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Smart Charging Development for Plug-In Hybrid and Electric Vehicles—Preliminary Use-Case Development for SAE Recommended Practice J2836

Smart Charging Development for Plug-In Hybrid and Electric Vehicles—Preliminary Use-Case Development for SAE Recommended Practice J2836

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PRODUCT DESCRIPTION

This technical update covers the complete set of functional requirements for integrating plug-in electric vehicles (PEVs) into the smart grid, along with the utility programs they will be able to participate in and a vision for getting these requirements into standardized implementations. The document will help utility and OEM staff gain a complete understanding of how they should go about developing PEV-utility requirements that will support programs for demand response and energy efficiency through their automated metering infrastructure.

Results and Findings

This technical update describes the scope and objective of developing Society of Automotive Engineers (SAE) Recommended Practice J2836 and SAE Technical Report J2847, describes the Intelligrid methodology that is being used to develop use-case and extract requirements, provides guiding principles for PEV utility requirements, provides a detailed description of use cases that have been developed, identifies new steps to harmonize with other standard organization entities, and provides information of standardized "objects" and logical nodes that need to be developed for communication of pricing control and demand response messages based on an International Electrotechnical Commission (IEC) Standard to extract PEV-utility requirements.

Challenges and Objective(s)

The first PEVs are expected to start production in late 2010. Both vehicle owners and utility companies would benefit if PEVs could draw power during off-peak periods. Implementing a demand response program will require grid-to-PEV bidirectional communications to allow the utility system to influence the timing and amount of energy PEVs draw from the grid. This report defines the technology needed for such "smart charging," provides the required development work currently underway as part of the SAE Recommended Practice J2836 and SAE Technical Report J2847, provides details of the individual use cases that have been developed so far, and reviews the current status of initiatives to accomplish it.

The future of PEV-utility interaction will not be limited to statistical patterns of electricity use. Rather, the PEV-utility interaction will be characterized by an ongoing interactive dynamic role with power generation and transmission and distribution (T&D) operations. The advent of electric vehicles and anticipated interactions with both electric load as well as power injection creates new sets of challenges that must be met with a forward-looking infrastructure. The objective of this project is to identify, define, integrate, and characterize new and existing requirements as well as anticipating future requirements for electric vehicle/customer systems dynamics with T&D operations. The report outlines use-case development efforts that are currently ongoing under the SAE Recommended Practice J2836 Committee to identify requirements for PEV-utility integration. From these requirements, the project proposes a strategy to integrate real-time customer communications into industry architecture for T&D field operations and provide a pathway for codification.

Applications, Values, and Use

Several drivers motivate development of smart charging for PEVs, including a concern over global climate change and the desire to achieve energy independence and energy security. With the consumers having experienced wild fluctuations in gasoline retail prices, consumers want cheaper, more stably priced and cleaner sources of transportation energy. Hence, the maturation of electric drive and energy storage technologies makes PEVs a practical option. PEVs also are attractive to automobile manufacturers as a way of complying with clean-air regulations and burnishing their environmental image. The key enabling technology for smart charging is the ability of PEVs to communicate with the smart grid. Much of the work already under way focuses on identifying and developing PEV-utility requirements and standardizing these communication requirements. Use-case development, the requirements it generates, and their associated communications objects defined here can be used as the basis for developing next generation PEV-utility communications infrastructures. PEV-utility requirements generated from these use-case development efforts also will integrate a growing library of useful use cases that are being developed by utilities for substation automation, distributed energy resources, wind power, solar power, evolving distribution automation and transmission, and electric vehicles.

EPRI Perspective

This pioneering work will support various standards development organizations (SDOs) to provide one central point for requirements. These SDOs include SAE, Institute of Electrical and Electronics Engineers (IEEE) as well as commercial and utility industry groups such as ZigBee/HomePlug alliance, OpenAMI, and OpenHAN. As part of the SAE Recommended Practice J2836 (communication between utility and PEV) effort, EPRI is working with SDOs, automotive original equipment manufacturers (OEMs), appliance manufacturers, and utility organizations to develop interoperable sets of communication standards**.** EPRI also is participating in efforts to establish automotive OEM engineering communications integration development and test plans.

Approach

As recently as 2007, the concept of a control and communication system to connect PEVs to the grid was foreign to automobile manufacturers, but a host of initiatives have since been undertaken to quickly enable smart charging. Several SDOs have already taken significant steps forward. The OpenHAN/OpenAMI/ZigBee alliance has released their specification for Smart Energy Profile v1.0; the HomePlug alliance is working on their IEEE P1901 specification; and SAE is developing requirements for control and communication between plug-in electric vehicles and the electric grid under the aegis of SAE standards J2847 and J2836. EPRI is encouraging the utility industry, automobile manufacturers, and vendors of infrastructure equipment to arrive at consensus on necessary standards.

Keywords

Customer, Metering, Data communications, Architecture, Object model, Standards, Harmonization, Interoperability, Design strategy, PEV, Demand response, OEM, Usecase, Smart charging, Utility demand response programs

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1
INTRODUCTION

Smart Charging[1]

First plug-in electric vehicles (PEVs) have been announced and will be in production starting with late 2010. These vehicles can be characterized by a large (10-15 kWh) on-board battery that is expected to be charged overnight and at home most frequently. At the same time, with the cordset and on-board charger, at least some of the owners may make them plug in their PEVs to any available standard 120V or 240V outlet anywhere, with the intent to use least amount of liquid fuels and to be environmentally conscious. It has however been proven that there are certain times of day when it is more preferable for PEVs to be charging from the grid (and certain others, that are not as preferred). Therefore, the vehicle owners and utility companies can benefit the most from having PEV if the vehicle was compliant with one of the energy efficiency or demand response programs. Even more so if the PEV can actually verify of its participation through some means. This would necessitate the ability of the utility system to somehow control, when required, the timing and amount of energy that the PEV draws from the grid, and then perhaps reward the owner for doing so through discounted rates, for example.

