
- Customer override (if allowed by utility);
- Time of day;
- Vehicle availability and diagnostics when discharge (or charging) is limited or unavailable;
- Vehicle and/or battery maintenance (both for customer and utility notification);
- Customer notification of changes in participation, tariff or program selection; and
- Customer override or limited utility control of vehicle discharge.

A Home Area Network (HAN) would be set up to enable wireless communications between the vehicle and the Smart Grid interface. To create the Smart Grid interface, an Advanced Metering Initiative (AMI)/ Smart Grid meter would be equipped to communicate with the vehicle. For example, Zigbee wireless technology may be suitable for the HAN. As an option, a wall-mounted display could be installed in the customer premise to indicate charge/discharge status, including remaining charge available, hours of discharge, remaining discharge hours, energy delivered, and credits. The customer would also be able to view month and year-to-date totals.

Scenario 2 assumes two-way communications between the AMI/Smart Meter. In addition, the energy or distribution control center or organization that would be responsible for dispatching vehicle storage would be equipped with a distribution management system (DMS) with requisite hardware and software systems designed to monitor, dispatch and control each vehicle. (Existing DMS would be modified to include V2G monitoring, control and discharge features.) The DMS would include software algorithms and rule-based logic that would automate the vehicle discharge process. If the V2G program is designed to unload feeder or substation peaks, additional controllers may need to be installed at individual substations.

The centralized DMS would also interface with APS billing and accounting systems to record vehicle energy production by interval. These systems and associated business processes would need to be modified to record PHEV/EV output, and to enable payments or credits for PHEV/EV energy supplied to the grid. Customers would receive billing credit for V2G output according to energy produced during on and off-peak intervals. Customers also would receive supplemental billing reports to inform them of the amount of the credit, accumulated energy production, number of discharge intervals, and any other information that may be provided to the customer. It could include additional credits received if the vehicles are used as a demand response resource, when higher credits would apply. The latter would add greater complexity and modifications to accounting and billing systems, and associated business processes.

Scenario 3 – Distributed V2G Control

Scenario 3 presents the most complex V2G supply arrangement, and contemplates use of charging stations (with both charge and discharge capability) located in parking lots, on-street parking, work sites

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and other suitable locations where customers could easily access charging pedestals. The charging pedestals would be equipped with a wireless communications interface similar to the HAN described above or capable of communicating via cables that would connect the pedestal receptacles to the vehicle. All hardware and software used in public locations likely will need to meet evolving network cyber security standards, particularly if PHEV/EV is to be used to provide operating or capacity support to the electric grid.

Beyond the communications interfaces described above, it is premature to speculate as to what other on-board equipment might be required to enable V2G. Electric vehicle systems are likely to evolve dramatically over time but their role in V2G interactions will be determined against a broad backdrop of overall system architecture and yet to be determined hierarchy of needs. For example, several studies contemplate using the V2G inverter to provide reactive support for steady state reactive power deficiencies or dynamic voltage support during system contingencies. Other applications include providing black start capability or regional support during major contingencies or regional outages. Because the inverters employed today typically operate at fixed power factor, modifications would be needed to provide reactive power support requirements. Similarly, the control system algorithms needed for black start support when all other load is off-line presents potential challenges, including monitoring and real-time adjustment of protection and regulating device for high V2G penetration.

4.4.3 Home and Business Equipment Required to Enable V2G

The primary equipment needed in customer premises to accommodate V2G, beyond those needed for interconnection, protection and charging, is the local area network described above. Other options for communications and control include wide-area networks (WAN) where the utility would control V2G for multiple locations, and thereby avoid the need for an HAN. From a consumer perspective, the installation of wall-mounted display panels that provide vehicle charge and discharge status, energy delivered and savings likely would be a desirable feature – an alternate and less costly approach would be to access the same information via customer-owned computers. However, the cost of wall-mounted displays is expected to be reasonably low.

While a future application might include the ability to operate the V2G as a micro-grid, either for a single location or group of customers, this type of operation is prohibited in the APS service territory for a variety of important operational, legal and regulatory reasons. The additional equipment would include, at a minimum, utility interface devices capable of automatically disconnecting the utility grid from these locations, auto-synchronizing equipment for reconnection, and monitoring and tracking hardware/software that could follow load. It is unknown to what degree inverter design would need to be modified to track customer load and to reduce harmonics to acceptable levels while disconnected from the utility grid.

A summary of equipment that may be needed to enable V2G operation for the above three scenarios is listed in Table 14. For Scenario 2 and 3, we assume the existing systems would be modified to include software that would performV2G monitoring and control functions.

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Table 14: Summary of Required V2G Equipment

Description
(1) Scenario 1 – Passive Charging
TOU/AMI meter
Display Panel
V2G Processor Modifications to Accommodate Discharge
Billing and Accounting System and Process Modifications for V2G
(2) Scenario 2 – Active Utility V2G Control
DMS Modification (Software Only)
HAN Interface
2-Way Communication Systems
V2G Processor Modifications to Accommodate Discharge
Billing and Accounting System and Process Modifications for V2G
(3) Scenario 3 – Distributed V2G Control
Charging Station
DMS Modifications
Substation Automation (for T&D Support Options)
V2G Processor Modifications to Accommodate Discharge
Billing and Accounting System and Process Modifications for V2G

4.4.4 Billing and Information System Requirements to Enable V2G

Utilities play a critical role in establishing the PHEV/EV charging infrastructure, both as the provider (except in some deregulated environments) and the distributor of electricity. PHEV/EV will add load to the power system and could be capable of "smart-charging" and discharging to help manage this load through time-of-use and/or special tariffs. Although PHEV/EV tariff structures and required regulatory changes are as yet unknown, the future will require changes for the settlement and payments processes of utilities and other stakeholders.

NIST's Priority Action Plan (PAP) 11 electric transportation group is considering PHEV/EV settlement and payment processes that may need to be developed or modified, depending on the types of tariffs, regulatory changes, and evolution of technologies and standards that are likely to prevail. The PHEV/EV settlement and payment issues that could most impact utilities include:

- **Separate metering of the PHEV/EV load:** Any tariff that singles out PHEV/EV for special pricing, requires the assignment and tracking of carbon credits, or applies transportation taxes to PHEV/EV loads will require metering of the PHEV/EV load. This necessitates the authentication of load as a "PHEV/EV load", metering that PHEV/EV load with a certified End Use Measurement Device (meter or sub-meter). It also requires a certification process to confirm the use of that device for billing/revenue purposes and the continued accuracy of both utility-owned and privately-owned meters. *(Tariffs that treat all types of loads equally, such as Time-of-Use and Demand Response, would not require certified metering.)*
- **Utility single statement billing:** Providing single statement bills that include PHEV/EV charges will require significant changes in the utility billing systems, if the PHEV/EV charges are to be included with the utility bill for the service location/premise. It will also require the establishment and staffing of a customer inquiry and reconciliation process, and regulatory approval for changes to the billing format.
- **Regional PHEV/EV charging rates:** Plans that provide the same PHEV/EV charging prices everywhere (e.g. tiered or TOU) in a region, regardless of the energy supplier, would require a settlement process that could include TOU metering of energy at the charging facilities, or an estimating mechanism if actual prices are not available or not yet determined. This would require the redesign of settlement and payment systems to accommodate this new process; the establishment of settlement agreements with the plan provider among multiple parties that include charging facilities, utilities, and energy suppliers; and the redesign of rates to accommodate any estimation process.
- **Regulation changes allowing resale of electricity:** Currently, non-utilities are not authorized to resell electricity. If these regulations were changed to allow charging stations to resell electricity to PEVs, different models for providing electricity could arise with as yet unknown ramifications for utility tariffs, settlement requirements, and billing.

- **Location of the End Use Measurement Devices (meter):** The meter can be located at the location of service delivery or on the vehicle. However if the meter were located in the vehicle, new business models, as well as new settlement and payment processes, would be required.
- **Delinquency and non-payment rules:** Utilities have very strict rules with respect to non-payment. These are governed by state commissions which set criteria for refusing service. These criteria may limit the ability to refuse service to a payment delinquent customer during specific time periods. If a utility provides single statement billing, the PHEV/EV charges accumulated on the electric bill would be governed by these rules. This would increase the utility's uncollectable revenue and the risk of nonpayment. It also raises social policy questions such as:
  1. How to proceed if PHEV/EV charging bills are not paid? Can the service to the home be turned off?
  2. How will refusing service for non-payment of PHEV/EV charging related charges are impacted if the PHEV/EV is the primary mode of transportation for employment?
  3. The utility delinquency and non-payment policies currently in force were not intended to consider these and other social issues that may arise as a result of refusing PHEV/EV charging service. They would therefore have to be reconsidered in order to align with PHEV/EV charging and single statement billing.

4.4.5 Safety Concerns and Associated Equipment

As already noted, various electric codes and standards will need to be followed in order to ensure the safe installation of PHEV/EV charging equipment.

As V2G standards requirements are defined, it is likely that several safety considerations will come to the fore to be addressed by the appropriate body.

Many of the standards and issues already addressed by APS and other utilities for photovoltaic solar installations also will apply to PHEV/EV discharging in that an energy system that discharges power to the grid, be it solar or battery, will need to meet interconnection guidelines and requirements:

- It is likely that PHEV/EV capable of discharge into the grid will be required to meet current and future/modified IEEE 1547 interconnection standards:
  1. PHEV/EV operates via an inverter; hence, current rules for photovoltaics, energy storage, micro-turbines and other inverter-based devices will apply to PHEV/EV.
  2. It is likely that IEEE 1547 will be modified to account for the unique operating/charge/discharge characteristics of PHEV/EV; for example, if PHEV/EV are to be used for load following, ramping, voltage control, etc., IEEE 1547 would need to address the rate of charge/discharge, power factor controls, voltage regulation and impact of PQ events including momentary and sustained interruptions.

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3. Other IEEE standards (1741 & 519) require the inverter to operate at unity power factor - a rule based (as opposed to technical) requirement.

- For V2G Level 1 charging & rating less than load plus transformer rating, single pole switch should be sufficient. The level of current is sufficiently low to enable use of 120 volt switching device.
- For V2G Level 2 (or higher) where output is greater than load, the following may be needed:
  1. 240 volt supply (120v suitable for Level 1 charging).
  2. Double pole switch to accommodate 240 volt switching.
  3. Visible disconnect (Note: not all states & utilities agree on this).
  4. Automatic V2G shutdown in vehicle inverter controls with 5-minute minimum shut down per IEEE 1547.
- Distribution recloser operation presents a compelling argument about over-reliance on V2G for capacity support, voltage & power factor control, frequency response service, etc:
  1. IEEE 1547 now requires a minimum 5-minute shutdown when the inverter is shut down because of an interruption (e.g., recloser operation).
  2. During the shutdown, the V2G support also is interrupted. The loss of V2G can impose higher voltage regulation, load following, frequency response on the grid; particularly if an entire substation with high V2G levels is interrupted.
  3. At the transmission level, interruptions are uncommon; in contrast, long feeders can experience dozens of interruptions annually; the availability and reliability of V2G may fall short of transmission-based distributed generation (DG) (or DG with dedicated feeds).
- For high V2G penetration levels, feeder protection systems, including substation relays, line recloser setting and fuse selection may need to be adjusted or additional forms of protection installed:
  1. High levels of back-feed could cause poor coordination of interrupting devices and fuses.
  2. Inverters do not provide fault current (above 1.0 to 2.0 per unit), and should interrupt quickly (with a few cycles), which should lessen the impact.
  3. However, lateral operations could cause significant in-feed from adjacent lines that have not been interrupted.
  4. Significant V2G output, as noted above, could impact voltage regulator operation, local transmission company controls, and protective relaying. The types of protection needed to accommodate PHEV/EV may need to be more sophisticated than current levels.

5. Smart Grid could play a key role in accommodating large numbers of PHEV/EV, as these systems could adjust relay, regulator, and recloser trip settings – real time. Sophisticated controls, algorithms and rules would be needed for SmartGrid to work properly.

- The impact of V2G on distribution feeder and station reliability also becomes a factor at high penetration levels:
  1. If V2G is to be relied upon for capacity support, the 5-minute shut down for recloser and fuse operations must be addressed.
  2. The loss of V2G could create much greater feeder and substation demand, thus creating further overloads (as opposed to providing capacity support).
  3. Large in-rush currents – from load interrupted and restart of PHEV/EV – will impose even higher demand, complicating/extending outage restoration, and possibly causing damage to existing equipment.
- The impact of large non-linear loads on the utility distribution system and customer load has not been fully addressed:
  1. Small amounts of harmonics from a few devices may not be a factor.
  2. Large amounts of V2G can create higher order current harmonics that can de-sensitize relaying, damage utility and customer equipment, create load imbalance, cause over-voltages, create resonant conditions: all to the detriment of the safe and efficient operation of the power delivery system.

4.5 Key Issues and Relevant Stakeholders

4.5.1 The Evolving Market for PHEV / EV

As is the case with all new developments, the PHEV/EV industry is struggling to understand and address the numerous issues that have thus far been presented. The industry is certain that other, as yet unidentified, issues will come to the fore and require attention even as light duty PHEV/EV begin to roll off production lines towards the end of 2010.

Part of the issue is the pace at which PHEV/EV technologies and business models are evolving. Various standards setting bodies and user groups are investing considerable time and resources into assessing and addressing immediate issues and requirements, but much remains to be done. Key stakeholders include consumers (both private and commercial), vehicle manufacturers, utilities and ancillary service providers (hardware, software, communications infrastructure, etc).
Several regulatory issues will need to be addressed before utilities are able to fully align themselves with other industry stakeholders and arrive at a simple V2G vision. These can be defined as follows:

- Resale of electricity by non-utilities – Resale of electricity by non-utilities is not presently allowed under federal law, and will need to be addressed if a robust non-utility public charging infrastructure is to be developed.
- Cost allocation – Issues include whether to cover the expense of providing customers with in-home charging infrastructure; also, whether a separate revenue grade meter will be required for in home PHEV/EV charging.
- Development of special tariffs for PHEV/EV customers to incentivize adoption and/or encourage charging during non-peak times.
- Vehicle roaming and the billing and settlement processes associated with out-of-home-area charges.

Each of these involves a highly complex series of issues, questions and legal considerations, none of which will be straightforward to resolve, with many requiring both Federal and State involvement. To achieve a full V2G 'vision', the following (and numerous other) issues/challenges will need to be addressed/overcome:

- Proven, robust PHEV/EV battery and system technology.
- Complex PHEV/EV charging and discharging rate structures.
- Robust standards and protocols for secure real-time communication exchanges between vehicle, premise and utility.
- Complex and accurate billing and settlement solutions (including net metering considerations).

