ELECTRIC POWER RESEARCH INSTITUTE

Open Standards-Based Vehicle-to-Grid

Integrated Resource Planning Considerations

2018 TECHNICAL REPORT

Open Standards-Based Vehicle-to-Grid

Integrated Resource Planning Considerations

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ABSTRACT

The focus of this document is to discuss the unique aspects of assimilating the growing class of V2G (Vehicle to Grid) capable Electric Vehicles into Integrated Resource Planning (IRP) processes. In this discussion, earlier work on integrating distributed energy resources (DERs) into IRP is heavily adopted as a framework for V2G-capable EVs. This report is one of the three reports being published to encompass the overall scope of the project that was funded by the California Energy Commission, titled 'Distribution System Constrained Vehicle to Grid Services for Improved Grid Reliability and Stability'. The other two reports address Open Standards based Technology Implementation and Valuation aspects of this technology. The overall project focused on use cases around facility demand management, local and macro distribution system supply balancing, and reverse power flow applications. Use cases addressed primarily peak shaving and renewables ramping support. A variety of distribution and macro level valuation tools were developed and deployed to create a comprehensive valuation assessment of the broad penetration of vehicle-to-grid capable vehicles on the California distribution system.

Plug-in electric vehicles (PEVs) capable of V2G services are at least five years away, and their scale introduction is going to need a way for this feature to be incentivized through electric utility program offerings or market participation. Learnings from this project can be carried forward to create a set of operational assumptions, and coupled with growth forecasts, can assist in creating planning assumptions for the IRP processes in the next 10-year scenario planning phase. By starting this process early when PEVs are at the cusp of achieving mass-market appeal, studying the approaches to model and assess the capabilities of PEVs at scale could provide a sound foundation to build future IRP scenarios inclusive of PEVs in an applicable context. The report also describes the growth scenarios of EVs in the California grid and the potential impact they can have if the California Governor's Executive Order of 5M vehicles by 2030, or even a smaller number of EVs, were to be made available for sale in CA. Since EVs are going to be primarily behind-the meter resources, their accounting for grid services may be accommodated in the context of distribution system planning. Therefore, the PEV role in the Distribution Resources Plan (DRP) is also described.

Keywords

Vehicle to Grid (V2G)
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Integrated Resource Planning (IRP)
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KEY RESEARCH QUESTION

The focus of this document is to discuss the unique aspects of assimilating the growing class of V2G (Vehicle to Grid) capable Electric Vehicles into Integrated Resource Planning (IRP) processes. In this discussion, earlier work on integrating distributed energy resources (DERs) into IRP[1] is heavily adopted as a framework for V2G-capable EVs.

RESEARCH OVERVIEW

Plug-in electric vehicles (PEVs) capable of V2G services are at least 5 years away, and their scale introduction will require a way for this feature to be incentivized through electric utility program offerings or market participation. Learnings from this project can be carried forward to create a set of operational assumptions, and coupled with growth forecasts, can assist in creating planning assumptions for IRP processes in the next 10-year scenario planning phase. By starting this process early when the PEVs are at the cusp of achieving mass-market appeal, studying the approaches to model and assess the capabilities of PEVs at scale could provide a sound foundation to build future IRP scenarios inclusive of PEVs in an applicable context. The report also describes the growth scenarios of EVs in the California grid and the potential impact they can have if the California Governor's Executive Order of 5M vehicles by 2030, or even a smaller number of EVs, were to be made available for sale in CA. Since EVs are going to be primarily behind-the meter resources, their accounting for grid services may be accommodated in the context of distribution system planning. Therefore, the PEV role in the Distribution Resources Plan (DRP) was also described.

KEY FINDINGS

- Guaranteed verifiable availability and performance of PEVs to deliver the services they commit is a key factor in obtaining storage-like treatment in the Long-Term Procurement Plan (LTPP) and the IRP planning and procurement processes at the Independent System Operator (ISO) / market level. This is currently governed by SB350 and CPUC Scoping Memo R.16-02-007[2]. The fact that PEVs are mobile and *only* available 20-22 hours a day at varying locations needs to be factored in.
- The issue of Interconnection Requirements per CPUC Rule 21 under R.17-07-007[3] also must be resolved through uniform requirements based on common sense and consensus. This is critical for reverse power flow capable EVs (being treated like generating resources). Specifically, harmonization among IEEE2030.5, IEEE1547, SAE J3072 and SAE J2847/3 as well as UL1741 is critical. This was a key learning of the project itself.

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[1] Developing a Framework for Integrated Energy Network Planning (IEN-P): 10 Key Challenges for Future Electric System Resource Planning. EPRI, Palo Alto, CA: 2018. 3002010821, to be published

[2] Integrated Resource Plan and Long-Term Procurement Plan, http://www.cpuc.ca.gov/irp/

[3] Interconnection Rulemaking, http://www.cpuc.ca.gov/General.aspx?id=6442455170

- Dynamic Rate tariffs may be beneficial for PEV customers and others, but may need changes to account for low or no cost consumption, spring excess supply periods, and incentive curtailment during peak intervals. CPUC R.12-06-013[4] Residential Tariff Rulemaking is addressing this and specific provisions for PEV charging are in the mix. A recently held[5] Zero Emission Vehicle (ZEV) Tariff Design workshop made initial contributions to this effect.
- In the siting of public / commercial infrastructure[6], the investor-owned utilities (IOUs) may prioritize focusing on installations at sections of distribution systems where there are likely to be excess supply issues, or intentionally couple solar plus charging to reduce grid impacts, while also helping local commercial establishments. In other words, PEV infrastructure planning may need to be done jointly with Distribution System Planning *and* Distribution Resources Planning[7].
- Lastly, the DRP[8] process across IOUs is underway, and the plans generally are updated every three years, with the 10-year horizon each time. Therefore, if even some of them start including PEVs, they may justify inclusion in electric utility DRPs and other related planning exercises, including pilots targeting PEVs for grid services.

WHY THIS MATTERS

This report is the first of its kind looking at the issue of holistically integrating Plug-in Electric Vehicles as a class of Distributed Energy Resources within the Integrated Resource Planning process. It is the first ever effort to line up a fast-growing class of DERs (PEVs) against distribution or ISO level planning processes such as DRP, IRP and LTPP. It provides a framework and directionality of growth of PEVs as a resource class, and how they can be integrated as a new resource class into these proceedings. The report also finds existing gaps in how the PEVs are treated from the planning perspective, as well as the additional information required to ascertain value.

HOW TO APPLY RESULTS

For the grid planners looking to integrate PEVs into their procurement planning, this report provides information on growth projections of both PEVs as a DER class and the capabilities of each PEV for grid services. For the technology providers, this discussion provides technology performance and cost benchmarks to attain to be of meaningful value to the grid.

[4] Residential Tariff Rulemaking http://www.cpuc.ca.gov/general.aspx?id=12154
[5] CPUC ZEV Rate Design Forum, 6-7 June, 2018, http://www.cpuc.ca.gov/energy/electricrates/
[6] Zero Emission Vehicles, http://www.cpuc.ca.gov/zev/#Infrastructure
[7] Distribution Resources Plan http://www.cpuc.ca.gov/General.aspx?id=5071
[8] ibid

LEARNING AND ENGAGEMENT OPPORTUNITIES

- There are two other companion reports being released that address technology and valuation aspects of Vehicle to Grid integration. EPRI continues to extend the technology application and integration in the form of additional federal / state funded programs, and members can reach out to the PM to participate on the Technical Advisory Committee.
- This work was funded by the California Energy Commission. Grid Planning staff at ISO and DSO level participating in IRP, LTPP or DRP process will relate to this report. Additionally, Integrated Resource Planning staff within the Energy and Environment Sector will also benefit from this discussion.

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PROGRAM: Program 18, Electric Transportation

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INTEGRATED RESOURCE PLANNING WITH DISTRIBUTED ENERGY RESOURCES

Introduction

The focus of this document is to discuss the unique aspects of assimilating the growing class of V2G (Vehicle to Grid) capable Electric Vehicles into Integrated Resource Planning (IRP) processes. In this discussion, earlier work on Integrating DERs (and specifically, energy storage) into IRP[9] is heavily adopted as a framework for V2G-capable EVs, which are:

- They are mobile resources with the primary purpose of mobility, but are plugged in 20-22 hours every day and are capable, subject to system constraints, of sending and receiving power and energy from the grid in response to a variety of grid service signals.
- Their location varies, but is primarily (about 97%) focused around workplace and residential locations – which are dispersed at the edge of the distribution grid for retail purposes and at potentially advantageous locations in fleet scenarios (including Mobility-as-a-Service (MaaS) fleets such as UBER, LYFT, MAVEN, etc.).
- A specialized case of stationary storage in that they are, by design, constrained in terms of energy and demand/capacity availability for grid support purposes given that their primary purpose is mobility. Demand from plug-in electric vehicle (PEV) battery recharging varies geospatially and temporally, and has specific implications for planning and modeling exercises.
- Unlike stationary storage, as behind-the-meter (BTM) customer-procured resources, V2G capable EVs may help alleviate upward rate pressure experienced by ratepayers due to the infrastructure investments being made by investor-owned utilities (IOUs) and publicly-owned utilities (POUs) to facilitate SB350[10] regulatory-driven expansion of transportation electrification.

On the flip side, at 6-20kW each and 10-30kWh each, EVs offer the most system benefit when treated in an aggregated manner, rather than on a unit basis. As such, most participation scenarios of EVs into the IRP process must consider the aggregator role as a key enabler to their effective participation in the IRP.

[9] Developing a Framework for Integrated Energy Network Planning (IEN-P): 10 Key Challenges for Future Electric System Resource Planning. EPRI, Palo Alto, CA: 2018. 3002010821.

Finally, the primary purpose of EVs remains zero emission mobility, and this aspect must take precedence over their participation in grid-support functions, which can be accounted through appropriate capacity and energy estimation assumptions.

Historical Context[10]

As of 2015, more than 30 states required electric utilities to do some form of resource planning to demonstrate that company investment plans to meet electricity demand are in the public interest.[11] Figure 1-1 highlights these states. In addition, in many states companies must seek power plant investment preapprovals by obtaining a Certificate of Public Convenience and Necessity (CPCN)[12]

Current resource planning practices are rooted in the 1970s. In that era, rapid load growth coupled with concerns over rising costs, reliability, and environmental protection led to development of least-cost planning[13] processes, with a goal of minimizing the total costs of an electric utility's[14] power generation resource portfolio, subject to reliability and emissions constraints (4). Growing regulatory, cost, and demand uncertainties contributed to development of IRP in the 1980s.