At present, as a result of Federal Energy Policy Act (EPAct) from 2005[2] promoting efficient energy utilization and Energy Independence and Security Act (EISA) of 2007[3] that mandates the grid to be secure and intelligent, several nation-wide initiatives to add intelligence to the power grid management and control are underway, including the IntelliGrid project from EPRI, Smart Grid projects at various utilities and Department of Energy as well as Automated Metering Infrastructure installations at a wide range of utilities across North America. All of these have a common goal of embedding intelligent power and energy management systems into the power delivery infrastructure to help monitor, manage and control the power flow and delivery all the way to the end use devices, with the objective to achieve the best throughput at the least operating costs.

These 'smart grid' systems are characterized by three elements in general – 1: A sensor system that determines the current state of the grid, 2: An intelligent power management system that determines and communicates the desired state of the system to the smart loads and 3: A network of smart loads, that receive these communications, act on the command and report their current state to the smart grid. Therefore, to enable this vision of 'smart grid', the related initiatives are focused on all three aspects, of which the first two (sensors and intelligent power management)

[1] Chhaya, S., 'On-Board Smart Charging Requirements for Plug-in Electric Vehicles', EPRI Report 1015877, Sept. 30, 2008
[2] US Department of Energy, Environmental Protection Agency, www.epa.gov/oust/fedlaws/publ_109-058.pdf
[3] US White House, www.whitehouse.gov/news/releases/2007/12/20071219-1.html

reside within the grid, while the third, the smart loads, are the end use devices such as programmable / controllable thermostats (PCTs), home energy management systems, smart refrigerators, washer/dryers, and, plug-in electric vehicles.

The 'smart' part of the 'smart' loads is both their ability to communicate as well as process the control signals received from the 'smart grid', which include both the communications functionality and the control algorithms that allow the battery charging to be controlled and feedback signals be computed for communicating with the smart grid. This functionality also applies to plug-in electric vehicles, for their owners to avail themselves of the maximum benefits of using electricity as a transportation fuel. Since PEVs are one such class of 'smart' loads, they inherit the requirement to be able to communicate and control power flow from the grid, as commanded by the smart grid. Collectively, these technologies enable what is termed as 'Smart Charging' functionality.

Current State of Smart Charging Technology

While until as recently as 2007, the concept of the PEVs' control and communication system connected to the grid was foreign to the automobile manufacturers, this situation is rapidly evolving and in the span of last few months, a whole host of initiatives have been established to quickly address this gap in automobile's capabilities to communicate with the grid and control its own energy draw from the grid as needed, as well as provide acknowledgement of having done so. These initiatives range from SDOs such as OpenHAN[4] / OpenAMI[5] / ZigBee alliance[6] releasing their specification for Smart Energy Profile v1.0[7] to HomePlug[8] alliance working on their IEEE P1901[9] specification to SAE developing requirements for control and communication between plug-in electric vehicles and the electric grid under the aegis of SAE standards J2847[10] and J2836[11].

Smart Charging - Drivers

Confluence of several factors is driving the need for smart grid wanting to 'talk' to smart charging plug-in electric vehicles. These are:

- Concerns over global climate change and a need to optimize the carbon footprint, resulting in a need for improving the load factor of existing capacity
- A national desire to achieve energy independence and energy security through relying on home-grown sources of energy, preferably clean

[4] http://osgug.ucaiug.org/utilityami/openhan/default.aspx
[5] http://osgug.ucaiug.org/utilityami/default.aspx
[6] http://www.zigbee.org/en/index.asp
[7] www.**zigbee**.org/imwp/download.asp?ContentID=12484
[8] www.**homeplug**.org
[9] http://grouper.**ieee**.org/groups/1901/
[10] http://
www.**sae**.org/servlets/works/documentHome.do?comtID=TEVHYB&docID=**J2847**&inputPage=wIpSdOcDeTaIlS
[11] www.**sae**.org/servlets/works/documentHome.do?comtID=TEVHYB&inputPage=wIpS

- A consumer sentiment wanting to pursue cheaper and cleaner sources of transportation energy, i.e., electricity, in light of price of crude oil almost permanently stationed above $100/bbl, and retail gasoline prices approaching $4/gallon
- A maturation of electric drive and energy storage technologies in terms of their reliability, robustness, size, weight and cost economics, owing to the widespread adoption of hybrid-electric vehicle technologies
- A desire for automobile manufacturers to both comply with applicable clean-air regulations as well as one-up each-other, as a means to bolster their environmental and technology credentials and image

The net result is that two of the largest industries in the North America – automotive and utilities – are simultaneously undergoing transformational changes that occur may be once in several decades.

Auto Industry Initiatives Around Plug-in Electric Vehicles

The automotive industry has undergone a massive shift in its attitude towards hybrids, and more specifically, plug-in hybrid and electric vehicles in just the last two years, since the announcement of Chevrolet Volt and Saturn VUE plug-in electric vehicles from General Motors Corporation, and the Ford Escape Plug-in Hybrid Electric Vehicle (PHEV) demonstration program in conjunction with Southern California Edison. Europeans and some Japanese automotive OEMs, not to be outdone by these developments, have announced their own production and demonstration programs for PHEVs and PEVs.