The Rocky Mountain Institute neatly summarizes an approach for bridging the six participation approaches (V0G through V2G NGU) outlined earlier in this chapter, but stops short of making premature judgments as to what will be required[68], as follows:

- Building out infrastructure with V1G capabilities in the short term, but using technology that can be easily upgraded to V2G later when the utilities, communications, and batteries are more advanced.
- An intermediate step—V2B—where vehicles plug into buildings with bidirectional interfaces and the vehicles become a source of backup power, and a potential for a further Business to Grid (B2G) supply of aggregated power. V2B offers many important advantages.
  1. First, it could reduce the number of users the utility would have to communicate with (buildings rather than individual vehicles). Buildings could thus add individual vehicle users while not requiring additional infrastructure immediately.
  2. Second, it offers a fairly easy transition as utilities and energy services companies develop smart grid and demand response relationships with buildings, as is already happening in many parts of the country

[68] Rocky Mountain Institute "Smart Grid Charette Report", v2.0, December 2008

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3. Third, many large buildings already have sophisticated energy management systems that could easily embrace V2B.
4. Fourth, the V2B + B2G = V2G paradigm could address the concern that V2G may prove unviable—or at least logistically difficult—due to the transaction costs and interoperability complexities of direct connections to numerous individual vehicles. Rebuilding an initial V1G infrastructure to shift to V2G seems costly and unnecessary.

- Patchwork: some individual regions or communities could establish V2G on their own. This possibility must be acknowledged, as well as the vehicles and infrastructure designed to accommodate it by defaulting to V1G or other low-level operation.

The report concludes that *"…if the evolution looked less like the imminent 'big bang' of the U.S. HDTV transition and more like the adoption of U.S. cellphone standards, each owner and region should still be able to benefit from the degree of evolution it has achieved."*

4.5.2 Standards for Equipment, System Communications & Security

As detailed in earlier sections of this study, various efforts by numerous SDOs are underway to identify and develop standards that will be required for electric vehicles. In recent months, NIST has become a driving force behind standards for electric transportation as part of its work to define and develop standards that will help facilitate the development of Smart Grid infrastructure in the U.S. While NIST is not developing any standards itself, it has organized a framework within which standards shall be developed and is engaged in identifying and charging those SDOs best qualified to develop electric transportation related standards with doing so.

This NIST effort is ongoing and has so far identified a number of 'use cases' through which it expects standards to be defined. These are outlined in the tables that appear in Appendix B.

Various use cases are under development and will likely result in the development of corresponding standards for consideration by the industry. It is likely however that these standards will take some time to emerge and be adopted.

From a V2G perspective, it is the PEV X2, X8 and X9 Use Cases that are most relevant:

- PEV_X2 PHEV/EV Load Management
- PEV_X8 PHEV/EV is not registered or monitored
- PEV_X9 PHEV/EV Used for Ancillary Services, e.g. countering frequency deviations, or providing operational reserve

These will consider the role of the PHEV/EV as an energy storage entity and consider its interaction with the location at which it is plugged in (home or business, for example) or grid from a discharging perspective. These use cases themselves remain in development and it is likely that the associated standards will take many years to develop. This underscores the premature nature of V2G related program discussions – while many stakeholders would like to believe and may even promote V2G as being 'just around the corner', the reality is that mainstream V2G programs are at least several years in the future.

Codes and standards development and infrastructure deployments will enable the success of these efforts. The first codes expected to be finalized are those concerning plugs and chargers, communication protocols, battery recycling programs, and the like. These will enable the introduction of smart, fast charging system installations at homes, businesses and public charging stations. By 2015, early V2G standards will be adopted, enabling limited V2G programs in areas of greatest demand. About 10 years later, all remaining issues, including warranty, roaming, billing, and settlement issues, could be resolved and standardized. This will enable fully interoperable and portable V2G programs for all plug-in vehicle operators by 2025.

In October 2009, EPRI submitted an excellent summary of codes and standards regarding plug-in electric vehicle charging to the California Public Utilities Commission.[69]

4.5.3 Issues Limiting V2G Use in Storage Applications

There are a number of issues that limit the amount that PHEV and EV can be used for energy storage applications. First, the charge that is likely to remain after vehicles are used for customer driving needs is likely to be small for most PHEV/EV in regular use. Second, battery storage, conversion, and inversion losses are expected to use up more than 25 percent of the energy used to charge the vehicle. Third, use for V2G energy storage will significantly shorten the vehicle's battery life.[70]

4.5.4 Remaining Charge and Driver Travel Requirements

The ability to use PHEV/EV to provide V2G services will depend on the charge likely to remain after the owner's travel needs are considered. While PHEV owners have the ability to burn gasoline if needed to make up for energy depleted by providing V2G/ V2B services, this is unlikely to be economic for the customer. For example, a PHEV running on electricity might cost 1.92 cents per mile in electricity costs[71], but costs about 10 cents per mile or about 8.1 cents per mile more than running in electric mode. Assuming 90 percent inverter efficiency, each kWh of energy sold back to the grid increases the customer's driving cost by about $0.29. Thus, the customer's on-peak rate would need to be about $0.29/kWh higher than their off-peak rate for the economics of burning gasoline to sell more energy back to the grid to make sense. This translates to a $290/MWh wholesale price premium above charging cost,

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[69] Rather than duplicate the information contained in that 20 page filing in this report, the document may be downloaded from the following location: http://docs.cpuc.ca.gov/efile/CM/108424.pdf

[70] The reduction in battery life due to deeply discharging the vehicle's batteries to provide V2G energy storage/arbitrage depends on how quickly battery cycle life drops off with depth of discharge. DOE future battery deep-discharge cycle life targets correspond with reductions in the cost of providing V2G energy storage services. Promising developments in LIFePO4 batteries may dramatically improve deep discharge cycle life; however, temperatures above 85 degrees F significantly shorten battery shelf life, and it is unclear how well this technology will perform in Arizona's above average temperatures.

[71] Based on 0.313 kWh/mile efficiency and $0.061/kWh off peak electricity.

something that rarely occurs in wholesale energy prices. EV customers are also unlikely to risk running out of stored energy needed for travel so that they can sell power back to the grid. NCI concludes therefore that both PHEV and EV owners would only likely sell back to the grid or building energy not needed for driving.

Some PHEV/EV owners will drive more than others, and there is a distribution of numbers of customers driving different distances. Although this is difficult to disaggregate accurately for hypothetical Arizona PHEV/EV owners, national transportation surveys are illustrative. Table 15, shows the share of customers that commute various distances and an estimate of the charge that would remain for the PHEV/EV storage capacities assumed in Section 1. For PHEV owners with a 25 mile or greater commute, no charge would remain after driving needs were accommodated. EV owners are likely to have some residual charge depending on their commuting distance, so for some customers, energy to provide V2G/V2B services would remain after their driving and 'spare tank'[72] needs are considered. According to highway statistics, annual per capita driving distances in Arizona are similar to the nationwide averages on which the data in Table 15 are based.[73]

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[72] See Section 5.5.2.1

[73] Federal Highway Administration, *2006 Highway Statistics*, Washington, DC, 2008.

Table 15: National Average Round Trip Commute – Distance, Share, and Usable Charge Remaining by Vehicle Type (kWh/Charging Cycle)

Distance (Miles)	Share	PHEV – Charge Remaining (kWh)	EV – Charge Remaining (kWh)
2-10	29%	3.9	16.8
10-20	22%	1.3	14.2
20-30	17%	-	11.6
30-40	10%	-	9.1
40-50	7%	-	6.5
50-60	5%	-	3.9
60-70	3%	-	1.3
>70	8%	-	-

4.5.5 Price Needed to Make V2G Program Attractive to Vehicle Owners

To evaluate customer economics for V2G and V2B applications two issues must be considered: how much V2G/V2B would cost the customer, and how much the customer would be likely earn or save by providing V2G/V2B services. The latter issue provides insights into the threshold issues for V2G/V2B customer economics.

For a customer to save costs or earn revenues, the value of the revenues or savings needs to exceed the costs incurred. Taking energy storage as a primary example, the revenue received or cost avoided when discharging the device needs to exceed the cost incurred to store energy plus the cost of storage losses. Losses are incurred in converting alternating current into direct current used to charge the battery, chemical energy losses within the battery, and losses to invert the direct current battery output back into alternating current suitable for home, business or grid use. At present, typical battery losses for this energy 'round trip' are in the 63 – 72 percent range. Storing energy is at best 70 percent to 80 percent efficient, while inverter efficiencies are typically 90 percent. Thus, the price of energy that is 'sold' when discharging the device into the grid or business needs to exceed the price of energy that is 'purchased' to charge the device by 39 to 59 percent, based on current efficiencies.

For the purposes of this analysis, NCI assumes 75 percent round trip efficiencies - slightly higher than the top of the current range to account for technological improvement. For this storage efficiency, energy prices during discharge need to exceed prices during charging by at least one third. So for example, an EV that takes 43 kWh to charge, could only provide about 32 kWh back to the system, assuming that that energy was not needed for driving. APS time of use residential rates, where on-peak rates are 3 to 4 times off-peak rates meet this hurdle, as shown in Table 16. The on- and off-peak differential in very large commercial customer TOU energy rates are very close to this ratio, and exceed this ratio to the extent that stored energy can be used to reduce on-peak demand charges. Thus there are potential revenues in storing energy for the V2B applications that should be weighed against equipment costs and costs associated with reductions in battery life.

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Table 16: APS Residential Time of Use Rates

Hours	May – October Billing Cycles (Summer)	November – April Billing Cycles (Winter)
On-Peak Hours	$ 0.24445 per kWh	$0.19825 per kWh
Off-Peak Hours	$ 0.06126 per kWh	$0.06124 per kWh

Direct V2G applications, where a large group of customers are aggregated to supply wholesale power back into the grid, are sensitive to the diurnal variation in wholesale energy prices. There is generally insufficient price variation within the off-peak or on-peak periods to support multiple charging and discharging cycles within each period. Nonetheless, APS demonstrates average on- versus off-peak wholesale energy price variation sufficient to generate gross revenues from V2G applications, provided there is energy available that the PHEV/EV customers do not need to meet their travel requirements. To determine payback, the potential for energy revenue needs to be weighed against the cost of equipment to provide V2G/ V2B services, but to do so NCI first explores the quantity of energy that is likely to be available after addressing the PHEV/EV owner's driving needs.

4.5.6 Impacts of V2G/V2B on Electric Vehicle Equipment

There are several vehicle equipment issues associated with use of the vehicle for V2G/V2B. Chief among them is the impact that frequent charging and discharging or deeper charging and discharging to support V2G/V2B functionality could have on battery life. Battery life is reduced depending on the frequency and depth of V2G/V2B discharging cycles.

Battery durability is rated in terms of cycle life, shelf life, and calendar life, as defined below.

- Cycle life: the number of charge-discharge cycles before a battery's nominal capacity falls below 80 percent of its initial rated capacity, or the number of cycles before internal resistance increases by a significant amount, such as double its initial value
- Shelf life: the time an inactive battery can be stored before battery's capacity falls below 80 percent of initial rated capacity
- Calendar life: the elapsed time before a battery (active or inactive) becomes unusable.

Battery life is limited due to unwanted chemical reactions which consume some of the active chemicals or impede their reactions. Even if the cell's active chemicals remain unaffected over time, cells can fail due to electrolyte leakage from deteriorating seals. High battery temperatures and cell voltages also reduce cycle life, but proper cooling and battery management systems can reduce the impact.
With deep discharges (e.g., 80 percent as is typical for EV's) cycle life of current Li-ion batteries can be low. The figure below shows an example of the sharp decline in cycle life with increasing depth of discharge.

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Figure 23: Deep Discharge Li-ion Battery Cycle Life vs. Depth of Discharge

The graph shows the minimum EV battery cycle life requirement of 1,000 cycles at 80 percent depth of discharge. HEV batteries are optimized for many shallow-discharge cycles (no less than 40 depth of discharge) in their lifetime. Lithium ion batteries in HEV applications can achieve 300,000 cycles and 10 year lifetimes.[74]

Further improvements to lithium-ion battery durability, cycle life expectancy, performance, safety, and cost are required for EV and PHEV applications. For instance, EV batteries must improve calendar life while PHEV batteries must meet calendar life as well as cycle life requirements. Also, PHEV batteries must be designed to offer the same high power output as EV batteries despite the PHEV batteries' smaller overall size and weight. Batteries must be engineered for high abuse tolerance.

The U.S. Department of Energy is now focused on high-energy PHEV batteries. It has set PHEV durability targets of 5,000 deep discharge cycles (at 70 percent depth of discharge), 300,000 shallow discharge cycles, and 15 year calendar life.[75] DOE has also set requirements for specific energy, energy density, and battery cost. PHEV battery development targets for high power/energy ratio batteries (short range) and high energy/power ratio batteries (longer range) are shown in Table 17.

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[74] David Howell, "Battery R&D for Electric Drive Vehicles", presented at the Advanced Battery Manufacturing Conference, April 16, 2009.

[75] Ibid.

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Table 17: U.S. DOE PHEV Battery Status and Development Targets[76]

Battery Attribute	High Power/Energy Ratio Battery	High Energy/Power Ratio Battery
Estimated range	10 miles	40 miles
Specific Energy	57 Wh/kg	97 Wh/kg
Energy Density	85 Wh/L	145 Wh/L
Shallow Discharge Cycle Life	5,000 cycles	5,000 cycles
Deep Discharge Cycle Life	300,000 cycles	300,000 cycles
Calendar Life	15 years	15 years
Maximum System Price	$500/kWh	$293/kWh

Although no PHEV battery can meet all the requirements shown in Table 17, some lithium-ion battery chemistries can meet a few requirements today. For instance, the LiFePO4 chemistry has been shown in laboratory tests to achieve a 5,000 deep-discharge cycle life[77]. However, this cycle life is achieved at the expense of low specific energy, which ultimately limits the range of the vehicle, and high cost, which limits the appeal of electric vehicles. Also, the impact of also subjecting the battery to hundreds of thousands of shallow-discharge cycles, as required for PHEV applications, is unknown.

A consequence of the use of PHEV/EV for energy storage, especially in applications that require deep discharge is that battery life will be shortened. Increasing the depth of discharge by exhausting the remaining charge can have a relatively large impact on battery life for customers that would otherwise discharge a small share of their battery's capability. Therefore, any potential revenues from providing V2G/V2B energy storage services would need to be weighed against significant additional battery replacement costs. Table 18 shows the battery life reduction by miles traveled associated with discharging a PHEV battery each day down to 30% charge and an EV battery down to 20% charge to provide grid or business energy storage based on current battery cycle life.