[11] These planning requirements typically fall into one of four categories: (i) IRPs; (ii) Plans submitted to obtain discrete approval for specific power generation or demand response resources; (iii) Plans associated with providing default electric service in competitive states; and, (iv) Long-term asset procurement planning.
[12] Adapted from *Developing a Framework for Integrated Energy Network Planning (IEN-P): 10 Key Challenges for Future Electric System Resource Planning*. EPRI, Palo Alto, CA: 2018. 3002010821
[13] "Least-cost planning" refers here broadly to any planning process designed to minimize costs subject to a set of constraints, rather than more narrowly to formal integrated resource planning.
[14] "Utility" here refers to any entity that acquires electricity resources to serve end-use customers.

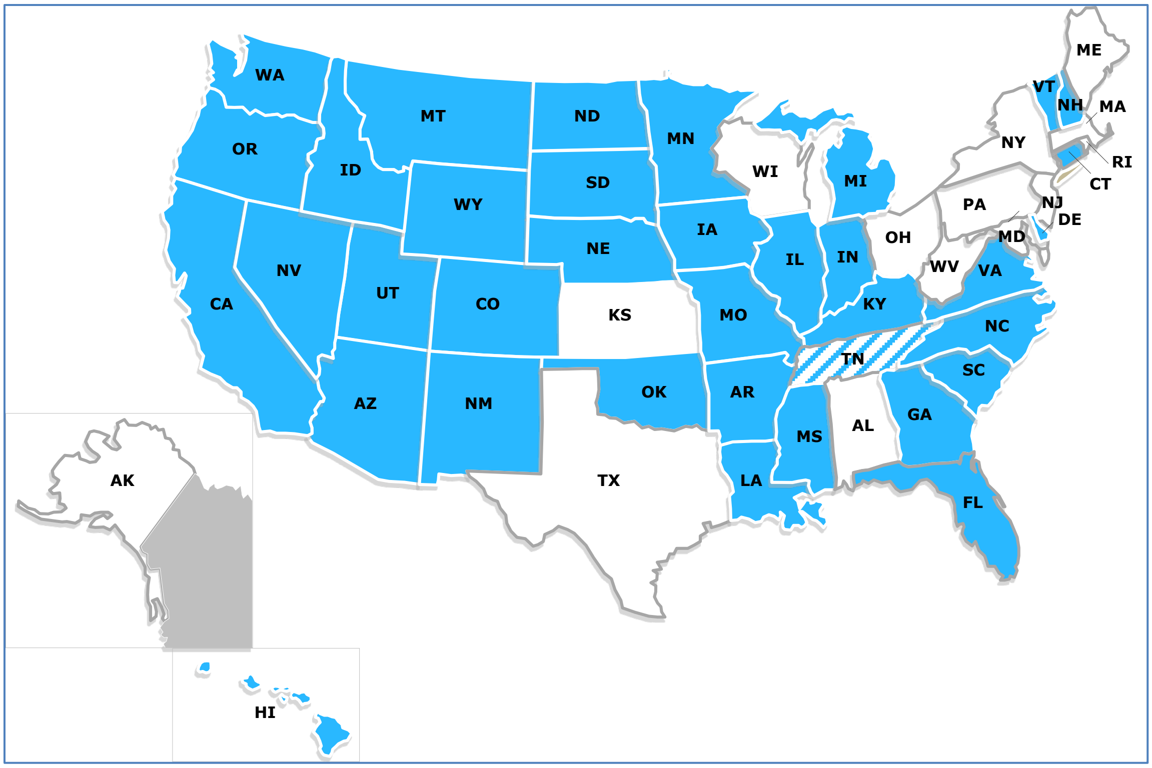

Figure 1-1
States that Required Integrated Resources Planning as of 2015[15]

Source: Adapted from United States Environmental Protection Agency Energy and Environment Guide to Action 2015. Based on research conducted for EPA by Synapse Energy Economics, updated from Synapse 2013. Additional updates by EPRI 2018.

Electric system resource planning has undergone three important changes since the 1980s. First, the passage in 1978 of the Public Utility Regulatory Policies Act[16] (PURPA) and the Energy Policy Act[17] (EPAct) in 1992 formalized and standardized IRP. In response to PURPA, individual states developed formal electricity resource planning processes, and began to require electric utilities to conduct resource planning under state oversight. The EPAct codified and standardized the evolving planning processes under federal law. By the early 1990s, all but nine states had some variant of an IRP process in place.

Second, the introduction of regional wholesale power markets in California, the Northeast, the Midwest, and Texas shifted responsibility for key aspects of resource planning. Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) that operate regional transmission grids and manage regional wholesale power markets now have some planning responsibilities that previously were solely the responsibility of electric companies,

[15] We have highlighted TN in Figure 1-1 because the 1992 Energy Policy Act requires the Tennessee Valley Authority (TVA) to prepare IRPs, and TVA is responsible for delivering electric service to most consumers and regions in the state. California and Florida have been added to the original version of Figure 1-1. With passage of SB-350 in 2015, electric companies in CA are required to submit IRPs. Electric companies in FL are required to submit IRPs in the form of Ten Year Site Plans.

[16] The Public Utility Regulatory Policies Act (PURPA, Public Law 95–617, 92 Stat. 3117, enacted November 9, 1978) was passed by Congress as part of the National Energy Act. This federal law was envisioned to promote energy conservation and greater use of domestic energy and renewable energy sources

[17] §111 of the 1992 Energy Policy Act (102 Congress HR 776).

particularly related to resource adequacy and transmission planning. FERC Orders 890 and 1000 mandated regional transmission planning requirements which typically are implemented by the RTOs/ISOs in regions where they operate.

Third, the structure of electric companies has changed significantly. The rise of regional wholesale power markets was accompanied by the divestiture of utility-owned generation assets in some regions, and altered the role of utilities. Rather than building, owning, and operating generation resources, some utilities began to purchase energy and capacity through a combination of bilateral and centralized market transactions. In recent years, an increasing number of companies with historic resource planning responsibilities have restructured and are no longer vertically integrated. This restructuring was also pushed forward by the advent of retail consumer choice in some regions of the country.

Contexts and approaches[18]

The planning process differs significantly across states, and it differs depending on the business structure of the electric company engaged in it. Companies with resource planning responsibilities today include a range of organizational structures, including investor-owned utilities (IOUs), generation and transmission cooperatives (G&T), publicly-owned utilities (POUs), load-serving entities (LSEs), “wires only” distribution companies, independent power providers (IPPs), and community choice aggregators (CCAs).

Each of these types of organizations has different responsibilities for generation (G), transmission (T) and distribution (D) systems and operations planning. Regardless of the many differences in planning processes, most resource planning processes are completed administratively and consider costs, benefits and risks over the long term.

Several vertically integrated electric companies continue to operate and conduct IRPs as part of the process to obtain approval to construct specific new facilities, retire existing facilities, and as part of routine communications with state public utilities commissions (PUCs). For Load-serving entities (LSEs) operating in restructured electricity markets, resource planning may be used to inform how they procure electricity to meet demand from customers who do not choose to buy electricity from a competitive electricity supplier. In regions where the grid is managed by an RTO or ISO, like California, regional transmission planning is often done by the RTO or ISO. Also, resource planning studies are now being conducted by public policy organizations, particularly in states with retail open access policies and with third-party administrators of energy efficiency and renewable energy programs.

State public utilities commissions (PUCs) typically are the state regulatory agencies that oversee development and implementation of IRPs. PUCs in different states take different roles in the IRP process. Typically, PUCs do not require or enforce specific IRP findings or outcomes, but rather engage in formal proceedings to approve the content of an IRP, and to acknowledge the IRP process was completed appropriately. In some states, such as California, Indiana, Georgia and Oregon, the review and evaluation of IRPs is conducted in formal regulatory dockets in which commission staff and stakeholders may issue formal or informal discovery and submit comments on an IRP’s assumptions and development. Electric cooperatives and municipal utilities are often not subject to state PUC oversight. Typically, boards of directors appointed by member-

[18] Op.Cit., EPRI 2018.

customers are responsible for oversight of electric cooperatives, and municipal governments that supply electric services regulate their own utilities.[19, 20]

Evolution of Resource Planning in the State of California[21]

In recent years, CA has adopted a variety of policies and programs that have significantly altered how resource planning is conducted. First, in 2003, energy regulators adopted a "loading order" to guide future energy decisions. This order provides a hierarchy of preferred resources to be used to close projected capacity needs. It prioritizes demand-side options by increasing EE and DR, and then meets new resource needs first with VER and DER, and second with "clean" fossil-fueled generation.[22] Prior to 2012, the work by the California Independent System Operator (CAISO), CEC and CPUC between 2006 and 2010 was done to align the TPP (Transmission Planning Process) and LTPP (Long-Term Procurement Plan). At the end of 2010, a Joint Scoping Memo and Ruling institutionalized the 2010 Long-Term Procurement Plan (LTPP) Standardized Planning Assumptions[23]. These were subsequently refined in 2012 and 2014 and built upon the template established in 2010. In 2012[24] (OIR 3/27/2012, Scoping Memo 1), the State of California established its Long-Term Procurement Plan (LTPP) proceedings to accomplish a safe, reliable and economically efficient electricity supply in California.

Second, CA adopted a distribution resource planning requirement that requires IOUs to develop Distribution Resources Plans (DRPs), which are intended to be blueprints for integrating DER into distribution operations, planning, and investment.[25]

Third — and perhaps most significantly — CA enacted Senate Bill 350 in 2015[26] which mandates the CA Public Utilities Commission (CPUC) to adopt a new IRP process that requires LSEs to meet greenhouse gas (GHG) emissions targets that reflect the electricity sector's contribution to achieving economy-wide GHG emissions reductions of 40 percent below 1990 levels by 2030. SB-350 also requires electric companies to: (i) procure at least 50 percent eligible renewable energy resources by 2030 (i.e. 50% RPS); (ii) double end-use EE savings in electricity and natural gas by 2030; and, (iii) achieve a series of other legislative objectives that impact long-term resource planning. The current LTPP proceeding is R.13-12-010[27]. In its current version (c2016), it has the latest set of assumptions around Flexible Loads and Resources that

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[19] EPA 2015, p 7-27.