While all of these OEMs are choosing to have their products going through real-world market and usability tests, their reasons for doing so are varied, and can be categorized as follows:

- Compliance with Zero Emission Vehicles mandate from the state of California and 14 other states on the East coast
- Competitive response for technology image and environmental stewardship
- Pure public relations exercise
- Making the technology ready through real-world experimentation
- Establishing technological leadership to change public perception about the company’s products and capabilities

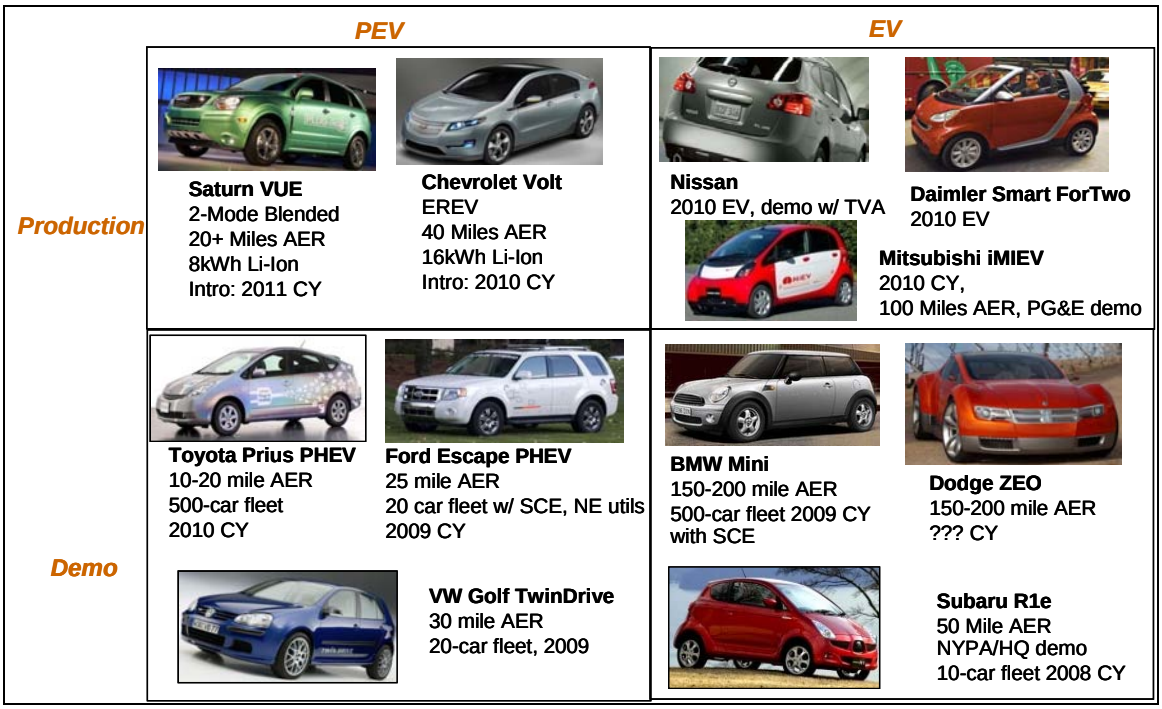


Figure 1-1
Announced PEV and EV Demo and Production Programs in 2008

Regardless of the strategic objectives of the OEMs, as long as their vehicles require energy to be drawn from the grid, the utility industry has an interest in ensuring that the charging of these vehicles is done in a benign manner at a minimum, and ideally in a manner beneficial to the grid. This is why there is a tremendous active interest from utility industry and EPRI in developing the technologies pertaining to the Smart Charging together, for joint deployment on both sides of the plug.

Emerging Consensus on Smart Charging Requirements for Automobiles

Based on the prevailing load management, load shifting and load shed programs currently in place across various utilities, for a PEV to be able to participate in these programs (and avail of the benefits accrued):

- The owner must be able to sign up the vehicle for the demand response program, associating its unique ID with the owner's utility account and assigning the vehicle charging the most beneficial electricity rate available from the utility for this purpose
- The PEV must be able to receive charge from the outlet using the SAE J1772-compliant charge coupler
- The PEV must have bidirectional communications capability through which it can send and receive utility load control requests, communicate its status and other relevant information to and from an off-board information portal, which can be the AMI meter, a sub-meter or home energy management system

- The PEV must be able to receive day-ahead or real-time pricing tariff for electricity and be able to use that information to assist the PEV charging system in setting an appropriate battery charging schedule every time the PEV is plugged into the wall.
- The PEV must be capable of receiving demand response request in the form of requested load reduction or charging interruption
- The PEV must be capable of combining the demand response (DR) request with the customer preferences for override (or not) for a given DR event, changing the charging profile of the battery while the DR event is in progress, and providing the external communications source with the signal of its compliance for settlement purposes.
- The PEV must be able to uniquely 'bind' itself digitally to the meter that measures consumption of the household of its owner (and to no other neighboring meter)
- The PEV must be capable of receiving an override command from the owner that temporarily suspends its participation in any energy efficiency or DR programs it may be registered to.
- At a minimum, in the absence of its ability to communicate with any intelligent information source such as an AMI meter, the PEV must be able to receive charge as determined by on-board battery charging controller.
- When away from home but in the same utility service territory and charging remotely, the PEV must be able to communicate with the nearby off-board meter to ensure the owner of the PEV is billed for the electricity usage versus the owner of the outlet.
- When PEV is away from home and roaming, the vision is that the PEV will have a cell phone type ability to still be able to charge and be billed for it through cross-utility settlement process playing out in the background.

In order for the PEV to be able to do this, it will need to have the following capabilities:

- On-board bidirectional communication channel that meets the SQRA (Security, Quality, Reliability and Availability) requirements with automotive grade performance requirements
- On-board intelligence in the form of control algorithms that enable the PEV to perform the required functions outlined earlier in this section, as well as sufficient processing capability in the form of RAM, ROM and throughput in some controller (preferably charging controller) box to house this additional software algorithms, variables and data.
- Connectivity with on-board charge management, powertrain and body control systems to ensure that the Smart Charging control system can communicate with the appropriate on-vehicle serial data buses for the necessary controller interactions.
- Additionally, given that although the same PEV can roam through 50 states and Canadian provinces as well as span various service territories with different communications hardware and protocol requirements on the meter side of the plug, the PEV will have only one type of hardware and software interface to the plug or EVSE (Electric Vehicle Supply Equipment). This means that the protocol conversion or bridging of the transport layer for on-board communications to the utility-compatible transport layer will be done off-board.