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[76] U.S. Department of Energy, *Energy Storage Research and Development: Annual Progress Report 2008*, Washington, DC, January 2009.

[77] Scott B. Peterson, Jay Apt, and J.F. Whitacre, "Lithium-ion battery cell degradation resulting from realistic vehicle and vehicle-to-grid utilization", published in *Journal of Power Sources* 195 (2010), pp. 2385–2392.

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Table 18: Reduction in Battery Life by Using V2G for Energy Storage – Current Cycle Life (Percent)

Distance Traveled (Miles)	Share	PHEV – Battery Life Reduction (percent)	EV – Battery Life Reduction (percent)
2-10	29%	55%	62%
10-20	22%	44%	62%
20-30	17%	0%	62%
30-40	10%	-	62%
40-50	7%	-	59%
50-60	5%	-	49%
60-70	3%	-	38%
>70	8%	-	-

The cost associated with the reduction in battery life due to the use of V2G will add significantly to the cost using V2G to provide energy storage for business and grid uses, especially for the share of the driving population that might have the highest usable charge remaining after driving needs are accommodated. Considering the possibility of $300/kWh EV and $450/kWh PHEV battery costs in 2020 and assuming that tax credits will not apply to replacement batteries, NCI estimated the cost contribution of the battery life reductions associated with V2G/ V2B use. Table 19 shows these costs. These costs when added to the energy costs associated with storage losses exceed the on- versus off-peak price differentials shown above. This finding indicates that V2G/V2B storage will generally not be cost effective for regular use with near term battery cost and cycle life assumptions. As battery costs decline and as DOE deep discharge cycle targets are approached V2G/V2B battery cost penalties will likely decline below a threshold value that currently renders these applications uneconomic. By 2020, advanced lithium ion batteries with significantly improved durability and increased cycle life in all climates may allow for V2G/V2B functionality at much more attractive prices than could be achieved with today's battery technology.

DOE cycle life targets of over 5000 deep discharge cycles suggest that battery calendar life would become the more limiting factor for using PHEV/EV for daily V2G/V2B energy storage if DOE battery cycle life targets were to be met[78]. If batteries could sustain more deep discharge cycles and if calendar life were to be limiting both with and without V2G/V2B use, the battery cost premium would disappear.

[78] For example 300 weekday daily deep discharge cycles per year for V2G/V2B use would correspond to 4500 cycles over a 15-year calendar life. A daily V2G/V2B deep discharge would not exhaust the battery's cycle life over a 10-year battery life for a target cycle life over 5000 cycles.

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Table 19: Incremental Battery Replacement Cost by Using PHEV/EV for Regular V2G/V2B Energy Storage ($/kWh per Storage Cycle)

Distance Traveled (Miles)	Share	PHEV	EV
2-10	29%	$0.22	$0.19
10-20	22%	$0.17	$0.19
20-30	17%	-	$0.19
30-40	10%	-	$0.19
40-50	7%	-	$0.18
50-60	5%	-	$0.15
60-70	3%	-	$0.12
>70	8%	-	-

4.5.7 Environmental Impact of V2G Supply Compared To Incremental Peaking Power Energy and Capacity Requirements

V2G/V2B energy storage is unlikely to significantly reduce emissions of many pollutants in the APS system. In V2G/V2B storage applications, PHEV/EV provides energy to the grid that is extracted from the grid during another period. Some losses occur through this charge and discharge cycle. Thus a primary emissions impact of V2G/V2B is associated with the difference in extra emissions during the charging cycle less emission reductions during the period when the vehicle is discharging power into the grid.

For instances where PHEV/EV is charged off peak and discharged into the grid on peak, the difference can be determined from the types of generators that are on the margin in either period. Our review indicates that gas combined cycle facilities are likely to be on the margin off peak, and gas-fired combustion turbines on the margin on peak. Since both burn natural gas, the primary differences are in the heat rates of the units. A combustion turbine heat rate might be around 9800 BTU/kWh while a combined cycle unit might be 7000 BTU/kWh. Nonetheless, storage and conversion losses narrow the off-peak efficiency premium.

NCI believes that PHEV customers will have a significant incentive not to discharge stored energy if doing so causes the customers to burn gasoline where they would not have otherwise. Thus, NCI limits the emissions impact assessment to the difference between the marginal utility emissions rates in the on and off-peak periods.

Major criteria emissions for a natural gas fired combined cycle and combustion turbine units are shown in Table 20, which demonstrates that emissions impacts vary by pollutant and that storage and conversion losses can cause emissions associated with energy stored off-peak to exceed emissions displaced on peak for some pollutants although net emission impacts can be relatively minor.

Table 20: Combustion Turbine versus Combined Cycle Emissions Accounting for Storage Losses (LB/MWh)

LBS/MWh	Primary Fuel							
Unit	Fuel	SO2	NOx	CO2	PM10	CO	VOC	HG
On Peak Combustion Turbine	Gas	0.0060	0.1844	1215	0.0125	0.0486	0.0345	0.0000025
Off Peak Combined Cycle	Gas	0.0044	0.0739	914	0.0127	0.0778	0.0034	0.0000019
w/Storage Losses		0.0059	0.0985	1218	0.0169	0.1037	0.0045	0.0000025
Savings		**0.0001**	**0.0859**	**-3**	**-0.0044**	**-0.0551**	**0.0300**	**0.0000000**

4.5.8 Management of Environmental Attributes

As described above, some of the primary impacts of using PHEV/EV in V2G applications involve storing energy at one time of the day to discharge during another time of the day. Emission impacts vary depending on the exact time of charging and of providing energy to the grid or business as well as the quantity of charge that an individual PHEV/EV provides. Tracking and trading environmental attributes of PHEV/EV would be difficult, since one would need to track the individual patterns of charging and discharging and assess the impacts. In some instances, using off-peak energy to displace on-peak energy can increase some pollutants while decreasing others. The tracking effort might require separate metering and recording of PHEV/EV data, likely an expensive proposition. Alternatively, some assessment could be made of the environmental attributes of wide classes PHEV/EV impacts using average charging patterns. In any case, an extensive development effort would be needed before environmental attributes of PHEV/EV could be tracked or traded.

4.6 Participation Processes

The V2G evolution is likely to be driven through need and demand – once the electric vehicle industry has developed sufficiently to warrant a commercial exploration of the electric system benefits of electric vehicles. At the present time, however, the focus has been on developing the initial standards that will be required to enable electric vehicle charging and as such, NIST and the Society of Automotive Engineers have been driving the debate and addressing the most urgent issues.

A good example of this work can be found in NIST PAP 11 group – which is squarely focused on addressing the immediate electric vehicle standards requirements and laying the groundwork for debate and standards development as needed.
As PHEV/EV move from area to area, a common interoperable model for price, DR events, energy characteristics for dynamic pricing across markets, signals for curtailment, and distributed generation resources will allow information supporting these uses to flow through the smart grid. In addition, a system is needed to determine how costs and payments for PHEV/EV are settled. Critical points include:

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- PHEV/EV mobile loads will stress the existing distribution infrastructure. By using PHEV/EV as electric storage during high demand periods, some of this stress can be offset. Models will resemble the existing electric storage models with the addition of parameters related to the mobile nature of PHEV/EV. Similar approaches to those used for non-mobile loads point to two related gaps: a common model for Demand-Response signals (grid safety, and pricing for demand shaping), and a common model for price, energy characteristics, and time for use. There are alternatives, including very specific demand control mechanisms, but the benefits of applying economic demand shaping appear to be much greater, particularly given the growth of Demand-Response use in other customer areas.
- PHEV/EV can act as both a load and power source. The impact of PHEV/EV on planning and managing the distribution system and the potential impact of mass numbers of PHEV/EV on system protection must be considered.
- Models for settlement of PHEV/EV energy costs and payments are developing slowly, and there are technical and policy/regulatory barriers. Some proposals support billing the PHEV/EV owner's home utility. Others suggest a simpler model similar to current gasoline stations. Still others suggest a mixture of prepaid and billed services, similar to cellular phone payment models.

The objectives of NIST PAP 11 include/address:

- Extract interface requirements from enhanced and polished use cases (based on SAE and NIST workshop Use Cases) - this includes recognizing the architecture of actors and messaging, settlement mechanism.
- Consideration of the appropriate mechanism for PHEV/EV settlement - Is it similar to the clearinghouse concept used by banks and media, where a third party batches orders each evening and divides the transaction values across all the parties involved? Is the transaction tied to the PHEV/EV owner or the vehicle? And/or, is the traditional gas station model using credit cards a process to build a model around?
- Distribution Management Systems (DMS) - must be able to communicate with PHEV/EV to influence charging profiles and discharging incentives through price signals or direct control signals.
- Determine whether vehicle needs to explicitly send charging requirements information to the "grid".
- Architectural decisions - should be flexible enough to accommodate varying regulatory requirements. For example, PHEV/EV may require sub-meters for roaming or if tariffs are developed that treat them separately from the rest of customer loads. This would involve policies, regulations, and testing and a decision whether existing standards for metering and retrieving metered data are adequate for PHEV/EV. Note that ANSI C12.19 has a robust metering model.

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- Development of high level information model in Unified Modeling Language (UML).
- Extend IEC 61850-7-420 for Distributed Energy Resource (DER) equipment to include PHEV/EV object models, as well as other related object models. IEC 61850-7-420 for DER currently addresses photovoltaic systems, fuel cells, diesel generators, batteries, and combined heat and power (CHP), with wind covered by IEC 61400-25. ANSI C12.19/22 defines object models for revenue quality metering. ZigBee SEP 2 defines models for HAN environment.
- IEC 61968 (Distribution CIM) - requires DER and PHEV/EV information models, but should be harmonized with the existing DER object models in IEC 61850-7-420, as well as all on-going DER 61850 development such as with PHEV/EV object models. In addition, IEC 61850-7-420 has architectural issues to be addressed and then needs to be described via System Configuration Language (SCL) specifications for PHEV/EV.
- Regulatory engagement – Request that regulators review the current regulatory electricity resale rules and metering requirements that will be impacted by roaming and ancillary service market support. Current regulations do not permit the resale of electricity as it is received in real-time by a customer, but if stored electric energy could be resold later, then this would open a new market. In addition, the current regulations would require that all accounting and cross-utility settlement issues would have to be managed by utilities or energy service providers, thus posing an enormous burden on them to manage these new complex accounting and settlement processes. On the other hand, if regulations were to change, the accounting model could change dramatically, and normal retail methods could be used or outsourced to credit card companies and other retail accounting providers.
- Similar to the IEEE 1547 electrical interconnection standards for DER, there may be a need for electrical interconnection and safety standards for chargers and discharging, as well as a weights and standards certification and seal for charging/discharging.

Addressing these points will do much to further debate around PHEV/EV grid connectivity from a discharge perspective but as is evident from the current work in progress, the exploration of these issues is still in its preliminary stages.

4.6.1 Manufacturers' Acceptance and Participation

As V2G issues are discussed, stakeholders will engage and define their own positions in line with their business cases and regulatory requirements and standards. It is premature to postulate as to the identities of these companies but reasonable to assume that the stakeholder groups and individual companies currently involved in the space at present will remain engaged and that the collaborative development of V2G will follow the same types of activities as those we are witnessing today – namely, user groups, standards setting bodies, vehicle manufacturers, utilities and regulatory bodies.

4.6.2 Other Barriers Affecting Vehicle Owners' Participation in V2G Programs

The key issues that are likely to impact participation in V2G programs are:

- Availability – it is yet to be seen whether V2G programs will emerge

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- Convenience – consumers and business are only likely to participate if doing so is easy and the benefit(s) clear
- Value – the benefit of participation will hinge around the financial value proposition – if participation is easy, will not damage PHEV/EV performance, hinder battery life and save or make the consumer a sufficient return, it is likely they will gain traction

As we have demonstrated in various sections of this chapter, the industry is many years away from finding itself in a position to appropriately and accurately depict V2G program design – let alone vehicle owner participation.

5.0 V2G/V2B Market Penetration and Company Impacts

5.1 Key Findings

- A variety of factors indentified in Section 4 will slow V2G/V2B implementation, and prevent any substantive implementation prior to 2020. Thereafter V2G/V2B will only be adopted for locations where the shared benefits of V2G/V2B for the vehicle and building owner exceed the costs of adding V2G/V2B infrastructure.
- By 2020, in-home charging stations will likely provide V2B capability at little incremental cost; however, workplace and commercial destinations may require new outlets to allow commuter vehicles to provide V2B services. The cost to retrofit existing parking facilities solely for V2B services is likely to be prohibitive; however, new parking space additions and parking space renovation may allow lower cost V2B outlets.
- Parking space turnover and technology diffusion will limit V2G/V2B adoption, but by 2035, NCI projects as many as 67,000 workspace and commercial destinations could be equipped with V2B capability in APS service territory provided that technology, cost, and warranty issues can be overcome and provided business models to share the benefits created can be developed. Few if any commercial vehicles will deliver V2G/V2B services since most will be in use on peak.
- Even with these robust adoption assumptions, V2B/V2G will make only a very minor contribution to reducing system peak loads.
- No substantive changes in emissions are expected from V2G/V2B adoption.

5.2 Detailed Discussion on V2G/V2B Market Penetration

The concept of V2G encompasses three major use scenarios: (1) managing the period of charging, selective mostly on-peak charging cuts based on a utility signal: (2) providing vehicle to business or home services; and ultimately, (3) back feeding into the grid. The first two scenarios are already subsumed in the current APS rate structure: the current APS time of use rate structure already provides a very large incentive for customers to charge off peak and thus is expected to succeed in managing the period of charging absent any additional V2G/V2B functionality. This also obviates the need for selective reductions of on-peak charging since on-peak charging is expected to be relatively small. Thus, this report focuses on providing services to the local home or business, or to the grid.

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Home and business services—e.g., the daily storage of energy off peak for use on peak—are likely to provide greater benefit to the consumer when weighed against their retail rates than when weighed against wholesale prices for providing similar services. The customer's on-peak to off-peak retail rate differentials are usually larger than similar differentials for wholesale prices. NCI expects that V2B capability, with the ability to communicate and respond to instructions from advanced home or business meters via Home Area Networks (HAN), will be standard features of post-2020 electric meters and standard equipment in new vehicles. This capability will allow V2B to reduce home demand with a large amount of flexibility, enabling all or nearly all residual charge to reduce on-peak building energy usage. V2G capability by contrast will require additional infrastructure investment. NCI expects that customers generally will provide services to their home or place of business rather than providing electric service to the grid. Nonetheless, some economic niche applications may exist where electric vehicles that are unused during on-peak periods provide opportunities for aggregation, providing V2G services and direct participation in wholesale market[79]. These opportunities are likely to be limited at least initially to certain niches in the market and are not expected to have wide scale impacts.