[20] In rare cases, such as in Kentucky and to a very limited extent in Minnesota, the state PUC reviews and regulates cooperatively owned utilities.

[21] EPRI 2018 Forthcoming.

[22] The loading order was adopted in the 2003 Energy Action Plan prepared by the energy agencies, and the Energy Commission's 2003 Integrated Energy Policy Report (2003 Energy Report) used the loading order as the foundation for its recommended energy policies and decisions.

[23] 2010 LTPP Standardized Planning Assumptions Joint Scoping Memo and Ruling http://docs.cpuc.ca.gov/EFILE/rulc/127542.pdf

[24] Order Instituting Rulemaking, 3/27/2012, Scoping Memo 1 http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/162752.PDF

[25] For more on these plans and the DRP proceeding, see CPUC, "Distribution Resources Plan (R.14-08-013)," http://www.cpuc.ca.gov/General.aspx?id=5071 .

[26] SB-350 is the "Clean Energy and Pollution Reduction Act of 2015." For more information, see "Order Instituting Rulemaking to Develop an Electricity Integrated Resource Planning Framework and to Coordinate and Refine Long-Term Procurement Planning Requirements," State of California Public Utilities Commission, February 19, 2016. Rulemaking 16-02-007.

[27] Planning Assumptions & Scenarios for The 2016 Long-Term Procurement Plan Proceeding and the CAISO 2016-17 Transmission Planning Process http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11673

should be used by procurement planners for modeling and procurement filings in the next LTPP / IRP process. Figure 1-2 describes the essential elements of this proceeding.

Assumptions

- Realistic but not overlooking potential technology advancements
- Real-world possibilities relative to market participant intent / positions

Scenarios

- Open and transparent process while protecting confidential information
- Inform TPP and analysis of flexible resource requirements to achieve reliable integration of new resources
- Designed to contain useful policy information, e.g., GHG goals, Reliability implications etc
- Limited number driven by policy objectives of current LTPP

Resource Portfolios

- Substantially unique from each-other

Transparent, Consistent and Coordinated Planning Process

Figure 1-2
2016 LTPP Guiding Principles Summary

Other recent CA legislative and regulatory decisions also are likely to impact electric resource planning in the state, including:

(i) Incentive programs to increase distributed generation (DG) deployment[28];

(ii) Initiatives aimed at better integrating DR into the wholesale energy markets and the CPUC's resource adequacy planning process[29];

(iii) Annual EE savings targets set by the CPUC;

(iv) An energy storage mandate requiring IOUs to procure 1,325 MW of storage by 2020[30]; and,

(v) Aggressive zero emission vehicle goals requiring 1.5 million PEVs and fuel cell EVs to be on the road by 2025.[31]

[28] CPUC, "Distributed Generation in California," http://www.cpuc.ca.gov/PUC/energy/DistGen/.
[29] See CAISO's Demand Response Initiative online: http://www.caiso.com/informed/Pages/StakeholderProcesses/CompletedClosedStakeholderInitiatives/DemandResponseInitiative.aspx .
[30] Decision Adopting Energy Storage Procurement Framework and Design Program. Decision 13-10-040. California Public Utilities Commission, San Francisco, CA 2013.
[31] Office of the Governor. 2013 ZEV Action Plan. Office of the Governor, Sacramento, CA 2013.

These initiatives are expected to drive DER penetrations much higher over the next decade.

Figure 1-3 describes the guiding principles of this set of planning assumptions:

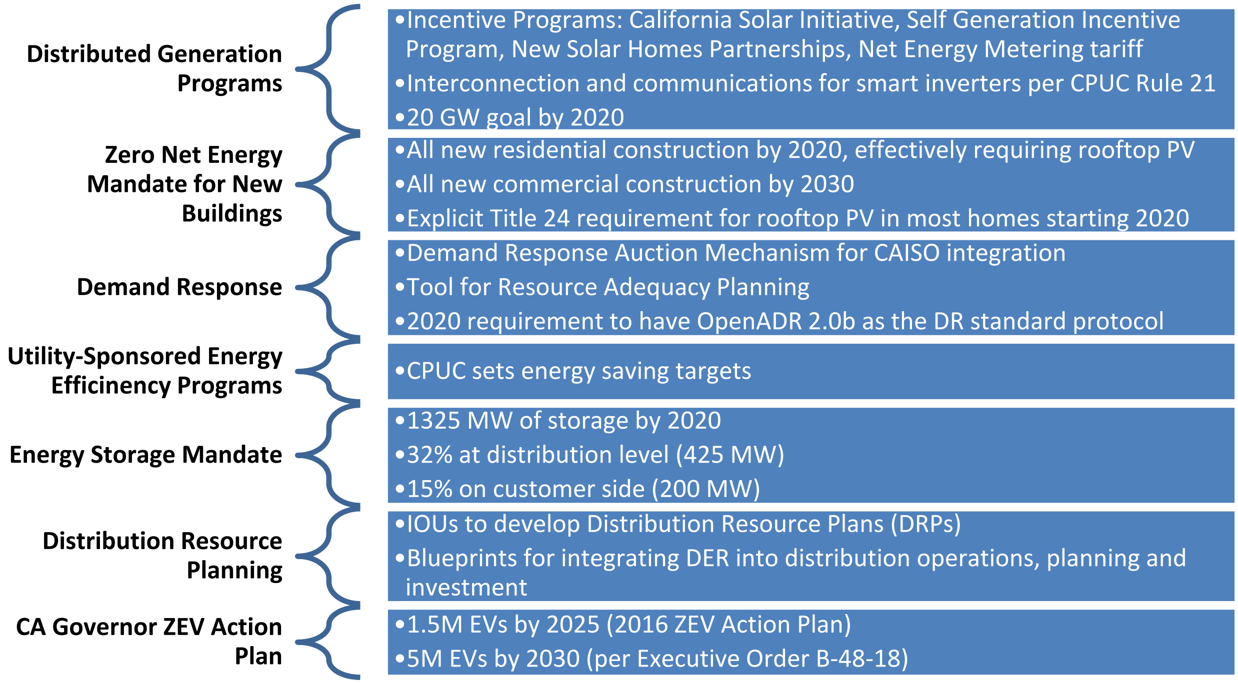

Figure 1-3
State of California Initiatives Targeting DERs

The California electric system is large, diverse and rapidly expanding to incorporate all the customer-sited (Behind the Meter or BTM) renewable DER assets as a growing class of resources. By some estimates[32], the renewable generation accounts for over 50% of the daily demand already (RPS requires 33% at present). The electric system in California includes the following key entities:

- Three large Investor-Owned Utilities (IOUs), two very large and many smaller municipals and a good number of smaller utilities and co-ops.
- The California Public Utilities Commission (CPUC) has the statewide authority to set and supervise the resource adequacy planning process, along with utility EE and DR programs across utilities in its jurisdiction.
- The California Energy Commission (CEC) is the policy and planning organization that provides electric demand forecasts used in resource planning, maintains load and resource data, as well as has the responsibility to oversee IRP for Publicly Owned Utilities (POUs) under SB350.[33].

[3232] In May 2018, the average of renewables serving load was over 36%, with the maximum during one 5-minute dispatch interval reaching nearly 74% (per the CAISO's Monthly Renewables Performance Report)
[33] Publicly Owned Utilities Integrated Resource Plans, http://www.energy.ca.gov/sb350/IRPs/

- The California Independent System Operator (CAISO) is responsible for managing the wholesale energy and ancillary services market that spans the state as well as operates the long-term transmission planning process.

The economic underpinnings for DER as a resource class for the planning process is enabled through CPUC and legislative decisions, as well as CAISO activities as shown in Figure 1-4.

Integrated Resource Planning Process for DERs

While the specifics of regulatory and planning treatment may vary from region to region, broadly speaking the principles remain the same. The fundamental treatment criteria and planning assumptions are similar in a variety of jurisdictions.

Approach to DER in IRP: Load Modifiers or Supply Resources

Heretofore, 'traditional' DERs such as EE and DR have been treated as load modifiers – to change the load (increase or decrease) in response to an external signal in sync with demand forecasts. This can be scheduled day-ahead or in real-time. With increased renewable penetration (likely to reach and the rise of the famous 'Duck Curve[34]) signifying increasing need to manage oversupply and resultant backflow of power upstream (from resources toward the substations), as well as steep ramp-up required during summer afternoons as a result of steep fall of renewable generation at the end of the day with the simultaneous load pick-up in the evening with Air Conditioners being turned on, the need to manage resource/load parity in real-time has become even more acute.

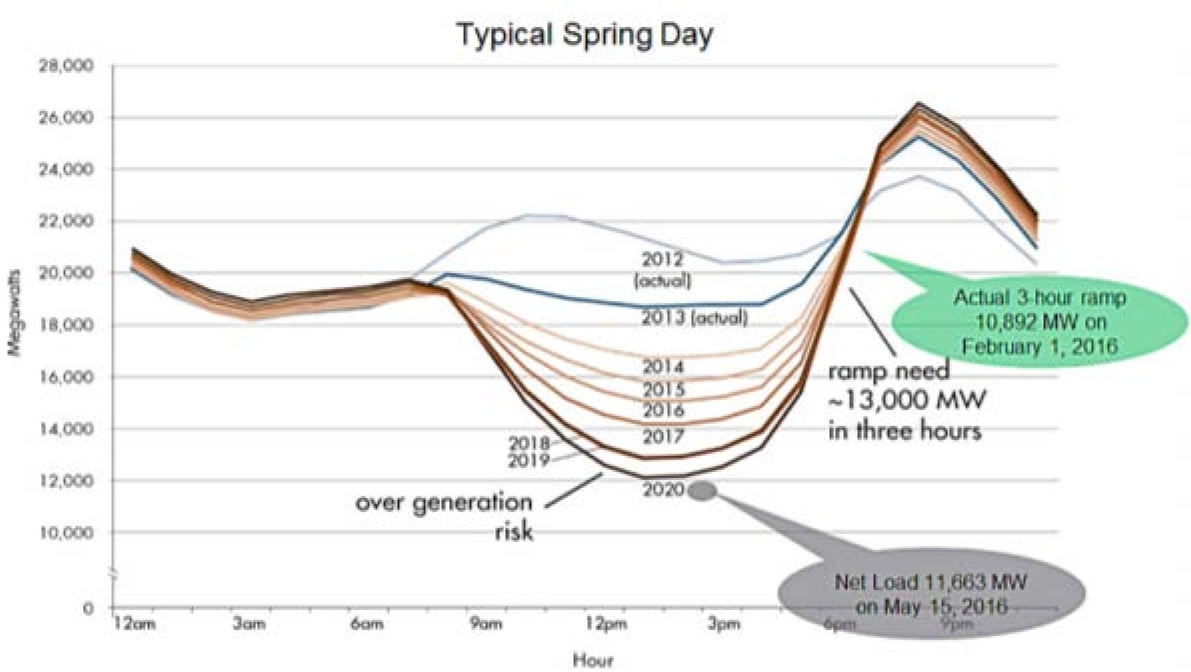

Figure 1-4
Duck Curve with Observed Net Load on CAISO from 2016 Data (Source, CAISO)

34 Flexible Resources Help Renewables, Fast Facts, CAISO, 2016, http://www.caiso.com/Documents/Flexibleresourceshelprenewables_FastFacts.pdf

In fact, the CAISO is recommending the following measures[35] to mitigate effects of over-supply:

- Expanding the CAISO control area outside of California to balance California oversupply with neighboring states' loads
- Increase participation in Western Energy Imbalance Market – again, with the same end objective
- Electrification of transportation – specifically for absorbing the 'shiftable' charging to oversupply periods of the day
- Change Time-Of-Use rates to encourage consumers to *consume* more energy during an oversupply period
- Increase Energy Storage
- Increase the flexibility of power plants for faster response to ISO dispatch instructions

Whether treating DERs as load modifiers or supply resources,[36],[37] the end result is the same operationally, but they are treated very differently for planning purposes.