Scope of This Report

This technical update therefore will provide a brief overview of:

- Scope, purpose, rationale of developing SAE Recommended Practice J2836 and SAE Information Report J2847
- Intelligrid Methodology for developing usecases
- Guiding Principles of usecase cases to extract PEV <-> Utility communication/messaging requirements
- Identify key elements (enrollment, vehicle startup, binding & rebinding, authentication, connection location, connection type, connection complexity, basic charging per utility programs, specific charging per utility program) that needs to be captured during usecase development
- Description of the Utility Programs
- Usecase activities
- Factors affecting different utility pricing structures
- Approach to development of a nationwide standard to develop Real time pricing (RTP) and Time of Use (TOU) Objects
- Selecting technology independent information models
- Creating technology independent object models Development
- Different Standardization efforts currently underway
- EPRI’s Role and Next Steps

2
SAE J2836 – COMMUNICATION BETWEEN PLUG-IN VEHICLES AND THE UTILITY GRID

Scope

SAE Recommended Practice J2836 establishes requirements and specifications for communication between plug-in electric vehicles and the electric power grid, for energy transfer and other applications.

Purpose

The primary purpose of J2836 is *grid-optimized energy transfer for plug-in electric vehicles* – that is, ensuring that vehicle operators have sufficient energy for driving while enabling the delivery of that energy to vehicles in ways that minimize stress upon the grid. This can be accomplished, for example, by vehicle owners' voluntary participation in a utility controlled-charging program in return for incentives, and the specification therefore supports information flows that enable such mechanisms.

The specification supports energy transfer via both Forward Power Flow (FPF) from grid-to-vehicle, and Reverse Power Flow (RPF) from vehicle-to-grid. Forward Power Flow is used to charge the vehicle's rechargeable energy storage system (RESS); support for FPF is mandatory for any implementation of J2836. Reverse Power Flow may be used to discharge the RESS, in order to provide support to the grid, or to power local loads during a grid outage; support for RPF is optional, though encouraged, for implementers of J2836.

Beyond its primary purpose of energy transfer, J2836 enables other applications between vehicles and the grid, such as vehicle participation in a utility-controlled charging plan, or participation in a home-area network (HAN) of utility-managed electrical devices. The J2836 protocol is designed to be extensible, so that as new applications emerge, additional messages can be added while maintaining support for the existing message set.

Rationale

J2836 supports AC or DC energy transfer, and replaces the earlier J2293 standard, based upon requirements jointly developed by vehicle manufacturers, electric utilities, grid operators, technology suppliers, and other stakeholders. These requirements are reflected in SAE Information Report J2847, *Use Cases for Communication between Plug-in Vehicles and the Utility Grid*.

Whereas J2293 focused on communication between the vehicle and local, off-board electric vehicle supply equipment (EVSE) with optional grid interaction, J2836 focuses on communication between the vehicle and grid, with the EVSE playing the role of local intermediary. Additionally, while J2293 included support for J1773-based inductive charging and J1850-based communication, these are no longer required and hence not supported by J2836. In order to maintain information for existing systems, this task force has reaffirmed J2293, preserving that specification at its last revision level.

This specification addresses major changes that have occurred since 1997 (when J2293 was published) in the technologies of electric vehicles, the grid, and information processing, including: (1) support for bi-directional energy transfer between vehicle and grid (FPF and RPF, as defined above); (2) support for new local communications media between vehicle and EVSE (to replace J1850), such as power line communication (PLC) and wireless transports (Zigbee, WiFi, etc.); (3) synchronizing with a major revision of J1772 which includes new connectors and signals between the vehicle and EVSE, and additional AC and DC power levels; (4) support for new vehicle architectures such as plug-in hybrid (PHEV) and plug-in fuel cell (PFCV) vehicles; (5) support for new rechargeable energy storage system (RESS) technologies and packaging methods; (6) support for vehicle telematics communication transports; and (7) support for new developments in both utility and customer premises equipment, such as advanced metering infrastructure (AMI) and home-area network (HAN) technologies.

Members

Key stakeholders (54 and growing) participating in the SAE J2836 activity include:

- Utility companies (SCE, PG&E, SMUD, SRP, Hydro Quebec, BC Hydro, First Energy, Consumers, AEP, TVA, EDF, ExcelCorp, ComEd, Southern Company, Reliant, SDG&E, SRP, EPRI)
- EVSE manufacturers (Clipper Creek, AeroVironment, Coulomb Technologies, Magna-Power, Eaton Corp)
- Vehicle manufacturers (Tesla Motors, GM, Ford, Chrysler, Phoenix Motor, Nissan, Toyota, BMW)
- Charger manufacturers (Delta-Q, AeroVironment, Intergrid)
- Technology suppliers (V2Green, Nextek Power Systems, VPT, AeroVironment, Semaconnect Inc)
- Researchers (Argonne National Lab, Georgia Tech)

SAE J2847 – Use Cases for Communication Between Plug-in Vehicles and the Utility Grid

Scope

SAE Information Report J2847 establishes use cases for communication between plug-in electric vehicles and the electric power grid, for energy transfer and other applications

Purpose

The purpose of J2847 is to

- To capture requirements associated with PEV infrastructure, core functions and related applications to facilitate successful integration of PEV into the utility enterprise
  - Develop ***Functional*** and ***Non-Functional*** requirements and specifications
  - Evaluate, Distill, Prioritize, and Publish requirements
- Develop and document the set of use cases which must be supported by SAE Recommended Practice J2836, *Communication between Plug-in Vehicles and the Utility Grid*.
- Requirements should support AMI as well as non-AMI environments
- Requirements should be independent of the transport layer (see Figure 2-1)
- Extract requirements from the usecases which must be supported by SAE Recommended Practice J2836, *Communication between Plug-in Vehicles and the Utility Grid*
- Select and develop a tool for common usecase repository/management
- Construct Technology Independent Information Models
- Develop a detailed roadmap to J2847
- Coordinate activities with Smart Energy Council and other Standard Development Organizations (SDOs) shown in Figure 2-2 and Figure 2-3.