Infrastructure for V2G services will require more investments than V2B, and V2G is unlikely to yield significantly more revenues or avoid significantly more costs than V2B. In many cases, the customer's own retail electric rates will create the larger incentive to provide energy storage services than wholesale rates for providing V2G services. Thus energy storage will be primarily a V2B service.

Section 4 identified key factors that will need to be addressed prior to the widespread adoption of V2G/V2B. First, battery cycle life and conversion, storage, and inversion efficiency would need to be improved, especially for batteries suitable for Arizona's above average temperature conditions. Second, battery costs would need to improve or tax credits extended to include replacement batteries. Third, an extensive set of codes and standards for V2G applications, currently under discussion, would need to be finalized. Forth, advanced metering and control - i.e. smart grid features for home and business use - would need to be widely available. Finally, customers would need to adopt the technology.

This combination of factors will slow V2G/V2B adoption, and prevent any significant implementation before 2020. Thereafter, V2G/V2B will be adopted almost exclusively for locations where the relative benefit of V2G/V2B exceeds the costs of adding V2B/V2G infrastructure. In-home charging stations will likely provide V2B capability at little incremental cost; however, workplace and commercial destinations may require new outlets and discharge pedestals to allow commuter vehicles to provide V2B services. The cost to retrofit existing parking facilities solely for V2B/V2G services is likely to be prohibitive. New parking facilities are more likely than existing parking to be designed and built to accommodate V2B/V2G capability, but the rate of new construction and substantial renovation will limit the availability of V2B/V2G sites, even if business model and payback issues were to be overcome.

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[79] Certain fleets of unused PHEV/EV school busses, for example, may be largely unused during summer peak periods but do not represent a significant quantity of load.

Section 5 - V2G/V2B Market Penetration and Company Impacts

5.2.1 V2G/V2B Analysis

NCI quantified the technical potential of V2G/V2B services by estimating the usable charge that would remain after customer driving needs were met, and the expected availability and access to discharge outlets. The cost of retrofitting existing parking was considered prohibitive and therefore the number of new destination parking spots where V2B capability might be added was a key driver of technical potential.

5.2.2 Residual Charge

NCI separately reviewed the amount of charge that is likely to remain in typical PHEV/EV after customer driving needs are met. Based on national driving averages[80], a typical PHEV owner will have exhausted or nearly exhausted their vehicle's electricity only range, and will switch to charge sustaining mode prior to completing their commute. Thus, little remaining charge typically would be available for PHEV to provide V2B services. Due to their higher electric range, EV are likely to have a larger residual charge after driving needs are met. NCI used the weighted average distribution of national average driving ranges and round trip storage efficiencies to estimate an outer bound on the amount of useable residual energy per PHEV/EV. NCI also considered customer risk aversion and the likelihood customers would hold a share of charge in reserve, i.e. 'spare tank' charge.

5.2.2.1 Customer Risk Aversion

Residual charge available to provide V2G/V2B services will be limited by the vehicle owner's aversion to the risk of fully consuming stored charge. This likely will not be a major concern for PHEV owners, where the consequence of running out of stored charge is limited to switching to more expensive gasoline mode. In contrast, EV owners would risk being stranded if their vehicle charge were depleted. Thus, NCI expects EV owners, if discharging for V2G/V2B during the day, would retain charge needed for their return trip plus some 'spare tank' reserve. For EV, NCI used an assumption of a 30 mile 'spare tank' range, beyond normal or expected driving needs. NCI also assumed a 5 mile spare tank range would address a PHEV owner's aversion to fully consuming residual charge and burning gasoline as a replacement.

5.2.3 Availability of and Access to Discharge Outlets

The availability of discharge outlets and the share of PHEV/EV with access to these outlets during on-peak periods will limit the percentage of PHEV/EV owners that will be able to provide V2G/V2B services. NCI holds that most commercial fleet vehicles will be in use during on-peak periods, and these will need to be fully charged to maintain adequate reserve; or will otherwise be without access to discharging infrastructure. NCI believes that, except for some niche applications, most or all commercial fleet vehicles would be unable to provide V2G/V2B services. Therefore, NCI estimated V2G/V2B potential by reviewing the likely access of residential vehicles to V2G/V2B discharging infrastructure. While home charging ports are likely to function as V2B discharge ports with little incremental cost, workplace and

[80] See 'Distance Traveled' and 'Share' in Table 18, Section 4 for national driving averages.

commercial buildings parking facilities face incremental costs to add V2B/V2G capability costs which will likely limit this functionality to new parking facilities.

5.2.4 Incremental Infrastructure Cost to Provide V2G/V2B Energy Storage Services

NCI reviewed the incremental costs of making a home or business charging port and meter capable of handling vehicle discharge for V2B services, and the cost of adding a new discharging port exclusively for V2G/V2B use.

NCI reviewed two incremental costs scenarios for providing V2G/V2B services, the incremental costs of making an individual charger and home or business infrastructure capable of handling V2B flows, and the cost of adding a new discharging station which would not be needed but for V2G/V2B use.

For residential applications with modest levels of PHEV/EV penetration, NCI assumed that APS time-of-use (TOU) structure would provide sufficient motivation for customers to charge during off-peak and discharge during on-peak pricing intervals, and NCI expects PHEV/EV to cause no shift in the timing of the system peak. Off-peak charging eliminates the need for direct utility control to ensure charging does not occur during the system peak. Reduction in on-peak charging is described as Scenario 1 in Section 4, and is the lowest cost V2G/V2B option in terms of incremental equipment needed to facilitate vehicle discharge to the electric grid.

Additional customer equipment needed for Level 1 or 2 residential V2G applications under Scenario 1 or 2 is fairly nominal, as vehicles are likely to be equipped with communications interfacing modules capable of communicating with smart meters. For example, chargers for the new Chevrolet Volt will be equipped with communications capable of interfacing with smart meters.[81] For Scenario 1, which assumes customers will charge and discharge during off-peak and on-peak intervals, respectively, little if any, additional equipment would be required. For Scenario 1, customers would receive credits based on-peak period energy offsets – a single, existing TOU meter should be suitable. However, a wall-mounted display that would provide interval usage, charging and discharge information, billing credits, monthly and year-to-date savings likely would be offered by suppliers or third-party sources. NCI estimate the installed cost for these displays to be less than $250.

Non-demand metered commercial customers would utilize similar equipment for Level 1 and Level 2 charging and discharge under Scenarios 1 and 2. The exception would be for businesses where one or more vehicles are owned by employees or customers (Scenario 3). For the latter, much more complex business metering and vehicle metering technology would be needed.

Scenario 3 equipment requirements include charging pedestals and infrastructure needed to accommodate electric vehicles. The cost of charging stations range from about $1,800 for a Level 2 automobile class charger to about $20,000 for a 200 kW commercial vehicle charger. The cost of

[81] "Speed Bumps Ahead for Electric-Vehicle Charging," IEEE Spectrum, Volume 47, Number 1, page 47.

associated underground infrastructure is location-specific, and varies significantly for new construction versus retrofits – the latter, on average, is far more expensive. Typical locations for charging pedestals would be municipal and privately-owned parking lots, business parking lots, and possibly along city streets where parking meters typically are located. In addition, major EV programs such as shuttle or school bus retrofits or new vehicles equipped with batteries would include electric infrastructure and parking lots designed to accommodate many vehicles, which maximizes economy of scale.

Due to the cost of the underground electric equipment and infrastructure needed to route cables to charging pedestals, it is unlikely the savings achieved by distributed/remote charging (Scenario 3) would justify retrofits; except for major programs such as bus stations where large amounts of EV charging would be installed at a relatively small land footprint. Accordingly, NCI anticipates that most remote charging stations – particularly for cars and small trucks – would be installed only at suitable locations that are newly constructed; for example, during the construction of new office buildings, shopping malls or parking garages, where the incremental cost of larger electric cable and additional routing of conduit to charging pedestals is relatively minor. Our approach for identifying the amount of eligible new construction and expected installation rate of charging stations is presented in below.

5.2.5 Residential V2B

By 2020, advanced meters are likely to be universally installed for residences within APS service territory. It is reasonable to assume that by 2020, standard PHEV/EV equipment will have the ability to communicate with local advanced meters via Home Area Network (HAN) technology. Protective equipment and systems needed for PHEV/EV charging, coupled with widespread advanced metering use by 2020, will provide all or most of the functionality needed for V2B applications with little or no incremental cost. To quantify V2B penetration for residential applications, NCI assumed that 10 percent of PHEV/EV vehicles will be connected to a charging/discharging port in their home port during the on-peak period, and that all or nearly all of these vehicles will provide V2B service to the residence.

While providing V2B services to reduce on-peak retail energy use, these vehicles are unlikely to provide significant V2G services, since V2G services are less remunerative and more expensive to accommodate than V2B services. Intelligent metering and V2B control can also lengthen or shorten the discharge duration to maximize the value of the vehicle in providing V2B services, and little or no charge will remain after serving the customer retail load.

5.2.6 Workplace and Commercial Destination V2B

Residential customers will typically charge at home over night. In a typical commuting scenario, the residential customer is likely to be located at a remote destination or on the road during most of the on-peak period. By contrast, workplace or commercial facilities may not have a great need for off-peak charging ports. For these locations, a separate discharging infrastructure might be needed just for the vehicles to inject power to provide on-peak V2B services. The ability of residential vehicles to provide V2B services at their workplace or commercial destinations in exchange for payments or utility credits will depend on the availability of and their access to discharging outlets at these remote locations.

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The incremental cost of retrofitting garage and surface parking lots for V2B is highly location specific; further, the cost is likely to be prohibitive. Retrofitting costs could include excavation, laying conduit, wire, internal wiring and breaker replacement, additional sub-metering and monitoring costs, panels, repavement, parking meter replacement, etc. Pavement type would also be a factor, e.g. retrofitting through concrete might be more expensive than through blacktop. Although some service could be available through conduit used for lighting, it is likely to be limited and expensive. Integrating V2B capability in new parking facilities is likely to have a lower incremental cost. Excavation and repavement would be limited and internal wiring, breakers, panels, and metering would be integrated in the design. Conceptually, a municipality or business might include V2B power outlets in their new parking facility design in order to attract customers, qualify as an environmentally sensitive building, or as a business revenue source.

Accommodating electrical vehicles can also help a new facility qualify as a green building under the Leadership in Energy and Environmental Design (LEED) Green Building Rating System™, a status awarded by the U.S. Green Building Council (USGBC)[82]. Many new buildings seeking LEED certification will install PHEV/EV conduit and outlets, allowing for earlier adoption of V2B once codes and standards have been developed. DOE efforts to increase the availability of charging ports could also allow for earlier adoption of V2B at remote locations, provided business model and other issues are resolved.

Although new facilities are likely to build in conduit allowing relatively low cost expansion to more PHEV/EV outlets, new facilities are unlikely to build more V2B outlets than expected PHEV/EV vehicles. Parking facility owners might not want to invest in PHEV/EV charging/discharging infrastructure until some minimum share of vehicles that park in the facility would actually use or provide the service. For example, if only 10 percent of vehicles using a facility were PHEV/EV, these infrastructure investments would receive 10 percent of the direct return they would receive if all vehicles in the lot were PHEV/EV. Although NCI projects that 17 percent of vehicle sales by 2035 will be PHEV/EV, the cumulative effect of sales to that point would mean that only about 6 percent of the vehicle population would be PHEV/EV by 2035. To wire an entire parking facility to serve 6 percent of the vehicles would be prohibitively expensive. It is therefore likely that new parking facilities that have PHEV/EV ports will have a limited number of these spots, and it is plausible that the share of these spots would be limited to the share of PHEV/EV likely to use the facility. NCI used the share of new parking facility construction equal to the share of PHEV/EV population to estimate the number of PHEV/EV discharge facilities likely to be available.

5.2.7 Total V2B/V2G Discharge Outlets

The projected total number of in-home and workplace and commercial destination discharge outlets is estimated in Table 21 for 2020, 2025, and 2035. Assuming that PHEV/EV owners are equally likely to park in a new or old lot, not all PHEV/EV owners will park where a V2B/V2G discharge port exists, although this limitation will decline as the share of renovated parking facilities increases by 2035. The

[82] http://www.usgbc.org/

number of PHEV/EV owners that park where there is a V2B/V2G discharge port will increase as the ratio of PHEV/EV vehicles to discharge ports increases. Assuming that PHEV and EV have equal access to discharge ports, the average accessible residual charge per vehicle will increase as the proportion of EV to PHEV increases. Technology diffusion rates associated with the economics of businesses installing V2B ports will slow and ultimately reduce the likely V2B adoption somewhat.

With these assumptions and robust assumptions about the resolution of cost, technological and commercial issues, the economic potential for home and business V2B reaches about 557 MWh of daily accessible charge by 2035. Assuming a 4 hour on-peak discharge period, the economic potential could reach about 139 MW of peak demand reduction by 2035; this value is less than 2 percent of APS expected system peak.

Table 21 - Projected Economic Potential of PHEV/EV Discharge Ports for Residential Vehicles

Year	Share of Parking Spaces New or Renovated Since 2010	Vehicles with Access to V2B/V2G Discharge Ports	Weighted Average Residual Charge (kWh/Vehicle)	Total Accessible Residual Charge (MWh/Day)
2020	61%	1,708	3.8	7
2025	85%	3,141	4.8	15
2035	100%	67,437	8.3	557

5.2.8 Battery Repurposing

Although some studies suggest an increase in battery repurposing as a V2G/V2B strategy[83], it is too early to predict or include the potential wide scale impact of this technology. As the population of PHEV/EV grows, a number of used vehicle batteries may be repurposed into stationary electrical storage. These batteries may become available as drivers retire their vehicle batteries due to age or obsolescence and as improved batteries are commercialized. Though old or obsolete, retired vehicle batteries may still be capable of holding up to 80 percent or more of their original capacity. Thus, they could be used as power and energy storage devices providing building and grid-support services (called Battery to Grid applications or B2G). A repurposed battery would require some ancillary hardware to facilitate its new use, including a new charger, inverter, cooling, and safety components - estimated at around $7,000 per facility. A key benefit of stationary use is extended battery life, since stationary use would be significantly less demanding than vehicular applications. The realization of these benefits requires coordination of relevant/interested stakeholder activities, standardization, code and safety procedure development, in addition to discharge structures to facilitate B2G unit participation in electricity markets.