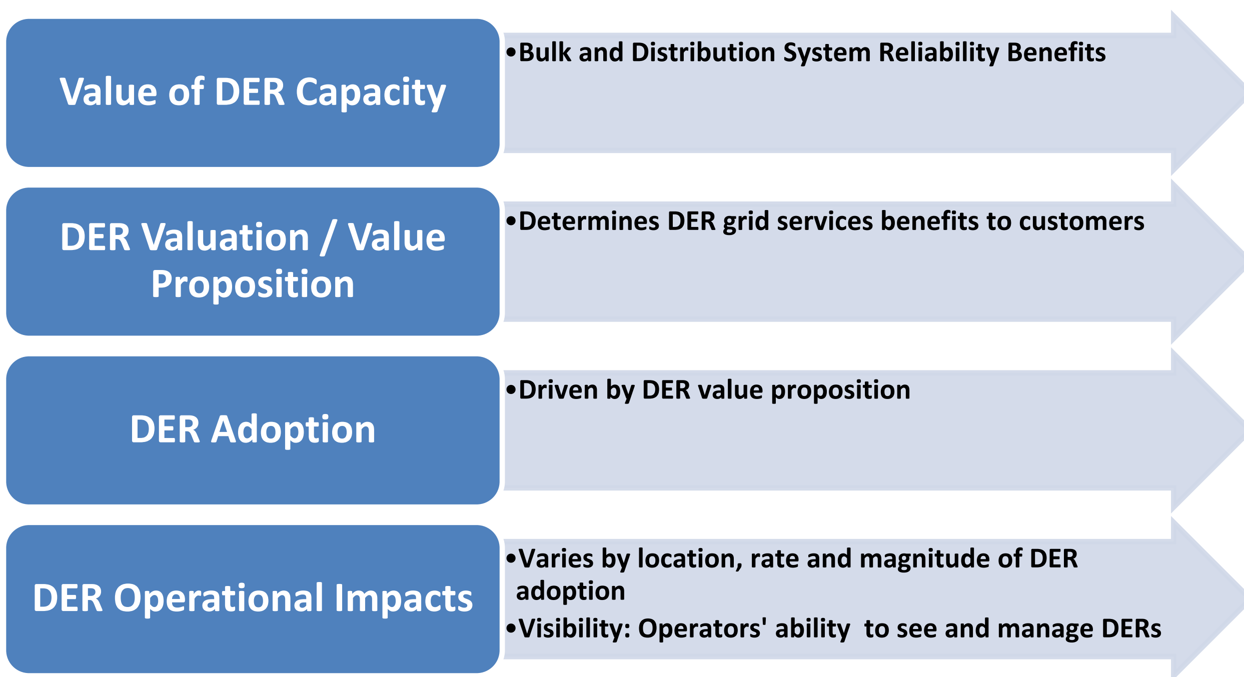

Figure 1-5
DER Treatment Impact on Resource Planning

[35] ibid

[36] CAISO defines Load Modifiers A voluntary load reduction, load shifting, or energy efficiency program that modifies the underlying load, which is captured in the natural load and affects future load forecasts. Non-dispatchable means dynamic rates and tariffs, energy efficiency programs and or permanent load shifting programs'. CAISO definition of a Resource (Dispatchable) is 'A demand response resource configured as a generation substitute and dispatchable by the ISO or IOU/DRP when and where needed and in the amount of energy needed'.

[37] ISO Demand Response Lexicon, 2013, http://www.caiso.com/Documents/Lexicon-DemandResponseandEnergyEfficiencyRoadmapWorkshop.pdf

For resource planning purposes, several factors are considered for developing reliable long-term forecasts. These are based on the potential adoption of DERs and their operational impacts, which may vary by location and visibility (Figure 1-5). The adoption is in turn driven by the value of DERs and the benefits that it provides to bulk and distribution system reliability. Additionally, the structure of a utility does affect the DER treatment. A vertically integrated (i.e., owning generation, transmission and distribution network all the way to customer) utility lacks the regular procurement process and therefore may not allow it to treat a DER as a resource. For a distribution utility (wires only or DSO including substations) with access to the wholesale market, procurement plans are a must, and mechanisms do exist to participate in both the load and resource side of procurement processes.

To date, DR has sometimes been treated as a Supply resource, but usually is treated as load modification for long-term planning, to enable its participation through market product such as DRAM[38] (Demand Response Auction Mechanism) in CAISO, and through a Distributed Energy Resource Provider (DERP) mechanism[39] with a minimum of 500kW threshold to bid into wholesale markets.

Role of Aggregators

CAISO energy market enables aggregators to participate as Scheduling Coordinators, as DERPs or through DRAM, while working with several commercial/industrial customers as the actual entities participating in this process. The latest round of DRAM pilot has also allowed residential / BTM coordinators (e.g., OhmConnect) to participate. DERPs or 'Scheduling Coordinators' are contractually responsible for meeting their market commitments and get compensated (or penalized) based on their verified performance[40].

The BTM resources have been found to be challenging in terms of M&V treatment as a wholesale or retail asset, and jurisdictional issues between system operators and regulators. *This is particularly relevant for EVs as the CPUC has instituted submetering requirements for EVs* through Ruling 13-11-002[41] and subsequent Resolution E-4651[42]. The submetering pilot[43] has completed phase 1[44] in 2017 and Phase 2 finished at the end of April 2018.

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[38] California's DRAM Tops 200 MW as utilities pick winners for distributed energy, GreenTechMedia, 7/26/2017, https://www.greentechmedia.com/articles/read/californias-dram-tops-200mw-as-utilities-pick-winners-for-distributed-energ#gs.T63Ix24

[39] Distributed Energy Resource Provider Participation Guide with Checklist, CAISO, v1.0, 8/26/2016, https://www.caiso.com/Documents/DistributedEnergyResourceProviderParticipationGuideandChecklist.pdf

[40] http://www.caiso.com/participate/Pages/BecomeSchedulingCoordinator/Default.aspx

[41] http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M081/K786/81786001.PDF

[42] http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M097/K049/97049639.PDF

[43] http://www.cpuc.ca.gov/general.aspx?id=5938

[44] http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442453395

2
ELECTRIC VEHICLES AS A SPECIAL CLASS OF DERS

All Electric Vehicles (EVs) have on-board batteries that need to be recharged from the grid. PEVs have the following characteristics which make them suitable to be treated as Load Modifiers (LMs) or Resources, both energy-constrained. (This energy constraint actually poses an operational risk that needs to be mitigated through aggregation of a large pool of PEVs.) These are:

- EVs are driven for 2 hours on average and remain parked and potentially plugged in for 20+ hours / day. This makes them almost as easily available as a BTM stationary storage device.
- EVs are parked almost 97% of the time either at a workplace (daytime) or residential (evening / overnight), which makes it easier to associate their locations relative to the distribution system segments.
- EVs have on-board chargers that can accept charge power from any wall outlet or an Electric Vehicle Supply Equipment (EVSE, or charge station). All EVSEs are compliant with SAE J1772 charge couplers and the interoperability is proven.
- PEV Charger capacity (power) has grown steadily from 3.3kW to 19.2kW on the AC side, with most of the EVs currently at 7.2kW. That means most EVs can charge at a 7.2kW rating.
- PEV battery storage capacity has continued to rise and is fast approaching sizes where a significant portion (up to 50-60%) of it remains unutilized on a day-to-day commute, and can be made available for grid services without compromising daily mobility needs of about 15-20kWh round-trip.
- For the vehicles to receive exogenous charge modification signals in the form of a direct load modification or pricing tariff, no dedicated / specialized communications pathway is required as all vehicles have access to a PEV Original Equipment Manufacturer (OEM) designed and integrated Telematics system, such as GM OnStar or direct 4G LTE link to the vehicle.
- The CAISO and CPUC, as well as the CEC have created a VGI Roadmap[45] that defines mechanisms through which individual and aggregated sets of EVs can be integrated into the California grid to provide grid services and to participate in energy markets at appropriate context.
- Prevailing communications standards do exist and have been developed both in the SAE (Society of Automotive Engineers) and IEEE (Institute for Electrical and Electronics Engineers) that span the entire range of grid/vehicle communications both in terms of signaling, physical layer communications, and cybersecurity, encompassing all possible communication pathways. These are under the umbrella of J2836, J2847, J2931 and J3072. These application layer protocol standards are based on both IEEE2030.5 (SEP2) for AC

[45]California Vehicle-Grid Integration Roadmap, CAISO, 2014, https://efiling.energy.ca.gov/getdocument.aspx?tn=217997

charger / utility or aggregator communications and IEC/ISO 15118 for charger/PEV communications.