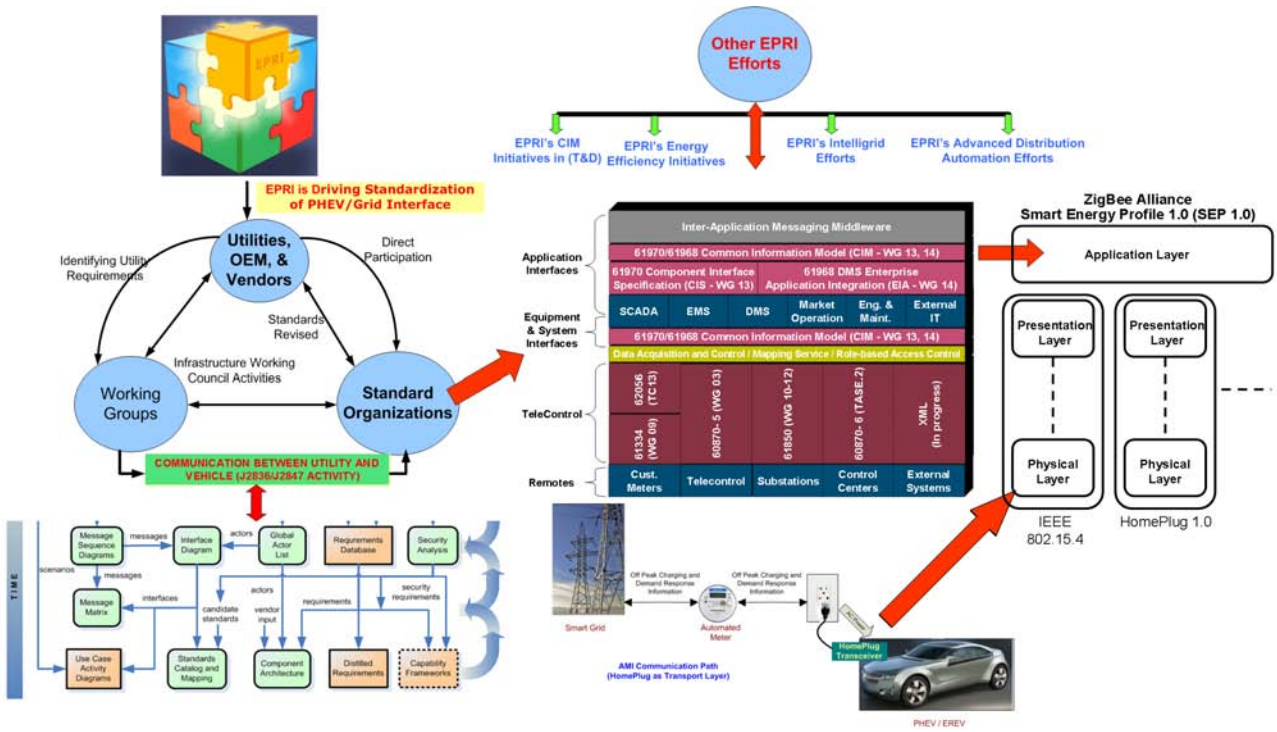


Figure 2-1
AMI-PEV Road Map – Driving Standardization of PEV/Grid Interface

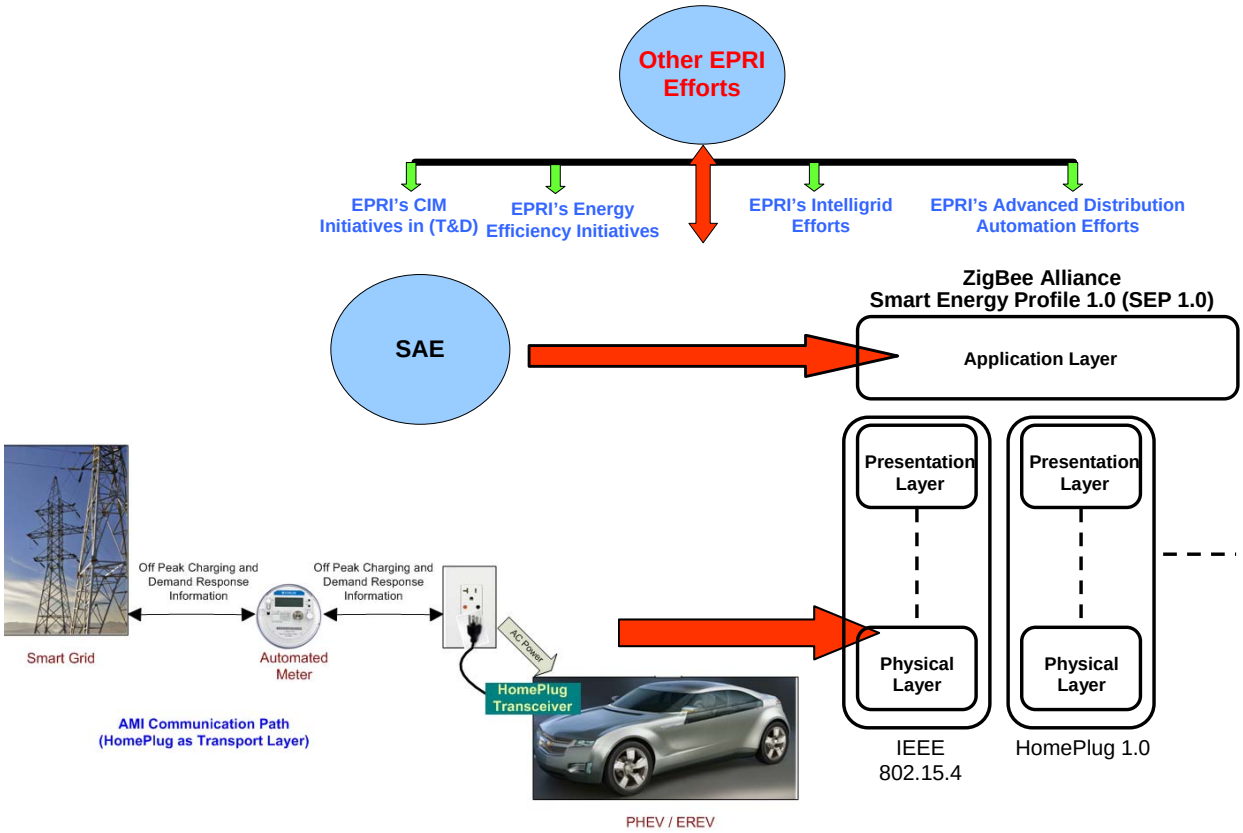


Figure 2-2
Coordinating Standard Development Activities With Zigbee + HomePlug Joint Steering Committee

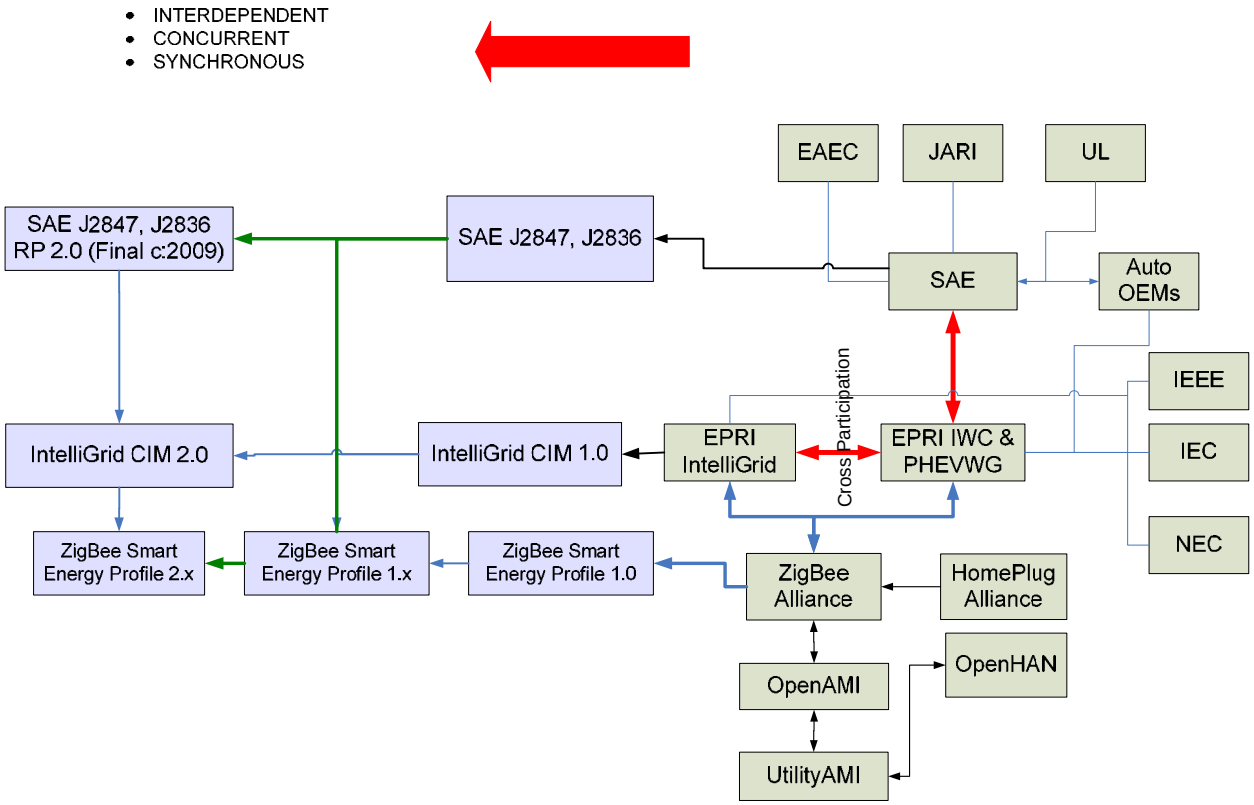


Figure 2-3
Coordination and Integration of Requirement Development and Extraction Activities Under SAE With Other SDOs

General Guidelines

- Support Demand Response, incentive charging, and roaming charging concepts without additional infrastructure aside from "energy metering device" & communications infrastructure
- Develop common on developing PEV ↔ Utility communications/messaging requirements without requiring a specific communications protocol
- SAE J2293/J2847 is the best forum to develop long-term PEV-utility Communication Solution
- Manage Cross industry and SDO liaisons
  - EPRI
  - IEC
  - NIST
  - SAE
  - Utility AMI

3
INTELLIGRID METHODOLOGY TO DEVELOP REQUIREMENTS FROM USE CASE ACTIVITY

This is the process recommended by the IntelliGrid Consortium for performing project planning, requirements definition, architecture development, technology selection and deployment. The steps described in this "cookbook" are illustrated in Figure 3-1 and Figure 3-2. Figure 3-1 illustrates the initial requirements definition and systems architecture development processes, while Figure 3-2 illustrates the later steps of business case analysis, technology selection, and deployment.