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[83] B. Williams and T. Lipman, "A Strategy for Overcoming Plug-in-Hybrid Battery Cost Hurdles in California: Integrating Post-Vehicle Secondary Use Values", TRB 2010 Annual Meeting CD-ROM, November 2009

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Repurposed batteries could be installed individually in homes or in larger centralized battery pack 'power plants'. Centralized plant installations may alleviate safety concerns associated with aged battery use in homes, whereas in-home installations may offer benefits to feeder-level electricity distribution networks. To estimate B2G adoption rates, further research is needed, as the expected lifetime of repurposed batteries is not yet fully understood. It is also not yet clear whether B2G markets are sufficiently robust to attract consumer interest or how markets and business models might evolve over time. The question of battery ownership is likely to become the subject of regulatory and commercial interest. A scenario in which third-party battery owners lease a significant number of batteries for use in vehicles and in B2G applications could engender greater support as the full lifecycle technical and cost implications of new battery technologies becomes clearer.

5.2.9 Incremental Revenues/ Cost Reductions from Providing V2G/V2B Energy Storage Services

In Section 4, NCI estimated a 2010 $ on versus off-peak price differential of about $0.16/kWh for residential customers. Comparable values for industrial and large commercial customers are approximately $0.10/kWh. Absent a cost premium associated with battery life reduction, i.e. if DOE deep discharge cycle life targets are met for batteries serving the Arizona climate and the climate of cities like Phoenix, the on- and off-peak price differential should be sufficient to produce positive V2B revenues or operating savings after accounting for conversion, storage and inversion losses.

5.2.10 Business Adoption of V2B Energy Storage Services

NCI expects that the simple payback for V2B with an assumed cost (2010 $) of $1,800 per connection will vary from 3 to 34 years, depending on miles driven per vehicle type. The exact share of the revenues credited to the owner of the V2B remote ports versus the amount that would be credited to the PHEV/EV owner as an incentive is unclear. The exact mechanisms by which businesses would address and resolve these issues are unknown. To illustrate economic potential, NCI applied a technology diffusion rate and assumed an increasing share of businesses would install V2B ports: results indicate 20 percent of new parking space owners would install V2B by 2015 and 80 percent of new parking space owners would install V2B by 2035, roughly consistent with a 20-year technology diffusion period.

5.2.11 V2G/V2B Energy Compared to PHEV/EV Energy Used

The V2G/V2B energy available for discharge will be a small share of the energy used for PHEV/EV use, since the primary purpose of the stored electricity is to provide energy for transportation. The relationship between PHEV/EV energy used and provided as V2G/V2B is illustrated in Figure 24.

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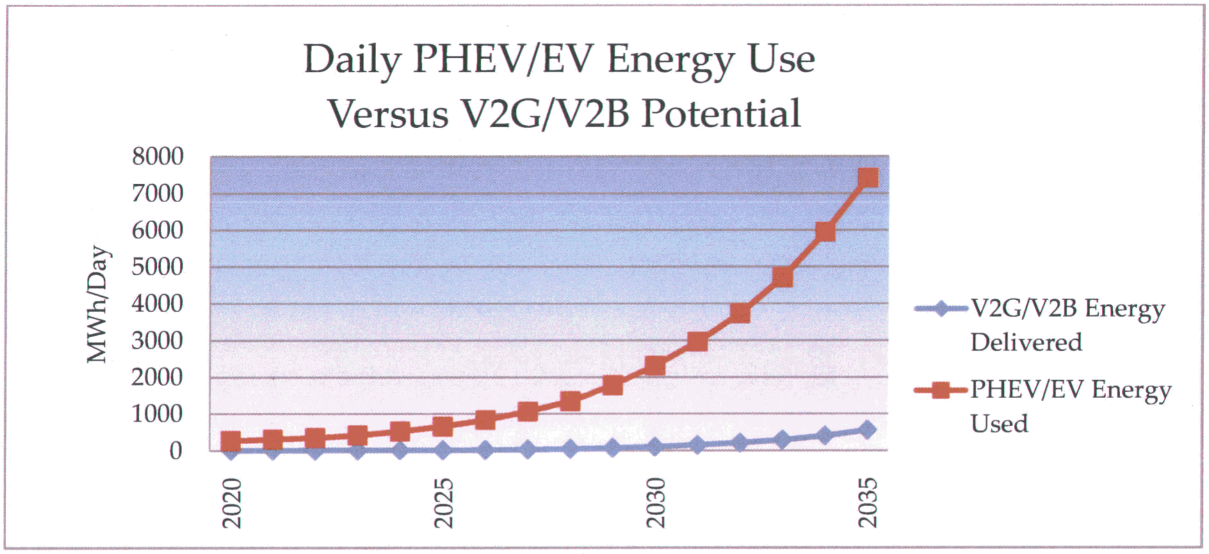
Figure 24 - Daily PHEV/EV Energy Used Versus Delivered as V2G/V2B Services



5.3 Company Impacts of Customers Providing V2G/V2B Services

NCI reviewed the likely impacts of customers providing V2G/V2B services, noting that each mode will be limited by vehicle discharge rates, connection sizes, or infrastructure upgrades. NCI notes that V2B could be helpful in firming distributed intermittent generation (e.g. residential, workplace or commercial destination solar electric installations); but firming intermittent generation may be a use of V2G/V2B that competes with daily delivery of fixed blocks of on-peak power. The impact of V2G/V2B on APS aggregate load is likely to be minor. Since the primary impact of PHEV/EV is on distribution line transformers and secondary lines/equipment, it is unlikely that V2G/V2B will reduce the cost of future investments, as the relative unpredictability of a small number of vehicles per transformer available to provide V2G/V2B services and the minimal likelihood of equipment deferral.

5.3.1 Value of V2G/V2B in Reducing Generation Requirements

PHEV/EV can reduce load in a V2B scenario or act as distributed generation in a V2G scenario; both functions would be limited by the speed and minimum duration of discharge, and whether the vehicle is in transit or connected to a V2G/V2B port. Both applications also would reduce transmission and distribution losses that otherwise would be provided by central generation. Both could result in small reductions in central generation additions needed to address load growth.

Any displacement of generating capacity would depend on the timing and duration of vehicle discharge. For this analysis, NCI assumed a 4 hour discharge period. V2G/V2B will be unable to discharge all of its energy in a single hour due to equipment and cable rating limits. For example, discharging 6 kWh of available energy through a 1.5 kW Level 1 connection would take a minimum of 4 hours, while

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discharging 24 kWh through a Level 2, 6.6 kW connection would take close to 4 hours. Increasing discharge speed also causes internal battery heating and shortens battery life. The amounts of potential generation displacement are estimated in Table 22 for a 4-hour discharge period, assuming six percent average marginal transmission and distribution losses, and a 15 percent reserve margin credit.

Table 22 - V2G/V2B Generation Displacement Potential (MW)

Year	Potential V2B Injections (MW)	Central Generation Displacement with Transmission and Distribution Losses (MW)	Central Generation Displacement with Losses and Reserve Margin Credit (MW)
2020	2	2	2
2025	4	4	5
2035	139	148	170

5.3.2 Generator Capacity Revenues or Costs PHEV/EV or V2G/V2B Could Earn or Displace Considering the Reliable Output of these Measures

The value of capacity displaced by V2B is captured within the rate structure for customers using V2B to reduce building load. Thus, no additional capacity revenue would be applied. Those providing V2G services directly to the grid might displace generator costs at the average cost of new peaking capacity, which for APS currently runs about $750/kW to $1,000/kW. Some reliability premium could be considered for the relative predictability of the availability of a large number of small V2G/V2B units compared to the availability of a single large generator. In addition, any reduction in the system peak also would reduce reserve margin requirements; typically about 15 percent.

5.3.3 Value of V2G/V2B in Firming Intermittent Distributed Resources

Customers using distributed intermittent resources to offset or partially offset their load could face additional demand charges if the intermittent resource were temporarily unavailable during the customer's peak; for example if an occasional cloud were to pass over a customer's distributed solar electric installation. V2B energy storage services could be used to address unanticipated peaks in customer net load; however, holding V2B capacity in reserve to respond to these peaks may prevent or partially prevent V2B from being used for energy storage for daily on-peak demand reduction services. If the vehicle providing V2B were discharging at full capability during a regular on-peak interval, no capability would remain in reserve to address loss of intermittent generation. Customers that do not pay monthly demand charges (i.e. most APS residential TOU customers) would not directly benefit from V2B performing this function. Those customers that pay monthly demand charges would need to weigh the impact of their intermittent demand charge reductions against their regular demand charge reductions and normal on-peak energy price premiums, since holding some V2G energy and capacity in reserve to address loss of intermittent resource events could reduce regular on-peak demand and energy reductions. These trade-offs will depend on the customer's load shape, share of power provided by intermittent resources, and the relative size of the customer's V2B capability and customer's load.

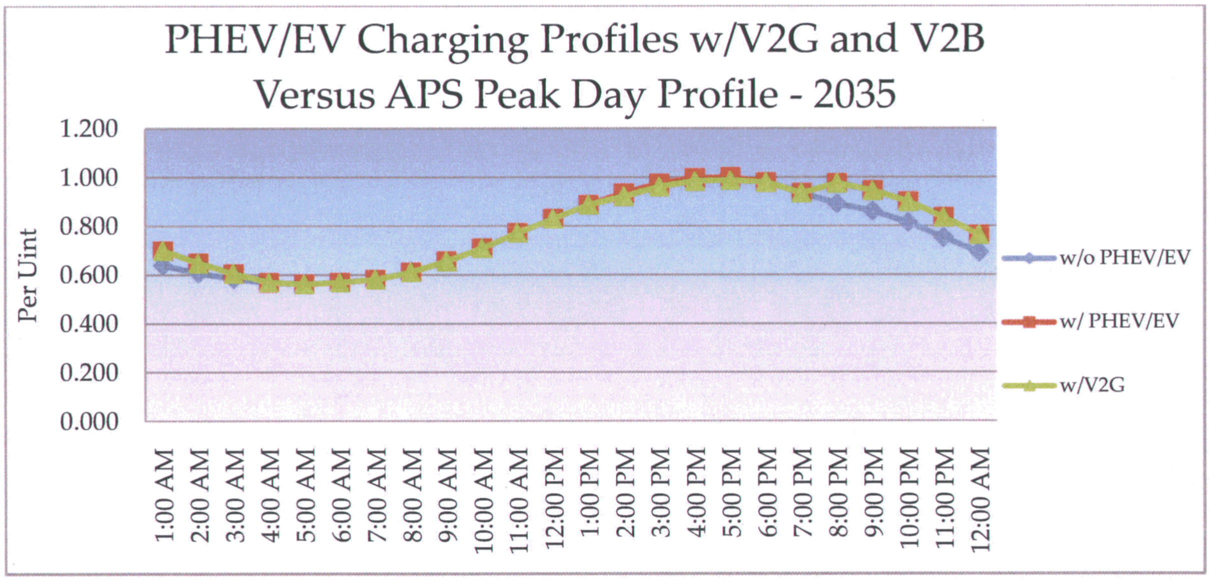
5.3.4 Value of V2G/V2B in Reducing Emissions

As highlighted in Section 4, V2G/V2B is generally not effective at reducing emissions, even though energy consumed off peak is likely to have lower marginal emissions than energy displaced on peak since both are typically gas-fired generation. The reduction in emissions is limited due to the conversion, storage, and inversion losses.

5.3.5 Load Shape Impacts

The hypothetical impact of V2G on APS load shape for the full technical potential for 2035 is illustrated in Figure 25. In this view, residual charge is used to reduce peak loads in the four highest load hours prior to the evening commute, flattening the APS load shape. The evening commute represents a time when most residential vehicles neither draw nor inject power.

Figure 25- Changes in Peak Day Load Profile due to PHEV/EV Load and V2G/V2B/ Capability per Unit of APS Peak Load – 2035



5.3.6 V2G/V2B Distribution System Impacts

A reduction in peak demand due to V2G/V2B power injections could reduce feeder and substation transformer peak loadings depending on the timing of the feeder and substation transformer peak. V2G/V2B is expected to have less impact on the need for street level distribution line transformer improvements caused by PHEV/EV. At the street level, transformer design must accommodate the more likely possibility of V2G/V2B injections not being available at the same time. With a small number of customers per transformer, the certainty of V2G/V2B injections is reduced.

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6.0 Appendix

Appendix A – Qualitative Characteristic Associated with Various Battery Types

Table A.1: Vehicle Battery Characteristics[84]

	LiCoO2	NCA	NMC	LiMn2O4	LiFePO4
Energy (W/kg or W/L)	Good	Good	Good	Average	Poor
Power	Good	Good	Good	Good	Average (lower V)
Low T	Good	Good	Good	Good	Average
Calendar life	Average	Very Good (if charge at 4 V)	Good	Poor	Poor above 86°F
Cycle life	Average	Very Good (if charge at 4 V)	Good	Average	Average
Safety	Poor	Poor	Poor	Average	Good
Cost/kWh	Higher	High	High	High	High
Maturity	High	High	High	High	Low

[84] IEA, 2009.