- In the 2016-2017 timeframe, pursuant to CPUC ruling R.13-11-007[46], in response to State Bill 350, covering Transportation Electrification, the CPUC, CEC, ARB, and California Governor's Office (GOBiz) established a multi-agency VGI Working Group to understand the need for and the requirements of a grid/vehicle communications standard.[47]

46 https://apps.cpuc.ca.gov/apex/f?p=401:56:14519318719481::NO:RP,57,RIR:P5_PROCEEDING_SELECT:R1311007

47 California Vehicle-Grid Integration Working Group, www.cpuc.ca.gov/vgi and the Working Group Report http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M211/K654/211654688.PDF

3
ELECTRIC VEHICLES IN CALIFORNIA

The PEV installed base in California is above 500,000 vehicles. By the end of November 2018, the nationwide installed base of EVs was about 1,050,000. The PEV market nationwide is growing at about a 20% annualized rate. The State of California accounts for more than 50% of the total vehicle sales nationwide and is on pace to accelerate even further. PEV sales growth forecasts vary by region, and an EPRI analysis[48] indicates that there is a strong possibility for EVs to acquire, in an optimistic scenario, about 60% market share by 2050, which translates to roughly 40% market share of new vehicle sales in 2030 (i.e., about 8-10M new vehicle sales/year) sold. This meshes well with the State of California Governor's mandate of 5 million EVs by 2030.

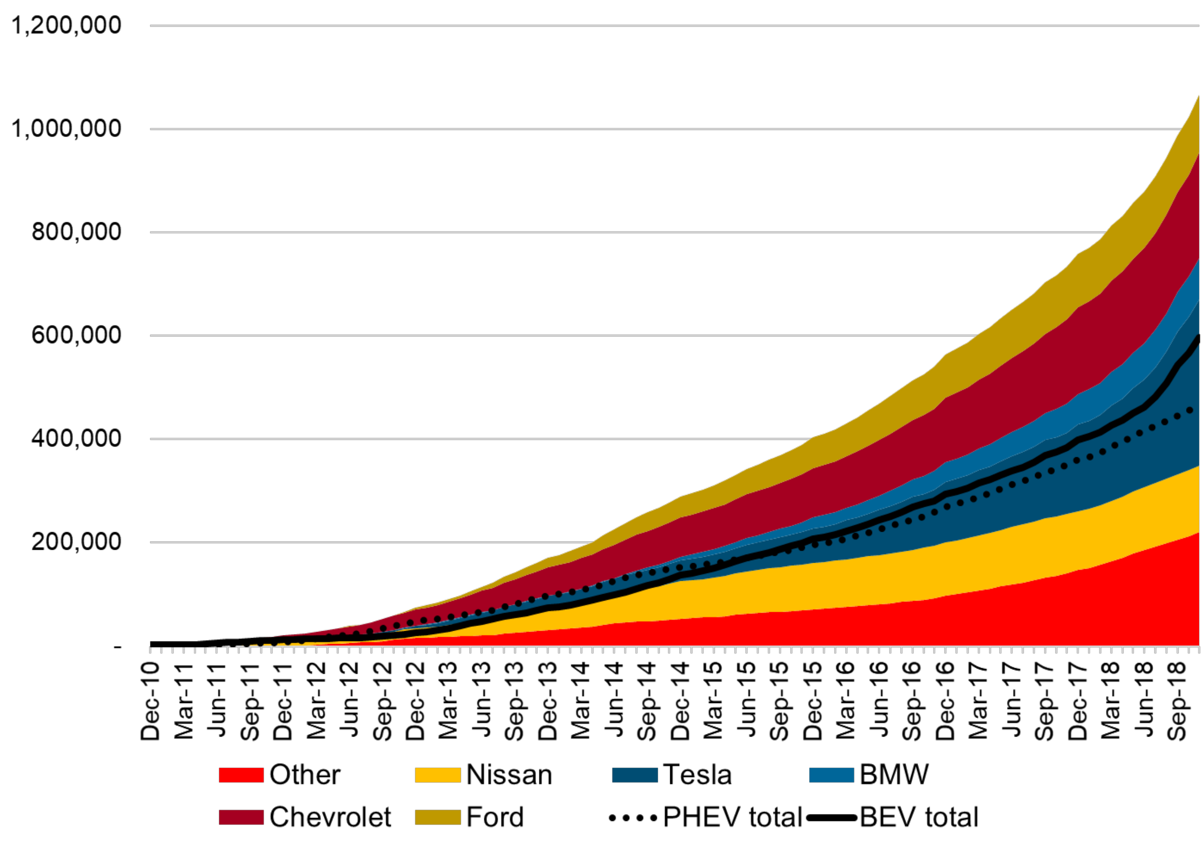

Figure 3-1
PEV Installed Base is 1,050,000 In the US – 11/30/2018

[48] *Plug-in Electric Vehicle Market Projections: Scenarios and Impacts*, EPRI, Palo Alto, CA:2017, 3002011613.

Given the necessity of estimating the potential impact of PEVs on utilities, EPRI has created a simplified methodology that provides three scenarios to estimate the market adoption of PEVs. The Low and High trajectories are intended to be used as plausible bounding scenarios. The Medium scenario may be considered a middle-ground estimate, but it is not intended to be used as a sales prediction.

The three proxy scenarios were developed as follows:

- **Low Scenario:** The Annual Energy Outlook 2015 (AEO 2015) Reference case was selected as the fundamental component of the Low scenario.[49] This version of AEO uses a vehicle choice model and assumptions that are generally unfavorable toward PEVs. In fact, the actual PEV market shares in 2015 and 2016 were about 50% higher than forecasted by the AEO 2015 Reference case. In light of this, the proxy Low scenario was set as the AEO 2015 Reference case multiplied by 1.5 (50% higher). The low proxy represents how PEV sales may grow if battery costs remain high, regulations that drive PEV sales are canceled, and incentives are reduced.
- **Mid-Range Scenario:** Two external scenarios provide a moderate long-term outlook for PEV adoption. These are the "Midrange PEV" scenario from National Research Council's *Transitions to Alternative Vehicles and Fuels* report, and the "Portfolio" scenario from the NREL *Infrastructure Expansion* report. [50, 51] These two estimates were chosen as a proxy for the Medium scenario from about 2035 onward, since other more recent scenarios predict significantly higher PEV sales in 2025. The Medium scenario long-term proxy was determined as a simple year-by-year numerical average of the NREL and NRC estimates.
- **High-Scenario:** The High scenario proxy is an average of two scenarios that employ assumptions that are highly favorable toward PEV adoption: the "Optimistic PEV" case in Appendix H of the NRC report and the "Electrification" case of the NREL report.

These proxy scenarios were then modified to account for regional differences, especially to account for the effects of the California Zero Emissions Vehicle (ZEV) mandate and sales-to-date in each region.

The California ZEV program uses a credit system and does not require the sale of a specific number of advanced vehicles. The credit structure is defined such that vehicles that provide greater zero-emissions capability earn more ZEV credits per vehicle, and the program includes several flexibilities that offer vehicle manufacturers options to comply with the program in diverse ways. In December 2011, California Air Resources Board (CARB) staff released a report that defined a proposed revision of the ZEV and tailpipe emissions regulations called the Advanced Clean Cars program. These modifications were approved by the Board in January 2012.[52] The staff report provided an expected trajectory of annual sales of different advanced

[49] *Annual Energy Outlook 2015*. U.S. Energy Information Administration, Washington, DC: 2015. DOE/EIA-0383(2015).
[50] *Transitions to Alternative Vehicles and Fuels*. National Research Council, Washington, DC: 2013.
[51] *Alternative Fuel Infrastructure Expansion: Costs, Resources, Production Capacity and Retail Availability for Low-Carbon Scenarios*. Prepared for the U.S. Department of Energy by National Renewable Energy Laboratory, Golden, CO: 2013. DOE/GO-102013-3710.
[52] *Staff Report: Initial Statement of Reasons, Advanced Clean Cars, 2012 Proposed Amendments to the California Zero Emission Vehicle Program Regulations*. California Air

vehicle types that would be required for manufacturers to comply with the regulation. These estimates assumed a significant number of fuel-cell electric vehicles (FCEVs) would be sold in California: less than 0.2% of new sales through 2017 but ramping up to 2.5% of sales by 2025. If these FCEV sales occur, the required PEV sales were less than 2.1% through 2017 and then ramping to 12.9% of new sales in 2025. In 2012, EPRI requested that CARB provide another scenario that assumed greater numbers of PHEVs with either 10 miles or 40 miles of all-electric range. This scenario increased the PEV estimate to 15.4% of sales by 2025.

After modification to account for the ZEV mandate, the projections are also modified to account for the trajectory of the actual local PEV sales using historical county-level sales data for 2010 through 2016. Beyond 2016, the regional projection (or national projection for the High case) is shifted up or down depending on the level of the local historical PEV sales relative to the average sales in the larger region. Specifically, the local sales bias is based on the local PEV market share in 2013 through 2016. As the projection advances farther into the future, the local effects diminish somewhat and the projections trend toward the projection for the larger region. This homogenization effect assumes that PEV technology becomes increasingly mainstream and that the geographic distribution of PEVs becomes relatively uniform. However, in areas where the local PEV sales rates from 2013 through 2016 are significantly different than the regional sales rate, that difference continues to impact the localized estimate over the long term (through 2050).