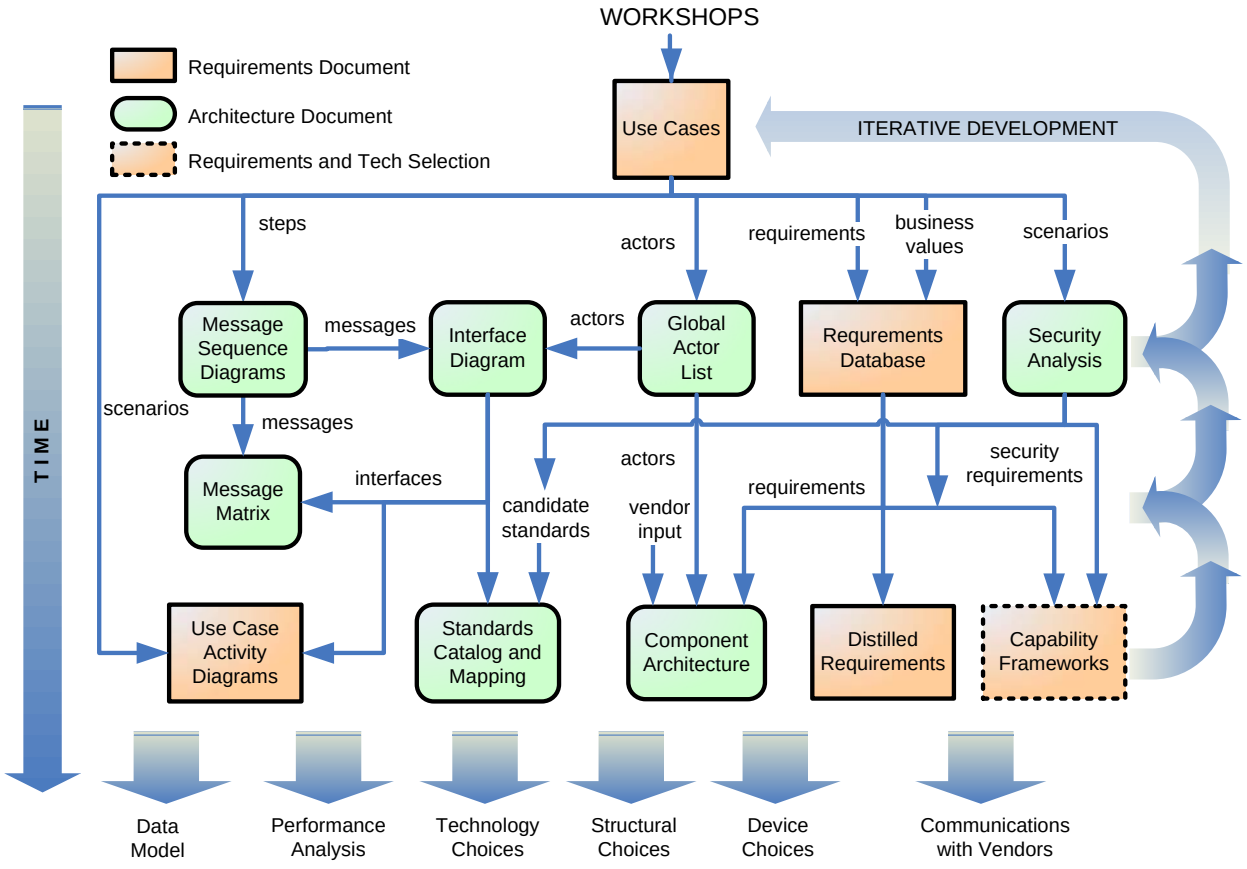


Figure 3-1
Requirements and Systems Architecture Process

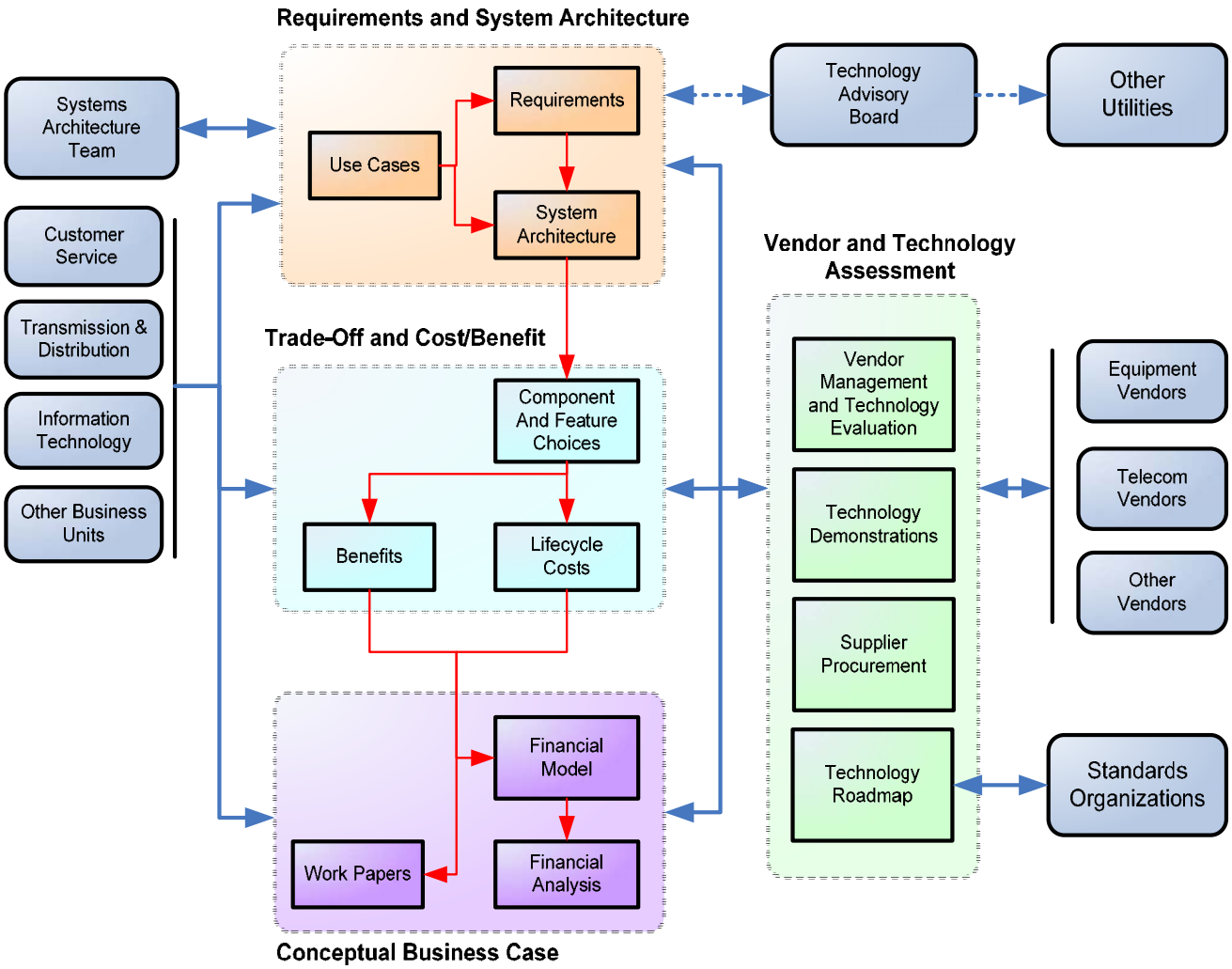


Figure 3-2
Technology Selection, Business Case, and Deployment Process

Intelligrid project stages include:

- Plan the Project
  - High-level business case
- Define Requirements
  - Identify stakeholders
  - Select Teams
  - Choose and develop use cases
  - Identify requirements and business value
  - Identify security risks

  - Distill Requirements
  - Extract Requirements
  - Develop technology independent information models (static models)
- Design an Architecture
  - Build in security
  - Build in network management
- Select Technologies
  - Trade-offs
  - Cost-Benefit Analysis
  - Final business case

Requirement Capture Methodologies

Use Case Methodology

To develop requirements based on Use Cases, the team must organize a process consisting of series of workshops using cross-functional teams. Use Cases place particular emphasis on how the system will actually be used when deployed rather than being constrained by the design of existing products. The team must clearly define the desired requirements, leaving vendors as free as possible to come up with innovative solutions.

Use Case Introduction

A use case is simply a "story" that includes various "actors", and the "path" they take to achieve a particular functional goal. By considering the actions of the actors working to achieve this functional goal, a completed use case results in the documentation of multiple scenarios, each containing a sequence of steps that trace an end-to-end path. These sequential steps describe the functions that the proposed systems and processes must provide, directly leading to the requirements for the given use case.

A use case may have many parts, but the following are the most important:

- The **goal** of the use case, which is usually its name. e.g. "Utility remotely connects or disconnects customer".
- The **narrative.** A short English text version of the story.
- The **actors**. An actor is anything in the system that communicates. It may be a person, a device, a piece of software, an organization, or anything else you can think of that acts on its own and can have goals and responsibilities. e.g. a "customer" or a "meter".
- The **assumptions** that the use case is based on. These can constitute requirements in and of themselves.

- The **contracts** and **preconditions** that exist between the actors, e.g. "The customer agrees with the utility to limit demand on selected days in exchange for a lower tariff."
- The **triggering event** that led to the scenario taking place.
- The **steps**. A numbered list of events that tell the story in detail. Each step identifies an actor, what the actor is doing, what information is being passed, and identifies to whom the information is sent. e.g. "7. The operator sends a curtailment command to the meter".

Use Case Selection

The selection of use cases depends on the high-level project goals and business drivers. A selection of use cases with utility wide scope have been identified by the IntelliGrid Architecture Project. The IntelliGrid Architecture team organized the energy industry into six functional domains:

- Market operations
- Transmission operations