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Appendix B – Detailed and Additional High Level NIST Use Cases

Table B.1: SAE Detail Use Case Description

E	General Registration/Enrollment Steps Initial Setup for PHEV-Utility Communication & Authentication
U1	Utility Programs - TOU
U2	Utility Programs - Direct Load/Price Control
U3	Utility Programs - TRP (Active Management)
U4	Utility Programs - Critical Peak Pricing
U5	Utility Programs - Optimized Charging
S1	Connection Architectures - Cordset EVSE 120V AC to vehicle)
S2	Connection Architectures - Premise EVSE (240V AC to vehicle)
S3	Connection Architectures - Premise EVSE w/Charger (DC to vehicle)
L1	Connection Location - Home: Connects at premise
L2	Connection Location - Another's Home Inside the utility's service territory & A: premise pays tariff B: customer pays tariff
L3	Connection Location - Another's Home Outside the utility's service territory
L4	Connection Location - Public: Curbside, workplace, business, multi family dwelling
PR1	Charging
PR2	Discharging
PR3	Plug In Electric Vehicle Diagnostics
PR4	VM specific functions

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Table B.2: Additional High Level Use Case Description

PEV_X1	PEV Network Testing, Diagnostics, and Maintenance
PEV_X2	PEV Load Management
PEV_X3	PEV Roaming Scenarios
PEV_X4	Utility Provides Accounting Services to PEV user
PEV_X5	PEV Load Management
PEV_X6	PEV is used as source for On-Premise Backup Power
PEV_X7	Impact of PEV as Load on Distribution Operations
PEV_X8	Impact of PEV as Electric Storage on Distribution Operations
PEV_X0	PEV is not registered or monitored
PEV_X9	PEV Used for Ancillary Services, e.g. countering frequency deviations, or providing operational reserve

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Appendix C – Market Technology Penetration Forecast Results for APS Service Territory

Table C.1: PHEV Annual Sales Estimates Through 2035

Year	Light Duty/ Privately Owned	Light Duty/ Privately Owned (Wealthy)	Light Duty/ Fleet Owned	Commercial (4-7 tons GVWR) /Fleet Owned	Commercial (7-13 tons GVWR) / Fleet Owned	Total
2010	5	2	7	1	0	**15**
2011	28	2	26	2	1	**59**
2012	53	7	59	7	3	**129**
2013	125	14	86	17	6	**248**
2014	164	28	148	30	11	**381**
2015	341	67	217	45	15	**685**
2016	437	88	268	65	22	**880**
2017	770	183	454	108	36	**1,551**
2018	1,301	237	658	146	50	**2,392**
2019	274	25	228	76	31	**634**
2020	80	14	128	60	21	**303**
2021	129	17	153	74	26	**399**
2022	272	20	213	91	39	**635**
2023	373	24	324	124	52	**897**
2024	455	40	463	183	73	**1,214**
2025	547	61	541	236	87	**1,472**
2026	765	80	636	301	104	**1,886**
2027	1,164	93	734	355	122	**2,468**
2028	1,660	143	841	421	143	**3,208**
2029	1,965	290	1,213	490	190	**4,148**
2030	2,256	377	1,492	566	243	**4,934**
2031	2,584	440	1,812	824	306	**5,966**
2032	3,361	510	2,164	1,028	377	**7,440**
2033	4,198	679	2,426	1,257	458	**9,018**
2034	5,120	864	2,647	1,386	516	**10,533**
2035	6,161	1,201	2,832	1,659	578	**12,431**

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Table C.2: EV Annual Sales Estimates Through 2035

Year	Light Duty/ Privately Owned	Light Duty/ Privately Owned (Wealthy)	Light Duty/ Fleet Owned	Commercial (4-7 tons GVWR) /Fleet Owned	Commercial (7-13 tons GVWR) / Fleet Owned	Total
2010	9	0	3	1	0	**13**
2011	19	3	4	2	1	**29**
2012	18	7	10	4	2	**41**
2013	23	10	19	13	6	**71**
2014	29	9	47	30	12	**127**
2015	36	12	80	43	21	**192**
2016	90	15	138	83	31	**357**
2017	296	19	220	115	45	**695**
2018	460	48	351	163	75	**1,097**
2019	76	25	176	159	55	**491**
2020	88	44	123	143	63	**461**
2021	107	34	153	208	78	**580**
2022	129	42	246	280	96	**793**
2023	185	51	363	341	132	**1,072**
2024	371	62	472	469	196	**1,570**
2025	435	75	557	620	253	**1,940**
2026	857	90	658	887	331	**2,823**
2027	1,398	104	962	1,126	392	**3,982**
2028	1,936	172	1,322	1,357	471	**5,258**
2029	3,146	284	1,667	1,618	551	**7,266**
2030	4,054	323	1,875	1,878	654	**8,784**
2031	5,757	739	2,132	2,215	801	**11,644**
2032	6,739	1,120	2,675	2,588	933	**14,055**
2033	8,698	1,319	3,643	2,991	1,077	**17,728**
2034	11,946	2,017	4,319	3,430	1,236	**22,948**
2035	15,696	3,100	5,050	3,900	1,353	**29,099**

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Table C.3: PHEV Market Penetration Estimates Through 2035

Year	Light Duty/ Privately Owned	Light Duty/ Privately Owned (Wealthy)	Light Duty/ Fleet Owned	Commercial (4-7 tons GVWR) /Fleet Owned	Commercial (7-13 tons GVWR) / Fleet Owned	Total
2010	9	2	9	1	0	21
2011	37	4	34	3	1	79
2012	90	11	94	10	4	209
2013	215	24	179	26	10	455
2014	380	52	325	56	21	834
2015	721	120	535	101	36	1,513
2016	1,158	208	777	166	57	2,366
2017	1,928	390	1,172	274	93	3,858
2018	3,229	627	1,744	420	143	6,163
2019	3,499	652	1,825	496	174	6,646
2020	3,575	664	1,735	555	194	6,724
2021	3,676	678	1,620	628	219	6,821
2022	3,894	692	1,379	712	255	6,932
2023	4,141	702	1,046	820	301	7,010
2024	4,433	715	1,281	973	363	7,765
2025	4,638	709	1,695	1,164	436	8,642
2026	4,966	701	2,178	1,400	518	9,763
2027	5,360	611	2,699	1,647	603	10,920
2028	5,718	518	3,215	1,923	696	12,070
2029	7,410	783	3,965	2,337	856	15,351
2030	9,585	1,145	4,915	2,842	1,079	19,566
2031	12,040	1,568	6,091	3,592	1,359	24,650
2032	15,130	2,058	7,521	4,529	1,697	30,935
2033	18,955	2,713	9,106	5,662	2,103	38,539
2034	23,620	3,537	10,541	6,865	2,547	47,110
2035	29,234	4,676	11,881	8,288	3,037	57,116

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Table C.4: EV Market Penetration Estimates Through 2035

Year	Light Duty/ Privately Owned	Light Duty/ Privately Owned (Wealthy)	Light Duty/ Fleet Owned	Commercial (4-7 tons GVWR) /Fleet Owned	Commercial (7-13 tons GVWR) / Fleet Owned	Total
2010	*9*	*0*	*5*	*2*	*1*	***17***
2011	*28*	*3*	*10*	*3*	*1*	***45***
2012	*45*	*10*	*20*	*7*	*3*	***85***
2013	*68*	*20*	*39*	*20*	*8*	***155***
2014	*97*	*29*	*83*	*50*	*20*	***279***
2015	*133*	*41*	*161*	*93*	*41*	***469***
2016	*223*	*57*	*295*	*176*	*72*	***823***
2017	*520*	*76*	*504*	*291*	*117*	***1,508***
2018	*980*	*124*	*836*	*454*	*192*	***2,586***
2019	*1,056*	*149*	*965*	*612*	*247*	***3,029***
2020	*1,134*	*193*	*1,008*	*754*	*311*	***3,400***
2021	*1,222*	*224*	*1,022*	*961*	*388*	***3,817***
2022	*1,333*	*259*	*1,048*	*1,237*	*482*	***4,359***
2023	*1,495*	*300*	*1,061*	*1,565*	*609*	***5,030***
2024	*1,838*	*353*	*1,357*	*2,003*	*793*	***6,344***
2025	*2,237*	*416*	*1,791*	*2,580*	*1,026*	***8,050***
2026	*3,004*	*490*	*2,297*	*3,385*	*1,325*	***10,501***
2027	*4,106*	*575*	*3,012*	*4,396*	*1,672*	***13,761***
2028	*5,582*	*698*	*3,971*	*5,589*	*2,068*	***17,908***
2029	*8,652*	*957*	*5,166*	*7,049*	*2,564*	***24,388***
2030	*12,618*	*1,236*	*6,484*	*8,784*	*3,154*	***32,276***
2031	*18,269*	*1,941*	*7,958*	*10,790*	*3,877*	***42,835***
2032	*24,879*	*3,019*	*9,671*	*13,098*	*4,714*	***55,381***
2033	*33,392*	*4,287*	*11,992*	*15,747*	*5,658*	***71,076***
2034	*44,967*	*6,241*	*14,644*	*18,709*	*6,698*	***91,259***
2035	*60,227*	*9,267*	*17,819*	*21,989*	*7,798*	***117,100***

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Appendix D – Federal and State PHEV/EV Incentives and Laws

Table D.1: Current Federal Vehicle Incentives

Federal Incentive	Description
New Qualified Plug-in Electric Drive Motor Vehicle Purchase Tax Credit	The minimum credit amount is $2,500, and the credit may be up to $15,000, based on each vehicle's traction battery capacity and the GVWR. The credit will begin to be phased out for each manufacturer in the second quarter following the calendar quarter in which a minimum of 200,000 qualified plug-in electric drive vehicles have been sold by that manufacturer for use in the U.S. This tax credit applies to vehicles acquired after December 31, 2009.
Credit for Certain Plug-in Electric Vehicles (2 and 3 wheeled low speed vehicles)	A tax credit of up to 10% of the cost of qualified low-speed electric vehicles, electric motorcycles, and three-wheeled electric vehicles, not to exceed $2,500, is available through December 31, 2011.
Plug-in Electric Vehicle Conversion Tax Credit	Through December 31, 2011, qualified plug-in electric vehicle conversions are eligible for a tax credit for 10% of the conversion cost, not to exceed $4,000.
Alternative Fuels Infrastructure Tax Credit	A tax credit is available for the cost of installing alternative fueling equipment for equipment placed into service on or after January 1, 2009. The credit amount is up to 50% not to exceed $50,000. Consumers who purchase residential fueling equipment may receive a tax credit of up to $2,000. The credit expires December 31, 2010.

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Table D.2: Current Arizona State Electric Vehicle Incentives

Arizona State Incentive	Description
High Occupancy Vehicle (HOV) Lane Exemption	Contingent upon approval from the Federal government, qualified low-emission and energy-efficient vehicles are permitted to use HOV lanes, regardless of the number of passengers.
Electric Vehicle (EV) Equipment Tax Credit	A tax credit of up to $75 is available to individuals for the installation of EV charging outlets in a house constructed by a taxpayer.
Alternative Fuel Vehicle (AFV) Parking Incentive	An individual driving a vehicle powered by an alternative fuel may park without penalty in parking areas that are designated for carpool operators.

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Table D.3: Current Arizona Laws and Regulations Affecting Electric Vehicles

Arizona Laws and Regulations	Description
Low Emission Vehicle (LEV) Standards	The Arizona Department of Environmental Quality (ADEQ) has adopted the LEV standards as set forth in Title 13 of the California Code of Regulations including the Zero Emission Vehicle sales and greenhouse gas emissions requirements. These regulations will apply to passenger cars and light-duty trucks beginning with model year 2012.
Joint Use of Government Fueling Infrastructure	To the extent practical, a state agency or political subdivision that operates an alternative fueling station must allow vehicles owned or operated by other state agencies or political subdivisions to fuel at the station.
Alternative Fuel and Alternative Fuel Vehicle (AFV) License Tax Exemption	The initial annual vehicle license tax on an AFV is lower than the license tax on conventional vehicles.
Alternative Fuel Vehicle (AFV) License Tax Electric Vehicle (EV) Parking	An individual is not allowed to stop, stand, or park a motor vehicle within any parking space specially designated for parking and recharging EV unless the motor vehicle is an EV and has been issued an alternative fuel vehicle special plate or sticker.
Neighborhood Electric Vehicle (NEV) Access to Roadways	NEV may not operate at speeds greater than 25 miles per hour (mph) but are allowed access to roadways with speed limits of up to 35 mph.

Source: U.S. Department of Energy

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Appendix E – Data Sources and Assumptions for Technical Potential and Payback Period Analyses

Table E.1: Data Sources and Assumptions for Payback Period Analysis

Data Type	EV	PHEV
Incremental Vehicle Costs	Mass production is assumed. Light-duty vehicle: ($571). Commercial truck (4 to 7 tons):. ($1,713). Commercial truck (7 to 13 tons): ($2,284).	Mass production is assumed. Light-duty vehicle: $1,424 Commercial truck (4 to 7 tons): $4,272. Commercial truck (7 to 13 tons): $5,696.
Battery Costs	All batteries are sized for 100 mile range in 2012 with excess capacity for air conditioning load and assumed to last at least 10 years in service. Cost is $500 per kWh in 2012 declining by 6 percent per year. Light-duty EV battery size: 43 kWh. Commercial truck (4-7 tons) EV battery size: 80 kWh. Commercial truck (7 to 13 tons) EV battery size: 100 kWh.	All batteries are sized for 25 mile all electric range in 2012 with excess capacity for air conditioning load and assumed to last at least 10 years in service. Cost is $750 per kWh in 2012 declining by 6 percent per year. Light-duty PHEV battery size: 12 kWh. Commercial truck (4-7 tons) PHEV battery size: 23 kWh. Commercial truck (7 to 13 tons) PHEV battery size: 30 kWh.
Infrastructure Costs	Light-duty vehicle/privately owned or privately owned (wealthy): $878 per charger in 2009. All others: $1,852 per charger in 2009. All charger hardware costs decline by 3 percent per year.	
Incentives	Federal Qualified Plug-in Electric Drive Vehicle Tax Credit: begins phase-out in 2018 when all manufacturers are assumed to reach 200,000 in cumulative vehicle sales. Phase-out credit is assumed to be 37 percent of full credit value in 2019. No credit is assumed in 2020 and later. No other incentives are considered.	
Operating Costs	Fuel prices are taken from the baseline gasoline and diesel price scenarios in the 2009 Annual Energy Outlook (nationwide). Electricity price assumed is held at $0.05175 per	Fuel prices are taken from the baseline gasoline and diesel price scenarios in the 2009 Annual Energy Outlook (nationwide). Electricity price assumed is held at $0.05175 per kWh.