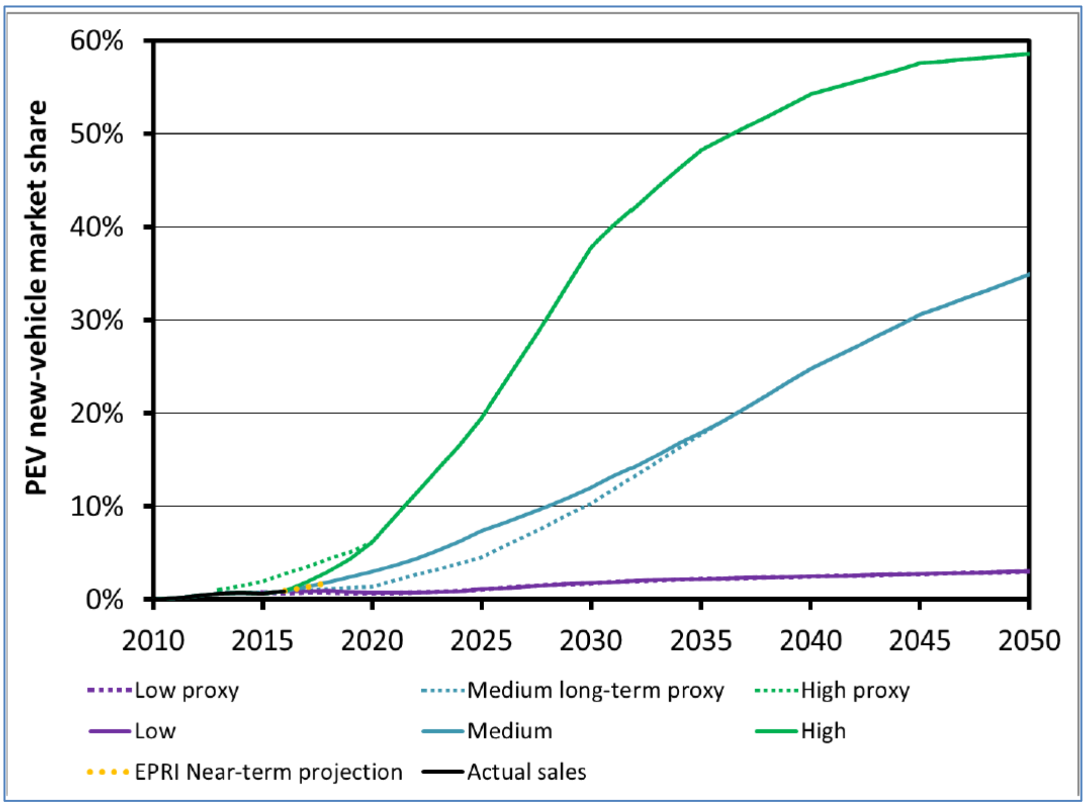

Figure 3-2
EPRI Forecast for US-Wide PEV New Vehicle Market Share to 2050, Low, Medium and High Projections

Resources Board, Sacramento, CA: 2011.

For the State of California, this translates to the cumulative installed base of anywhere from 1.6M to 5M by 2030, as shown in Figure 3-3. The target of 5.0M vehicles is used by the California Governor's Office for 2030, per the Executive Order[53].

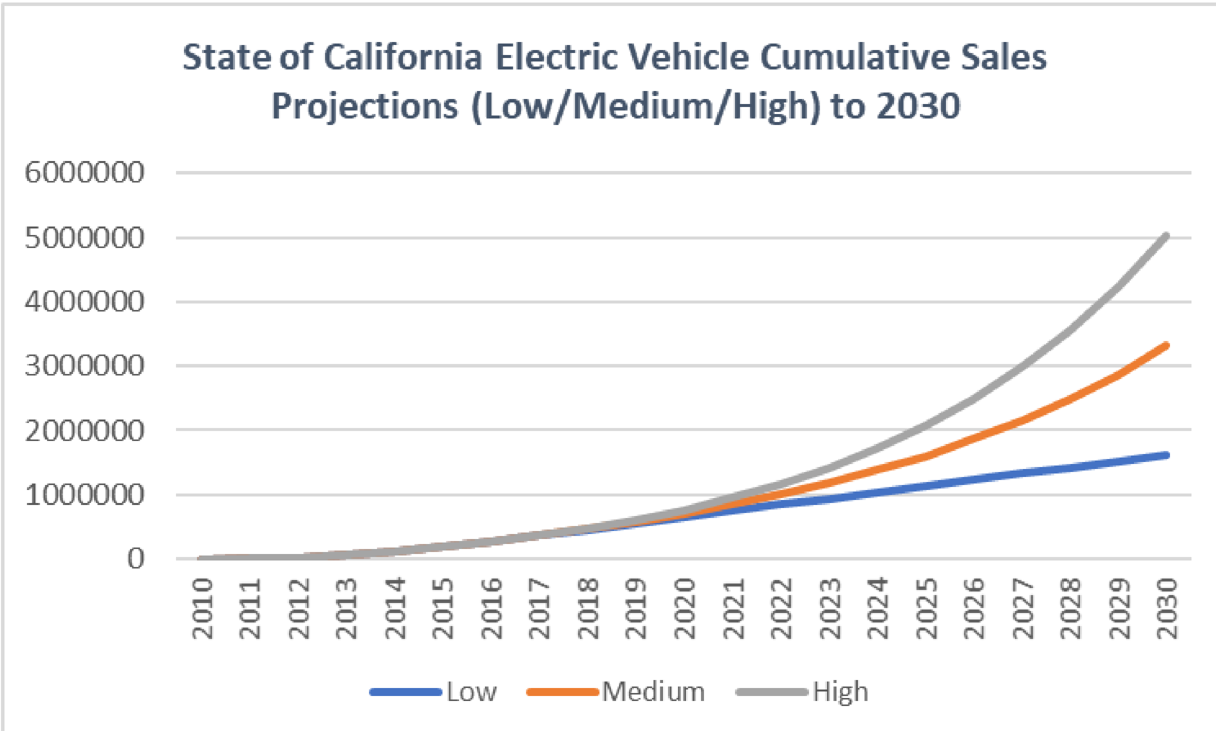

Figure 3-3
State of California PEV Fleet Projections to 2030, Low/Medium/High Scenarios (Source: EPRI Research)

Electric Vehicles have the following capabilities that make them particularly attractive as Flexible Loads (increase or decrease) in response to both Summer Peak events and for Overgeneration Mitigation through appropriate pricing mechanisms.

- **Charge Power:** 3.3-7.2kW AC from grid
- **Discharge Power for Reverse Power Flow-Capable EVs**: 3.3-7.2kW AC to grid
- **Smart Inverter Functions**: When the grid-tied inverter is connected to a powered EVSE, it acts as a current source. It has the capability to place its current vector at any leading or lagging phase angle compared to grid Voltage phasor. This means that Smart Inverter on-board can provide leading or lagging VARs for Voltage Support. The signaling for this is codified in SAE J2847/3. Furthermore, there is effort underway for on-board grid-tied bidirectional smart inverters equipped with IEEE2030.5 and SAE J3072 functions to be 'interconnection qualified' compliant with CPUC Rule 21.
- **Bandwidth**: The bidirectional (or unidirectional) charger has the capability to respond to charge / discharge current commands within 25-100ms. *This is a very important feature if*

[53] Governor Brown Takes Action to Increase Zero Emission Vehicles and Fund New Climate Investments, California Governor's Office Press Release, 1/26/2018: https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/

EVs, in an aggregated manner, were to be used as an Inertia Resource to balance system frequency fluctuations.

- **Signal Latency**: Over the internet or Telematics link, the signal latency depends mainly on the update rate that is set up between the signaling entity and the PEV. This is currently set up in a manner that the EVs can very readily respond to 5-minute ahead price signals. Some manufacturers' EVs can respond today at 250ms latency level, meaning they can participate even in a Regulation Reserve market.
- **Availability / Participation:** The PG&E/BMW iChargeForward[54] program currently underway is finding that the availability of customers at any given time on average is about 15% of total in terms of kW. This means that today's effective multiplier against the capacity available is about one-seventh or 15%. If the incentives hold, the participation becomes seamless and more streamlined in terms of avoiding customers' daily driving and charging routine, this rate can go as high as 30% by 2030 (our assumption that needs to be validated).

When all capabilities above are combined, the cumulative available Load Modifier capacity is between +/-3.5GW to +/-10GW[55]*, or a swing of twice that value (i.e., 7-20GW), if 100% of the vehicles are equipped with bidirectional charging equipment, but on average only 15%-30% were available at any given time for grid services.* This is also the capacity available over the ramp-period for ramping mitigation. Appropriate management of EV discharge power during this interval has the potential to reduce the duration of extreme ramps.

EVs with bidirectional power capability are as capable as the stationary storage systems that are grid-tied and can provide grid services of a fully grid-integrated storage system. Moreover, they can deliver these services at a fraction of the acquisition costs for equivalent amount of stationary storage because EVs are procured primarily for mobility purposes *by PEV owners,* and utilities are not required to pay for their acquisition costs. This makes them a very attractive resource / load modifier entity to be studied carefully for IRP / DRP integration.

[54] iChargeForward: PG&E's Electric Vehicle Smart Charging Pilot; Final Report, http://www.pgecurrents.com/wp-content/uploads/2017/06/PGE-BMW-iChargeForward-Final-Report.pdf

[55] At 1.5M Vehicles in 2030, +/-7.2kW each, and 30% available the number is +/-3.24GW
At 5M Vehicles in 2030, +/-7.2kW each and 30% available, the number is +/- 9.72GW. Incidentally, these values on the + side are on the conservative side (i.e., pessimistic) because each vehicle equipped with AC/DC on-board charger (that is 100% of them) can be made to provide Load Modifier services today. So, on the load modifier side, there is a significant upside. On the Resource side, the outlook is going to depend squarely on available incentives

4

EVS AS DERS IN THE CONTEXT OF IRP

This project demonstrated on-board V2G capable grid-tied EVs' technical capabilities in an interoperable manner to accomplish the following Load Modifier and Resource functions:

Table 4-1
Grid-Tied Vehicle-To-Grid Capable PEV Capabilities as Load Modifier and Resource

Context	Grid Function	Load Modifier	Resource
Facility	Charge Scheduling	X	x
	Local Demand Charge Reduction (Peak Shaving)	X	
	Local Backflow Prevention	X	
Local Transformer	Thermal Constraint-Based Load Limiting	X	
	Capacity-based Load Limiting	X	x
	Transformer-level backflow prevention	X	
DSO/ISO Level	Peak Shaving	x	X
	Oversupply Mitigation	X	
	Ramping Support	x	X

Legend: ***X = Primary function, x = Secondary Function (market-dependent)***

These services have been demonstrated experimentally using open standards-based technologies and are the superset of services that have been analyzed for value assessment.

Requirements for EVs to be Included in IRP / LTPP Portfolio

For a Load Modifier or a Resource to be included in the IRP / LTPP portfolio of DERs, it must pass several tests to confirm reliably and accurately its potential over a specified time horizon. Some of these are:

Reliable PEV Growth Forecast

For a DER to be included in the LTPP / IRP process, a reliable forecast of its market adoption is critical. This is the foundation upon which all the procurement plans are built. Any scenario assessment is subject to input uncertainties and modeling imprecision. What is known for certain is the state of California 2030 target for PEVs to reach 5 Million. While preparing the scenario assessment, EPRI looked at the PEV growth numbers from a variety of factors, also benchmarking our own numbers against publicly available data which are driven by automotive manufacturer product plans, manufacturing and supply chain investment numbers to ensure these numbers are triangulated and show potential. Given the major impact that regulations and incentives have had on PEV sales in the near-term, these were accounted for as well.

Furthermore, EPRI[56] bound the forecast through three scenarios – minimum, medium and high numbers. Minimum growth numbers are based on 'Business as Usual' PEV adoption from customers, Maximum growth numbers are based on growth rates significantly accelerating up as per-kWh battery costs reduce (they have seen cost reductions at an annualized rate of 14% per year for the last 10 years, currently at 15% of the numbers seen in the early days and are likely to go down further within 5 years). This has also led to Automotive OEMs having more freedom to make this technology available across multiple classes of vehicles (crossovers, SUVs, vans, etc.) while also providing ever-increasing driving range numbers. With relentless focus on infrastructure (including fast charging) from public agencies, especially in the state of CA and elsewhere, the appeal of EVs to customers is bound to increase. Coupled with petroleum price hovering around $70/bbl[57] with an OPEC target of between $80 and $100/bbl[58], EVs will continue to make more economic sense, especially if coupled with a variety of ownership models. However, achieving 5M vehicles installed base in CA by 2030 remains a tall order, so we also created a mid-range forecast (which is simply arithmetic average of the minimum and maximum forecasts) to have a realistic feel for what the volume may look like in 2030. Back in 2011, a Presidential[59] goal of 1M vehicles US-wide by 2015 seemed out of reach at the time, yet in mid-2018, we find the installed base at 856,000 PEVs and will likely reach the 1M mark nation-wide in another 12 months. Over 50% of these vehicles are in California. Policy and technology forcing do make an impact on nudging the industry in a certain direction, and in the case of EVs, the economics and exogenous factors (VW diesel scandal, for example) happened to have given the right impetus for industry to voluntarily and seriously look at developing EVs as an alternative.

Availability of EVs as Mobile Resources

At the end of 2017, the relative share of PEV installed base in CA among the IOUs was 30% PG&E, 40% SCE and 10% SDG&E. If we maintain this ratio to be constant (remaining 20% dispersed across the rest of the state), we can derive IOU-specific PEV capacity availability numbers. The aggregate 2030 numbers for V2G capable PEVs in the range of 7GW-20GW[60] even with 30% penetration of the grid-support technologies on vehicles, one can expect a 30% / 40% / 10% share of this installed base to appear across PG&E, SCE and SDG&E territories, meaning SCE could see a resource base of about 3GW, PG&E about 2GW and SDG&E up to 1GW to apply toward their procurement plans at the lower range, and roughly 3 times as much at the higher range in 2030. A strong case can therefore be made that at a macro level, this presents

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56 Plug-in Electric Vehicle Market Projections: Scenarios and Impacts, EPRI, Palo Alto, CA:2017, 3002011613

57 Per Platts, August 2018 Futures for Brent Crude were being priced at $74.74/bbl on 06/20/2018

58 OPEC's new price hawk Saudi Arabia seeks oil price as high as $100 – sources, REUTERS, 4/18/2018, https://www.reuters.com/article/us-opec-oil-exclusive/exclusive-opecs-new-price-hawk-saudi-arabia-seeks-oil-as-high-as-100-sources-idUSKBN1HP1LB

59 https://www.cheatsheet.com/automobiles/will-obama-executive-action-build-momentum-for-electric-cars.html/?a=viewall

60 Calculated as follows: 30% of 1.5M vehicles at missing text

significant market participation opportunity for EVs and procurement opportunity for planners at LTPP / IRP system level procurement or for EVs to participate in the ISO energy markets.

The second factor affecting PEV inclusion as a resource class is physical availability given that EVs are mobile. Therefore, when one starts focusing on whether a specific PEV is charging, where and at what time (geospatially and temporally), more uncertainty is introduced. However, in general, EVs tend to congregate on weekday day hours at workplace locations and evening hours at residential areas. Likewise, on weekends, they could be plugged in at home or away at any third location (commercial, recreational, etc.). So, even when inclusion of specific EVs in specific energy markets may be difficult to attain a particular service level commitment *individually,* if the means to aggregate these vehicles were to be introduced (either through actual aggregators or *Scheduling Coordinators,* or through the IOUs or POUs themselves acting as aggregators) and were to be brought into the mix to manage a group of EVs that can participate through them, then the complexity of managing individual customer preferences for mobility, participation, etc. could be managed by this aggregator.

Role of Aggregators / Scheduling Coordinators or DER Providers

By their very nature, V2G capable PEVs are BTM resources, and collectively they represent a meaningful entity across the IOU distribution grids: about 150,000 in PG&E territory, 200,000 in SCE territory and 50,000 in SDG&E territory as of this writing in June 2018. Which means that on average, they represent about 150MW, 200MW, and 50MW of load across the distribution systems whose summer peaks amount to 20GW, 30GW and 7GW respectively (approximately, assuming ISO peak procurement need of about 73GW). Since the ISO market allows any loads >500kW to be eligible bidders, the presence of aggregation function is essential to PEV participation in helping distribution and the ISO grid. Indeed, the currently underway Phase 2 of the PG&E/BMW iChargeForward Program utilizes Olivine as the Scheduling Coordinator, while BMW acts as the aggregator for a fleet of their participating vehicles (about 250 of them) as well as locally sited stationary storage. As the PEV proliferation grows across CA 3x-10x in the next 12-15 years, managing PEVs just as Load Modifiers may have a huge beneficial impact on the grid. Add to that V2G capabilities and selective additional benefits may be realized. There is therefore a need to have a dialog among the multiple state agencies, IOUs and other stakeholders about appropriateness of creating incentive mechanisms that are sustainable through business case-derived benefits to the grid. These benefits could be through utilization of PEVs for grid services that improve asset utilization and defer upgrades, as well as increase utilization of clean energy that is generated at the same location as PEV charging and is coincident.

Customer Participation Estimate and Incentives Required to Stimulate Participation

Once the PEV potential for assisting the grid, both as a Load Modifier and as a Resource is estimated, the next challenge becomes translating these benefits into incentives that are meaningful enough to attract PEV owners to participate in the grid services market. As with all other customer-oriented programs, the true potential of EVs as grid resources can only be realized if customer participation can be maximized and sustained. This requires an understanding of what attracts the customers to new programs, as well as what turns them away from participation. Here again, BMW's recent experience implementing iChargeForward[61] is a useful reference. BMW found that there is a threshold of up-front payment (lump-sum) to attract the customers (in hundreds of dollars), followed by a payment at the end of the program, that was based on the participation performance (below 50% participation rate would result in zero end of pilot payment, and above 90% participation rate would yield 100% of the end of pilot payment – or something along these lines), both collectively representing some estimated value to the grid based on the grid services that the program was designed to deliver. In addition, BMW minimized customer intervention once the one-time participation set-up was completed to register their vehicle with the program. Customers were automatically opted into the program and would only need to intervene through the mobile App if they wanted to opt out at any time. All other processing would occur in the background, silently and seamlessly.

PEV Technical Capabilities vis-à-vis Grid Services

All Electric Vehicles have on-board chargers and an ability to 'listen' to the grid conditions (at varying levels), through either open standards (IEEE2030.5 or IEC/ISO15118) or proprietary protocols through secure Telematics link or 4G LTE connection. As a result, it is possible, today, for utilities to signal to EVs to modify their charging pattern according to some grid constraints, for example, avoiding charging during peak periods and shifting it during off-peak intervals, or, intentionally charging during times when PV across distribution is providing more generated energy than can be absorbed by existing load. In other words, the unidirectional power flow capability of the EVs can be deployed to use EVs in Load Modifier role today.

When Reverse Power Flow (RPF) capability is added to EVs, as is being demonstrated in this project, as well as situational awareness of the local and macro distribution system so the on-board bidirectional power conversion system can respond either automatically or in response to grid signaling to provide grid services such as 'peak shaving' or 'ramping support', the value of the EVs can be further enhanced for the grid. The BMW project successfully demonstrated that not only can these services be delivered, but also that use of open standards that are vetted by OEMs and within Society of Automotive Engineers (SAE) can result in a signaling system that is robust and secure end to end using the prevailing Cybersecurity best practices.
It should be noted that the technologies being demonstrated on this project, while being integrated on-board two OEMs (Fiat Chrysler Automobiles and Honda R&D America), are the first-ever implementation of this standardized technology. As such, further robustness in specific areas (interconnection requirements being a major one) will need to be worked across OEMs, IOUs, SAE, IEEE and UL for harmonization and results shown to the CPUC to obtain guidance on which specific set of requirements are adequate to qualify V2G capable EVs as a 'generating' resource to pass the Rule 21 screen. The BMW project demonstration is the first successful step to validating and identifying key implementation / operational barriers that can now be assessed through experimentation and testing.

Value Assessment

In the value assessment phase of this project, considerable effort was spent by the team on developing value assessment tools to identify value at the local facility level to customers

[61] BMW iChargeForward – PG&E's Electric Vehicle Smart Charging Pilot, Phase 1 Report, Pacific Gas & Electric Company, 2016.

through rates and demand charge mitigation, at the distribution transformer level, as well as the distribution system level, to both create asset upgrade deferment and capacity avoidance for summer peaks, as well as ramping. Preliminary numbers resulting from this analysis are encouraging enough to sharpen the analysis assumptions and create a peer review process where these local, distribution, and ISO level benefits can be better quantified. Especially in the case of the distribution system benefit assessment section of the project, a methodology has been created and presented that can be applied to ‘at-capacity’ distribution system segments for value maximization.

Cost Assessment

Costs for the V2G capable EVs include on- and off-vehicle hardware and software piece costs, engineering development, as well as infrastructure development / operations/ maintenance costs, and service/support costs. To the extent that they are known, they were factored into the Value assessment (value is benefits net of costs) of the distribution system-constrained V2G services. However, these cost assumptions need to be verified to ensure no hard or soft costs (including obsolescence) are ignored.

5
DISTRIBUTION SYSTEM INTEGRATION AND CONTRIBUTION OF THIS PROJECT

California public agencies, directed by the legislative action (AB327, section 769) have taken on comprehensive reform measures to enable large-scale integration of distributed resources and creation of a regulatory framework to allow these investments to occur. The CPUC has, in response to AB327 utilities section 469, through R.14-08-013[62], instructed IOUs to create Distribution Resource Plans with the following key elements:

Annual Grid Level Scenarios and Assumptions

Scenarios and assumptions form the foundation of the Grid Modernization-related Distribution Resource Planning process.

Growth Scenarios

Scenarios estimate the growth of DERs across the distribution system driven by BTM adoption due to the NEM and ToU tariffs and system-wide planned growth of FTM DERs to comply with regulatory directives.