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	kWh. Light-duty vehicle/privately owned: 14,000 miles per year. Light-duty vehicle/privately owned (wealthy): 10,500 miles per year. All others: 23,000 miles per year. Light-duty vehicle gasoline fuel consumption is based on Federal regulations through 2035. Commercial truck diesel fuel consumption is based on 2007 EPA data. All fuel consumption numbers are adjusted by 20 percent in summer months to account for Arizona air conditioning loads. Light-duty EV efficiency is assumed to be 3.6 miles per kWh in winter and 2.9 in summer with 12-month average 3.2, increasing by 1 percent per year. Commercial truck (4-7 tons GVWR) EV efficiency is assumed to be 1.95 miles per kWh in winter and 1.56 in summer with 12-month average 1.7, increasing by 1 percent per year. Commercial truck (7-13 tons GVWR) EV efficiency is assumed to be 1.56 miles per kWh in winter and 1.25 in summer with 12-month average 1.4, increasing by 1 percent per year. Maintenance costs for EV are assumed to be equivalent to those of conventional vehicles. Battery replacement costs not considered	Light-duty vehicle/privately owned: 14,000 miles per year. Light-duty vehicle/privately owned (wealthy): 10,500 miles per year. All others: 23,000 miles per year. Light-duty vehicle gasoline fuel consumption is based on Federal regulations through 2035. Commercial truck diesel fuel consumption is based on 2007 EPA data. All fuel consumption numbers are adjusted by 20 percent in summer months to account for Arizona air conditioning loads. PHEV efficiency in combustion mode is assumed to be 70 percent higher than a standard conventional vehicle. Light-duty PHEV efficiency in electric mode is assumed to be 3.6 miles per kWh in winter and 2.9 in summer with 12-month average 3.2, increasing by 1 percent per year. Commercial truck (4-7 tons GVWR) PHEV efficiency in electric mode is assumed to be 1.95 miles per kWh in winter and 1.56 in summer with 12-month average 1.7, increasing by 1 percent per year. Commercial truck (7-13 tons GVWR) PHEV efficiency in electric mode is assumed to be 1.56 miles per kWh in winter and 1.25 in summer with 12-month average 1.4, increasing by 1 percent per year. PHEV operation is assumed to be 60 percent electric mode (privately owned) and 28 percent (fleet

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		owned and commercial) by mileage. Maintenance costs for PHEVs are equivalent to those of conventional vehicles. Battery replacement costs not considered.

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Table E.2: Data Sources and Assumptions for Technical Potential Analysis

Data Type	Source
New Vehicle Sales	Arizona sales are based on a combination of near-term forecasts for vehicles sales (from R.L. Polk) and longer-term growth estimates based on new car sales growth trends (National Automobile Dealers Association). Light-duty vehicle and privately owned and light-duty vehicle/privately owned (wealthy) sales are estimated using a stock and flow approach and historical vehicle scrap rates. Fleet-owned vehicle sales are calculated by estimating the registrations trend growth and the average vehicle stock turnover. Finally, Arizona sales in each segment are adjusted by the percentage of Arizona vehicle population in each county and the percentage of households in each county served by APS.
Addressable Market Factors	These factors are based on the percentage of vehicles nationwide that are used for trips greater than 80 miles or are otherwise unsuitable for replacement with a 100-mile EV. The method is adapted from McKinsey (2009). The EV market factor is based on percentage of vehicles used for trips of 80 miles or less. Light-duty vehicles/privately owned and privately owned (wealthy): 0.7 (EV), 0.3 (PHEV). Light-duty vehicles/fleet owned: 0.5 (EV), 0.5 (PHEV). Commercial trucks: 0.3 (EV), 0.4 (PHEV).
Income Distribution	Census data are used to calculate the percentage of light-duty vehicles in each county that may be owned by wealthy households.

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Appendix F – Other PHEV/EV-Related Standards

- NFPA 70-2008 (National Electrical Code), CEC C22.1 - 2006 (Canadian Electrical Code Part 1), UL Standards, International Standards, SAE Recommended Practices.
- NFPA 70 Article 625 - Electrical Vehicle Supply Equipment: EV coupler, cord and plug, interlock, automatic de-energization of cable, personal protection against electric shock, back feed, interactive systems, and ventilation.
- UL 2202 - Electric vehicle charging system equipment
- UL 2231 - Personal protection systems for electric vehicle supply circuits
- UL 2251 - plugs, receptacles, and couplers
- IEC 61851 Series - Electric vehicle conductive charging system
- IEC 62196 - plugs, socket-outlets, vehicle couplers and vehicle inlets - conductive charging of electric vehicles
- SAE J1772 Recommended practice - electric vehicle and plug-in hybrid electric vehicle conductive charge coupler
- (DOE) Key Interconnection Standards
- ANSI/IEEE Std 1001 –1988 "Guide for Interfacing Dispersed Storage and Generation Facilities with Electric Utility Systems"
- IEEE Std. 929 – 2000 "Recommended Practice for Utility Interface of Photovoltaic (PV) Systems"
- IEEE P1547 "Standard for Distributed Resources Interconnected with Electric Power Systems"
- UL Standards (UL1741 - PV)
- NEC

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Appendix G – Current Utility PHEV/EV Programs and Activities

Dominion Resources, Inc.

Dominion Resources, Inc. (Dominion) is a producer and transporter of energy. The Company's portfolio of assets includes approximately 27,000 megawatts of generation; 6,000 miles of electric transmission lines; 56,000 miles of electric distribution lines in Virginia and North Carolina; 14,000 miles of natural gas transmission, gathering and storage pipeline; 28,000 miles of gas distribution pipeline, and 1.2 trillion cubic feet equivalent of natural gas and oil reserves. Dominion also owns the underground natural gas storage system and operates over 975 billion cubic feet of storage capacity and serves retail energy customers in 12 states. The Company operates in three segments: Dominion Virginia Power (DVP), Dominion Energy and Dominion Generation.

The company is actively involved in a number of PHEV/EV related research efforts and is engaged in various standards setting activities. The company is working with EPRI, GM and other groups to understand the potential utility system impacts that PHEV/EV might have in their service territory.

As part of the 'Renew Virginia' initiative, Dominion Virginia Power is installing electric vehicle charging stations at certain state rest areas. The stations charge vehicles at 120 volts and will eventually be upgraded to 240 volts. The Virginia Department of Transportation is working with Dominion to identify other facilities for electric vehicle charging station installations. Use of the stations is currently complimentary.

Dominion is participating in several public/private research initiatives to test hybrid vehicles and related systems and has partnered with GM to test the upcoming Chevrolet Volt prior to public marketing to assess how utilities can manage PHEV/EV technology.

Pepco Holdings, Inc.

Pepco Holdings, Inc (PHI), and its subsidiaries, Delmarva Power & Light, Atlantic City Electric, and Potomac Electric Power Company (PEPCO) service about two million electric customers in five states from Southern NJ through Washington DC. Delmarva Power provided seed funding for Mid-Atlantic Grid Interactive Cars Consortium research and has been working with the University of Delaware on V2G research for over five years.

PHI has filed its 'Blueprint of the Future' with the jurisdictions it serves, outlining how the company intends to transform its T&D infrastructure into a SmartGrid with a focus on environmental stewardship against the backdrop of decoupling.

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PHI is also involved in various EPRI research initiatives and expects to receive 10 Chevy Volts in 2010. The company hopes to use its AMI system to monitor PHEV/EV loads as they start arriving in their service territories and is actively engaged with various standards setting initiatives and discussions to ensure that the industry develops at an appropriate and not overly accelerated pace in recognition of the significant expenditure that will be required to develop the infrastructure required to support growing PHEV/EV adoption.

Duke Energy

Duke Energy provides electricity services to customers in North Carolina, South Carolina, Indiana, Kentucky, and Ohio. Duke Energy is one of several leading utilities that exemplify the preparation needed to avoid the risks and capture the benefits of electric vehicles.

The executive team at Duke Energy views plug-in vehicles as the consummate smart appliance because of their combined capabilities of energy storage, mobility, communications, and other onboard intelligence. Duke Energy has compiled a detailed database of its customer demographics and potential market adoption of plug-in electric vehicles. It is using this information, along with electricity demand profiles at the individual feeder level, to model potential impacts on distribution system reliability and investment. Separately, Duke uses internal cost-to-serve data with collaboratively developed consulting tools to model the net value of location-and time-specific charging of plug-in vehicles at the individual feeder level.

Duke Energy has five plug-in cars in its current vehicle fleet and have made a commitment that by 2020 all new corporate vehicle purchases will be plug-in electric vehicles. The company's support for PHEV/EV is primarily focused in two areas.

- Raising public awareness as to the benefits of PHEV/EV.
- Working with industry organizations, major automotive manufacturers and start-up companies to shape how electric vehicles will interface with the nation's power grid and ensure that the electric grid remains safe and reliable while ensuring that customers have the option to participate and that the experience is convenient and cost effective.

The utility is also in the process of designing several EV pilots and corresponding rate structures. Unlike Southern California Edison, Duke is not in favor of separate in-home PHEV/EV sub meters, believing that this will add unnecessary cost to in home fast-charger installations.

AEP

AEP is actively considering the impact of EV in its service territories and is likely to tailor its EV programs for each of the 11 states in which it operates. The utility remains actively involved in the NIST and SAE standards development efforts and has been a leader in defining issues that need to be resolved, including that of metering, billing and account reconciliation and 'resale of electricity' regulation.

AEP is actively involved in studying and developing EV technology for mass deployment.[85]

- AEP has converted two hybrid vehicles to PHEVs and is using them within its own vehicle fleet to gain real-world, first-hand experience with the technology.
- AEP is part of a research and development effort, along with the Electric Power Research Institute (EPRI), General Motors (GM) and 33 other top utilities, to facilitate integration of PHEV into the grid.
- AEP is working with EPRI and GM on the Chevy Volt to define technical features related to charging and the creation of a seamless customer experience with the dealer, utility and electrician.
- AEP is a member of the Electric Drive Transportation Association, the preeminent U.S. industry association dedicated to promotion of electric drive to achieve highly efficient and clean use of secure energy in the transportation sector.
- AEP is working with The Ohio State University - Center for Automotive Research (OSU-CAR) on issues related to public charging stations and the promotion of off-peak charging.

Southern California Edison

Socal Ed is, arguably, the most proactive of all U.S. utilities in the Electric Transportation arena. Its EV Technical Center – unique in the utility industry – provides a broad range of electric transportation services, focusing on solutions for automakers, battery manufacturers, government agencies, business and industrial fleet customers, residential customers and more.[86] With capabilities on par with those of national labs, the Pomona, California based Center is ISO 9001:2008 registered, and one of only two U.S. Department of Energy test sites approved to evaluate electric vehicle baseline performance, vehicle and fleet operation.

Established in 1993, the Center conducts work that serves several purposes:

- To understand and help minimize potential impacts of increasing quantities of transportation connecting to the grid.
- To evaluate various electric-drive technologies for use in SCE's own fleet applications to meet federal and state regulations.

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[85] AEP

[86] Southern California Edison

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- To assist SCE's Transportation Services Department in overseeing and maintaining the nation's largest and most successful fleet of pure battery-electric vehicles. Since inception, SCE's EV fleet has logged more than 17 million tailpipe-emission-free miles.
- To provide education and outreach to SCE's customers on the safe, reliable and energy-efficient use of electric-drive technologies, and to help customers shift charging to off-peak (low-energy-use) periods.

The Center:

- Tests battery-electric, hybrid-electric, plug-in hybrid, plug-in hybrid fuel cell and fuel cell propulsion systems for on and off-road applications.
- Evaluates and tests advanced battery modules, battery packs, battery management systems and various types of chargers.
- Supports the development of more energy-efficient battery charging systems.
- Evaluates advanced batteries and other energy storage technologies for stationary applications, such as home energy storage, telecommunications and emergency backup power.
- Partners with government and industry to demonstrate hydrogen and fuel cells and understand the safety and electrical system impacts of hydrogen generation, compression, storage and delivery.
- Provides consulting services for industry.

The Center's equipment includes:

- Fully equipped electric vehicle testing and maintenance facilities.
- A dedicated maintenance bay for hydrogen ICE and fuel cell vehicle prototypes.
- A test facility to safely assess and evaluate performance and electric load characteristics of fuel cell stacks.
- State-of-the-art battery testing laboratory.
- A "garage of the future" demonstration facility capable of simulating 120/240 volt charging, vehicle bi-directional energy flow, home energy storage, photovoltaic energy generation, and next-generation advanced meter control.
- Charging test equipment and environmental chambers.
- Fast charge testing facilities.
- A climate-controlled lab to test sensitive electronic equipment.

SoCal Ed is also proactively developing PHEV/EV rates and currently offers several - depending on when customers charge their vehicle and total home energy usage. SCE customers who purchase a plug-in electric vehicle can sign up for one of the following three choices:

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- SCE's standard residential rate. Under the standard residential rate plan, the price per kilowatt-hour is tiered and increases as the amount of energy usage over your baseline allocation increases.
- Whole-house "time of use" rate. This rate option uses a tiered structure similar to the standard residential rate, but provides lower electricity rates at night, when many plug-in electric vehicle owners are likely to charge their vehicles.
- Electric-vehicle-only "time of use" rate. This rate uses a second meter to measure the electricity you use to charge the vehicle, so that it can be billed at a separate rate from the rest of the home. Rates are discounted for charging that occurs during off-peak night-time hours. This option potentially gives customers the lowest rates for electric vehicle charging, but also involves more initial set-up cost and time.

SoCal Ed also remains an active and involved member of the Society of Automotive Engineers and has been a leading force in the development of various PHEV/EV related standards under the auspices of the SAE and NIST.

Xcel Energy

Xcel Energy has been proactively involved in Smart Grid related technologies, in particular through its investment the SmartGridCity project in Boulder, Colorado. The project, which was completed (in terms of infrastructure construction and installation of system software), in September 2009, is the first fully functioning smart grid enabled city in the world.

The project ties together a number of automated functions including: switching power through fully automated substations; re-routing power around bottlenecked lines; detecting power outages and proactively identifying outage risks. The deployment integrated more than 20 applications, 95 new interfaces and more than 300 test cases. Analysis of early results from the program suggests the system is capable of reducing power outages on the company's distribution system through adding real-time monitoring capabilities of the electric grid status which allows the company to predict equipment failure and proactively make repairs before an outage occurs.

Towards the end of 2009, Xcel Energy launched an in-home energy management Web portal provided by GridPoint that will give all Boulder customers with a smart meter the ability to review their in-home energy usage. This service will enable customers to design and personalize energy consumption strategies.

The company's Utility Innovations subsidiary has worked closely with the National Renewable Energy Laboratory to understand the potential impact of plug-in hybrid electric vehicles. In 2007, the company deployed several plug-in hybrid electric vehicles to investigate real-world duty cycles and obtain user feedback. This research led to the publication of NREL's "Costs and Emissions Associated with Plug-In

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Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory" Report (available at: http://www.xcelenergy.com/SiteCollectionDocuments/docs/41410.pdf).

The company is involved with a PHEV demonstration with Toyota for the hybrid electric Prius. Toyota will send 10 of its new plug-in hybrids to SmartGridCity in March 2010, the first wave of about 150 it hopes to test in United States this year. These vehicles will be at the heart of a new research project by the Renewable and Sustainable Energy Institute, a joint venture of the Department of Energy's National Renewable Energy Laboratory and the University of Colorado at Boulder. Vehicle charging solutions will be provided by GridPoint.