Role of EVs

Preparing PEV growth forecasts by distribution system location contributes to scenario development. The challenge integrating EVs into a typical scenario is addressing the mobility behavior. Vehicles are parked part of the day at commercial / workplace locations and around residential locations overnight, and sometimes these locations may belong to different utility territories given the commuting distances.

Integration Capacity Analysis (ICA)

The Integration Capacity Analysis creates an estimation of additional DER capacity that can be integrated at individual nodes in the system, helping DER providers interconnect the forecasted DER. This analysis is essentially a distribution system wide hosting capacity analysis through EPRI DRIVE[63] (Distributed Resource Integration and Value Estimation tool), performed for specific locations on the distribution grid as needed. Hosting capacity can be defined as the integration capacity in the distribution system governed by ‘headroom’ at any given feeder before backflow results. ICA by definition is static in nature and looks at the worst-case scenario, while computing hosting capacity, which allows, in theory, for PV installation matching only the spring-time (light-load) conditions. That would leave significant opportunity for adding hosting

[62] Distribution Resources Plan, http://www.cpuc.ca.gov/General.aspx?id=5071
[63] EPRI Distribution System Integration and Value Estimation Tool, v1.0, https://www.epri.com/#/pages/product/3002008297/?lang=en

capacity *if dynamic adjustments to a variety of parameters were to be made in accordance to real-time conditions*. Flexible loads are a potential enabler of increasing hosting capacity, in addition to Volt/VAR optimization functions of smart inverters, per CPUC Rule 21.

Locational Net Benefits Analysis (LNBA)

LNBA is the analytical process used to estimate the benefits that can be realized by siting a DER at a given node on the distribution system. The value is in the form of avoided distribution / transmission upgrade costs or Resource Adequacy related benefits or avoided costs.

Role of EVs in LNBA

Earlier in the project, LNBA methodology was used to identify the value that can be accrued to integrating V2G capable EVs into a specific segment of the distribution system. EVs as flex loads offer specific services, that can be applied toward cost avoidance as well as Resource Adequacy computation. As the number of EVs grow in specific distribution systems, their usefulness to the IOU will only continue to increase. Furthermore, V2G capable EVs and the services they can provide through localized management further enhance their value to the distribution system. The value analysis segment in this report explains the use cases, the process used for assessing location-specific value as net benefits.

Grid Needs Analysis (GNA)

This is the distribution planning process that identifies the distribution system locations that would benefit most from specific grid services, the specific DERs – type and amount with the grid services they would enable – in an open and transparent manner as the basis for the GRC (General Rate Case).

EVs as a part of GNA

IOUs are developing their plans for public charging infrastructure under their rate-based SB350 Transportation Electrification related commitments. If ICA and LNBA are performed by accurately accounting for the beneficial grid impacts provided by managed PEV charging (and discharging), then additional incentives can be designed around the capability of EVs to provide grid services.

Grid Modernization Plans (GMPs)

At periodic intervals, typically every 3 years, IOUs are expected to present GMPs for the future 10 years, providing detailed distribution modernization plans as the sum of all of the GNA efforts, in a prioritized order, so that the Grid Modernization keeps pace with the need of the distribution grid under increased DER / renewable penetration.

EVs as a part of GMPs

Given the periodic and continual nature of the GMP process, EVs as a growing and cost-effective class of DERs and Flex Loads can become a regular part of the ongoing process, and may be thought of as grid resources as much as ZEVs that create positive environmental impact, and less as a load that must be served.

Grid Modernization Plan Review, Approval and Investments

Review and approval steps are performed for each GRC update, which is informed by appropriately performed ‘design of experiments’ and pilot projects.

PEV Infrastructure Planning as a part of GMP Investments

PEV-related services and incentive plans may be proven through pilot studies to deliver reliable value in line with GMP data. Approved investments may then be deployed in the form of what was proposed as a part of the GRC, and at-scale performance may be assessed.

6 V2G CAPABLE PEV IMPACT ON OPERATIONS

Screening Tools

The very first aspect of how to assess PEV operational impacts is to leverage existing screening tools for interconnection / grid integration purposes. This project relied on using CPUC Rule 21 as the requirement to interconnect the V2G capable EVs. However, the learnings derived from that process need to be socialized with the IOUs to ensure that an appropriate suite of standards are defined for the agreeable OEM interconnection requirements. These may be published along with the value / incentives available to customers for vehicles equipped with a given suite of VGI technologies.

Production simulation models

In addition to the regional system model, these models also incorporate intermittent generation and V2G capable EVs having accurate representations of load and reverse power flow capability. The combined model dispatches the EVs in terms of data and control system integration requirements to synthesize a set of value-added use cases as defined in LNBA.

Pilot projects – nature and scope

As mentioned, the LNBA informs the nature and scope of the services that could provide the best value from EVs at particular locations on the distribution grid. The best possible distribution system segments for these integration scenarios may be validated both in terms of technology performance and consumer participation data to maximize consumer interest and acceptance.

Interconnection standards for effective integration of V2G capable EVs into the grid

As mentioned, one major discovery of this project was the gap in what was previously considered to be an appropriate interconnection standards suite. IOUs, CEC, standards bodies and OEMs, as well as network providers have yet to coordinate an effort to ensure a consensus set of standards is developed, verified, and adopted.

7
SUMMARY AND SCOPE FOR FUTURE WORK

Summary of the Report

This project overall explores the topic of understanding the technical feasibility of an open, scalable approach to V2G-equipped PEVs, and is primarily an exercise in assessing technical feasibility. PEVs capable of V2G services are at least five years away and their scale introduction is going to need a way for this feature to be incentivized through electric utility program offerings or market participation.

Learnings from this project can be carried forward to create a set of operational assumptions, and coupled with growth forecasts, can assist in creating planning assumptions for the IRP process in the next 10-year scenario planning phase.

By starting this process early when PEVs are at the cusp of achieving mass-market appeal, studying the approaches to model and assess the capabilities of PEVs at scale could provide a sound foundation to build future IRP scenarios inclusive of PEVs in an applicable context.

The report also describes the growth scenarios of EVs in the California grid and the potential impact they can have because of the California Governor's Executive Order of 5M vehicles by 2030, or even a smaller number of EVs were to be made available for sale in CA.

Since EVs are going to be primarily behind-the meter resources, their accounting for grid services may be accommodated in the context of distribution system planning. Therefore, the PEV role in the DRP was also described.

Key Take-Aways from This Report

The key take-aways of this report are as follows:

1. Guaranteed verifiable availability and performance of PEVs to deliver the services they commit is a key factor in them obtaining storage-like treatment in the LTPP and the IRP planning and procurement processes at the ISO / market level. This is currently governed by SB350 and CPUC Scoping Memo R.16-02-007[64]. Whereas avenues of value are identified in earlier chapters, it's important to note the need to conform to the existing process. The fact that PEVs are mobile and *only* available 20-22 hours a day at varying locations needs to be factored in.
2. The issue of Interconnection Requirements per CPUC Rule 21 under R.17-07-007[65] also must be resolved through uniform requirements based on common sense and consensus. This is critical for reverse power flow capable EVs (being treated like generating resources).

[64] Integrated Resource Plan and Long Term Procurement Plan, http://www.cpuc.ca.gov/irp/
[65] Interconnection Rulemaking, http://www.cpuc.ca.gov/General.aspx?id=6442455170

Specifically, harmonization among IEEE2030.5, IEEE1547, SAE J3072 and SAE J2847/3 as well as UL1741 is critical. This was a key learning of the project itself.

3. Dynamic Rate tariffs may be beneficial for PEV customers and others, but may need changes to account for low or no cost consumption, spring excess supply periods, and incentive curtailment during peak intervals. CPUC R.12-06-013[66] Residential Tariff Rulemaking is addressing this issue, and specific provisions for PEV charging are in the mix. A recently held[67] ZEV Tariff Design workshop made initial contributions to this effort.
4. In the siting of public /commercial infrastructure,[68] the IOUs may prioritize focusing on installations at sections of distribution systems where there are likely to be excess supply issues or intentionally couple solar plus charging to reduce grid impacts, while also helping local commercial establishments. In other words, PEV infrastructure planning may need to be done jointly with Distribution System Planning *and* Distribution Resources Planning[69].
5. Lastly, the DRP[70] process across IOUs is underway, and the plans generally are updated every three years, with the 10-year horizon each time. So if even some of them start including PEVs, they may justify inclusion in electric utility DRPs and other related planning exercises, including pilots targeting PEVs for grid services.

Gaps and Future Work Focus

- *Analysis and Forecasting of PEV V2G Adoption* – Given that the forecasted PEV growth, as well as load growth, as a function of IOU and Distribution System Segments sets the foundation for all the planning and procurement work, forecast model refinement and validation are worthy exercises that have not yet taken place.
- *Interconnection Requirements Formulation for V2G Capable PEVs* – This project clearly showed the gaps in what is expected from the utility side to connect any Generating Resource (such as a V2G capable PEV) to the distribution system. Utilities would like to treat these PEVs as equivalent to stationary storage, subject to UL and IEEE standards. Automotive OEMs who carry the on-vehicle inverter prefer to certify to their own certification body (as against UL). This divergence in requirements needs to be reconciled and homogenized.
- Rate and Incentive Design: Clearly, the work in this space has already begun with the CPUC ZEV Rate Design workshop in response to California Governor Brown's EO B-48-18 requiring 5M EVs in California by 2030. IOUs have recommended tariff revisions that need to be validated through pilots involving real customers, OEMs, utilities, and third-party stakeholders, to create required datasets for analyzing and verifying tariff effectiveness and design recommendations.

Through the leadership of California Governor's office (GOBiz), ARB, CPUC, CEC, and the IOUs, the state of California is setting the standard globally in terms of providing a regulatory and technical framework to maximize PEV adoption as well as grid preparedness so PEVs can act as grid resources as a matter of routine at some point in the future.

[66] Residential Tariff Rulemaking http://www.cpuc.ca.gov/general.aspx?id=12154
[67] CPUC ZEV Rate Design Forum, 6-7 June, 2018, http://www.cpuc.ca.gov/energy/electricrates/
[68] Zero Emission Vehicles, http://www.cpuc.ca.gov/zev/#Infrastructure
[69] Distribution Resources Plan http://www.cpuc.ca.gov/General.aspx?id=5071
[70] ibid

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