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Appendix H –Forecast PHEV/EV Load

Table H.1: Projected PHEV/EV Energy (MWh/Charging Cycle)

Year	Residential	Commercial	Total
2009	0	0	***0***
2010	0	1	***1***
2011	2	1	***3***
2012	3	3	***6***
2013	6	7	***13***
2014	10	15	***25***
2015	17	28	***45***
2016	28	49	***77***
2017	53	80	***133***
2018	93	126	***219***
2019	101	154	***255***
2020	108	174	***282***
2021	114	200	***314***
2022	123	233	***356***
2023	135	272	***407***
2024	156	347	***503***
2025	178	446	***624***
2026	218	576	***794***
2027	273	737	***1,010***
2028	345	928	***1,273***
2029	511	1,169	***1,680***
2030	724	1,454	***2,178***
2031	1,032	1,790	***2,822***
2032	1,405	2,180	***3,585***
2033	1,880	2,644	***4,524***
2034	2,528	3,157	***5,685***
2035	3,395	3,729	***7,124***

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Table H.2: Projected PHEV/EV Energy (GWh/Year)

Year	Residential	Commercial	Total
2009	0	0	***0***
2010	0	0	***0***
2011	1	0	***1***
2012	1	1	***2***
2013	2	2	***3***
2014	3	4	***7***
2015	5	7	***12***
2016	7	13	***20***
2017	14	21	***35***
2018	24	33	***57***
2019	26	40	***66***
2020	28	45	***73***
2021	30	52	***82***
2022	32	61	***93***
2023	35	71	***106***
2024	40	90	***131***
2025	46	116	***162***
2026	57	150	***207***
2027	71	192	***263***
2028	90	241	***331***
2029	133	304	***437***
2030	188	378	***566***
2031	268	465	***733***
2032	365	567	***932***
2033	489	687	***1,176***
2034	657	821	***1,478***
2035	883	970	***1,853***

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Table H.3: Annual Diversified PHEV/EV Load – Maximum Demand Impacts (MW – Off Peak)

Year	Residential	Commercial	Total
2009	0	0	***0***
2010	0	0	***0***
2011	0	0	***0***
2012	1	1	***2***
2013	1	1	***2***
2014	2	3	***5***
2015	3	5	***8***
2016	6	9	***15***
2017	10	14	***24***
2018	18	22	***40***
2019	19	26	***45***
2020	20	29	***49***
2021	21	33	***54***
2022	23	38	***61***
2023	25	44	***69***
2024	28	56	***84***
2025	32	72	***104***
2026	38	92	***130***
2027	47	118	***165***
2028	58	148	***206***
2029	85	186	***271***
2030	119	231	***350***
2031	168	284	***452***
2032	228	347	***575***
2033	303	421	***724***
2034	406	503	***909***
2035	542	594	***1,136***

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Appendix I –PHEV/EV Load With Unconstrained Charging

Table I.1: Annual Diversified PHEV/EV Load – Maximum Demand Impacts (MW – Off Peak) – Unconstrained Charging

Year	Residential	Commercial	Total
2009	0	0	0
2010	0	0	0
2011	0	0	0
2012	0	0	0
2013	0	1	1
2014	1	1	2
2015	1	2	3
2016	2	3	5
2017	4	5	9
2018	7	9	16
2019	7	10	17
2020	8	12	20
2021	8	13	21
2022	9	15	24
2023	10	17	27
2024	11	22	33
2025	12	28	40
2026	15	37	52
2027	18	47	65
2028	23	59	82
2029	33	74	107
2030	47	91	138
2031	66	113	179
2032	90	137	227
2033	120	167	287
2034	160	199	359
2035	215	235	450

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Table I.2: Annual PHEV/EV Impacts Coincident with System Peak (MW) – Unconstrained Charging

Year	Residential	Commercial	Total
2009	0	0	0
2010	0	0	0
2011	0	0	0
2012	0	0	0
2013	1	1	2
2014	1	2	3
2015	2	3	5
2016	3	5	8
2017	6	9	15
2018	10	13	23
2019	11	16	27
2020	12	18	30
2021	12	21	33
2022	13	25	38
2023	15	29	44
2024	17	36	53
2025	19	47	66
2026	23	61	84
2027	29	77	106
2028	37	97	134
2029	54	123	177
2030	76	153	229
2031	109	188	297
2032	148	229	377
2033	198	278	476
2034	266	332	598
2035	357	392	749

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Acronyms:

Descriptions
ADEQ - Arizona Department of Environmental Quality
AFV - Alternative Fuel Vehicle
AMI - Automated Meter Infrastructure
ARRA - American Recovery & Reinvestment Act (ARRA) of 2009
BEV - Battery Electric Vehicle
CAFE - Corporate Average Fuel Economy
CEC - Canadian Electrical Code
CHP - Combined Heat and Power
DER - Distributed Energy Resource
DG - Distributed Generation
DMS - Distribution Management Systems
DOE - Department of Energy
DR - Demand Response
E10 - Ethanol 10 percent fuel blend
EEI - Edison Electric Institute
EIA - Energy Information Administration
EPA - Environmental Protection Agency
EPIC - Electric Powered Intracity Commuter
ERRI - Electric Power Research Institute
ET - Electric Transportation
EV - Electric Vehicle
EVCort – Battery Electric Ford Escort
EVSE - Electric Vehicle Supply Equipment
FERC - Federal Energy Regulatory Commission
GHG - Greenhouse Gas
GVWR - Gross Vehicle Weight Rating
HAN - Home Area Network
HEV - Hybrid Electric Vehicles
HOV - High Occupancy Vehicle
IEA - International Energy Agency
IGBT - Insulated Gate Bipolar Transistor
ISO - Independent System Operator
ITT - International Telephone and Telegraph
LEV - Low Emission Vehicle

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LiCoO2 - Lithium Cobalt Oxide
LiFePO4 - Lithium Iron Phosphate
Li-ion - Lithium-ion
LiMn2O4 - Lithium Manganese dioxide
LTC - Local Transmission Company
LTP - Load Tap Changer
MPG - Miles Per Gallon
NCA - Lithium Nickel Cobalt Aluminum
NEC - National Electric Code
NEV - Neighborhood Electric Vehicle
NFPA - National Fire Protection Association
NGU - Next Generation Utility
NHTSA - National Highway Traffic Safety Administration
NiMH - Nickel Metal Hydride
NIST - National Institute of Standards and Technology
NMC - Lithium Nickel Manganese Cobalt
NOX - Mono-Nitrogen Oxides
PEV - Plug-in Electric Vehicle
PHEV - Plug-in Hybrid Electric Vehicle
PIR - Phoenix International Raceway
PQ - Power Quality
PUC - Public Utilities Commission
PV - Photovoltaic
REC - Renewable Energy Certificates
SAE - Society of Automotive Engineers
SCL - System Configuration Language
SDO - Standards Development Organization
SG - Smart grid
SWA - Southwest Airlines
TC - Timed Charging
TOU - Time of Use
UL - Underwriters Laboratory
UML - Unified Modeling Language
USABC - U.S. Advanced Battery Consortium
V0G - Convenience charging
V2B - Vehicle-to-Building
V2G - Vehicle-to-Grid
V2G NGU – Vehicle to Grid Next Generation Utility
V2H - Vehicle to Home

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VOC - Volatile Organic Compounds
WAN - Wide Area Networks
XFMR - Transformer
ZEV - Zero Emission Vehicle

Technical Terms:

Terms
Ancillary Services: Energy related commodities purchased by market operators to ensure reliability, such as spinning reserve, non-spinning reserve, operating reserves, responsive reserve, regulation up regulation down, and installed capacity.
Black start: process of restoring a power station to operation without relying on external energy sources.
Calendar life: the elapsed time before a battery (active or inactive) becomes unusable.
Charger: On-board devices that change AC power to DC power to recharge an EV's battery pack, as well as associated wiring and connectors to the electrical supply.
Conductive charging: a vehicle-grid connection that uses direct electrical contact (i.e., wires) to transfer energy to a vehicle battery.
Convenience charging (V0G): vehicle starts to charge as soon as it's plugged in, like a typical appliance.
Conventional motor fuels: petroleum-based fuels widely used today, including gasoline, diesel, propane, and natural gas.
Converter losses: electric power converted to heat within the electric power supply components that convert input power at one voltage to output power at a different voltage level.

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Corporate Average Fuel Economy standards: Federal regulations that require a minimum sales-weighted harmonic mean fuel economy, expressed in miles per gallon (mpg), of each vehicle manufacturer's fleet of passenger cars or light trucks with a gross vehicle weight rating (GVWR) of 8,500 pounds or less.
Cycle life: the number of charge-discharge cycles before a battery's nominal capacity falls below 80 percent of its initial rated capacity, or the number of cycles before internal resistance increases by a significant amount, such as double its initial value.
Deep-discharge cycle: depletion and replenishment of stored energy from a battery equivalent to the majority, typically 70 to 80 percent, of rated capacity.
Distributed generation: generation of electricity from many small energy sources.
Electric distribution network: a set of equipment, including medium-voltage (less than 50 kV) power lines, electrical substations and pole-mounted transformers, low-voltage (less than 1 kV) distribution wiring and sometimes electricity meters, that are used in the final stage in the delivery of electricity to end users.
Electric Vehicle: a car, truck, or other vehicle that uses one or more electric traction motors for propulsion; EV typically means a plug-in vehicle that stores all its energy in an on-board energy storage device (e.g., battery) and recharges using grid electricity.
Fast Charging technology: a charging system that uses on-board temperature regulators, such as a cooling fan and associated control circuitry, to help enable a high rate of battery charging.
Federal Qualified Plug In Electric Drive Motor Vehicle Tax Credit: A U.S. tax credit, enacted in the Energy Improvement and Extension Act of 2008 for the purchase of plug-in hybrid vehicles, worth \$2,500 plus \$417 for each kilowatt-hour of battery capacity over 4 kilowatt-hours, up to \$7,500 for cars under 10,000 pounds, \$10,000 for larger vehicles under 14,000 pounds, \$12,500 for bigger trucks under 26,000 pounds, or \$15,000 for larger trucks and equipment.
Fisher-Pry modeling technique: a method used to evaluate the rate at which new technologies diffuse and substitute for each other in the market, based on the work of J. C. Fisher and R. H. Pry.
FreedomCAR and Vehicle Technologies Program: a federally funded program, managed by U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, aimed at developing energy efficient and environmentally friendly highway transportation technologies.
Gas-fired combustion turbine: a power plant that extracts energy from a flow of combustion gas and can be used to generate electricity.
Gas-fired combined cycle units: a power plant that uses a gas turbine installed in conjunction with a heat recovery steam generator, which uses the turbine's hot exhaust gases to generate steam which in turn drives a steam turbine, and can used to generate electricity.
High energy battery: an energy storage device optimized for high specific energy or storage capacity and limited specific power output, typically suitable for EV applications.
High power batteries: an energy storage device optimized for high specific power output and limited specific energy capacity, typically suitable for PHEV applications.
Hybrid Electric Vehicle: a car, truck, or other vehicle that combines a conventional (usually fossil fuel-powered) powertrain with some form of electric propulsion and energy storage device (e.g., a battery) that is recharged from on-board sources without using grid electricity.

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Inductive charging: a vehicle-grid connection that uses inductive coupling (wireless) to transfer energy to a vehicle battery.
Inverter losses: electric power converted to heat within the electric power supply components that convert direct current to alternating current.
Level 1 charging system: a conductive vehicle charger and coupler rated at 120 Volts and 16 Amps, as defined by the SAE J1772 standard.
Level 2 charging system: a conductive vehicle charger and coupler rated at 240 Volts and 80 Amps, as defined by SAE J1772 standard.
Level 2 California new-vehicle emissions standards program: vehicle emission standards more stringent than Federal standards, to be phased in between 2010 and 2016.
Level 3 charging system: a conductive vehicle fast charger and coupler rated at up to 480 Volts and 400 Amps, the topic of an upcoming SAE standard.
Light-Duty Vehicle: any car or truck with GVWR up to 8,500 lbs.
Medium Commercial Vehicle: any vehicle with GVWR greater than 14,000 lbs. and up to 26,000 lbs.
NEC Article 625: Electric Vehicle Charging System section of the NEC.
National Electrical Code: a document published by National Fire Protection Association that influences many state and local fire and building codes.
On-board vehicle charging systems: power electronics on an EV or PHEV that convert AC power from the grid to DC at the correct battery voltage (typically 150 to 300 V) and control the charging rate.
Off-peak charging: the practice of carefully timing a vehicle battery charge only during off-peak utility periods.
Opportunity charging: practice of charging vehicle batteries at any convenient time, regardless of the battery's state of charge.
Peak load shedding: an energy demand management technique in which electricity consumption is reduced in response to supply conditions, timing, and/or price signals from the utility.
Peak vs. off-peak periods: times of day corresponding to high or low points on an electric utility's daily load curve and associated with high and low TOU rates.
Plug-in hybrid electric vehicle: a HEV with batteries that can be recharged by connecting a plug to an external electric power source.

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Power electronics: solid-state electronic devices, such as inverters, converters, and rectifiers, used for the control and conversion of electric power.
Power factor: the ratio of the real power (capacity of the circuit for performing work) flowing to the load to the apparent power (product of the current and voltage of the circuit), expressed as a percentage.
Shelf life: the time an inactive battery can be stored before battery's capacity falls below 80 percent of initial rated capacity.
Smart Charging (V1G): vehicle communicates with the grid in real time, and charges exactly when the grid needs it to. The vehicle also can provide ancillary services for extra revenue.
Small Commercial Vehicle: any vehicle with GVWR greater than 8,500 lbs. and up to 14,000 lbs.
Solar reflective glass technology: high thermal performance glass that minimizes sun loading on a vehicle interior.
Timed charging: vehicle doesn't charge until a given time (from an installed program or a signal from the utility) when rates and grid load are low.
Time of Use rates: utility charges that are assessed based on the time and/or season of electricity use.
Traction motor: an electric motor providing the primary rotational torque of a machine, usually for conversion into linear motion.(traction)
V2G Next Generation Utility: V2G but in the future, when the grid has become smarter and more reliant on renewables, efficiency, etc.
Vehicle-to-Building: like V2G, except the electrified vehicle does NOT communicate with the grid but instead with an individual building's energy management system.
Vehicle to Grid: a system in which electric or plug-in hybrid vehicles communicate with the power grid to sell demand response services by either delivering electricity into the grid or by throttling their charging rate.
Zigbee wireless technology: a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for wireless personal area networks (WPANs) and useful for communications among smart meters, smart appliances, and energy management systems in a home or building.
2-way communications: data transfer (e.g., price signals, real-time consumption, distributed generation availability) to and from customers and the electric utility.