- Distribution operations
- Centralized generation
- Distributed energy resources
- Customer services

A seventh domain, federated systems management, was also identified, which consists of technological functions, such as network management and security that cut across all of the other domains. Among these domains, IntelliGrid has documented eighty high level activities. These activities can be used as a basis for the use cases to consider.

Use Case Workshops to Develop Requirements

Introduction

A Use Case is a sequence of events that describes one way to use a particular system. It is a story about how a particular user of a system reaches (or fails to reach) a goal. There may be several different scenarios within each use case, each telling a slightly different variation of the story, but all talking about the same goal.

When brainstorming system requirements, there are always a few problems:

- It's difficult to tell whether you are listing real requirements, or just a "wish list".
- It's difficult to know if you thought of everything.
- Once you have your list of requirements, it's not always easy to organize or track it.

The Use Case process of defining a use case forces people to find as many true requirements as possible because:

- It's done from the users' point of view, so it's easier to tell what's really necessary.
- It follows a complete path, so you have more confidence you caught everything.
- Because they're based around user goals, there is a natural way to organize them.

The utility will need to form a number of cross-departmental teams and have assigned them to write Use Cases. As each team develops its story about the system, the team members will discover and make a list of requirements.

The utility assembles the Use Case Workshop members and plans a series of Use Case workshops. There are a number of industry tools that help to facilitate the development of Use Cases. The industry has standardized on a technology suite called Universal Modeling Language (UML) to help facilitate this process. An overview of UML techniques that are used for Use Case development is discussed in the subsequent sections. Following successful completion of the applicable Use Cases, system architects will need to refine the functional and non-functional requirements process.

Use Case Workshop Membership

The membership of the use case teams should comprise people from internal organizations who are stakeholders or actors in the use case. The teams should contain both subject matter experts as well as decision makers. The subject matter experts provide the technical knowledge needed to ground the use case in reality and the decision makers should be managers with sufficient seniority to choose new policies. It is beneficial to include a workshop facilitator with experience in the use case and requirements gathering process. Each use case team should also have a leader who can guide the team and represent the team in system architecture meetings.

Use Case Workshop Planning

Prior to holding the use case workshop, the team leader(s) and facilitator should create a narrative that describes the high level goal of the use case. The facilitation team can also create straw man content for the workshop including:

- Actors and stakeholders
- Scenario steps
- Discussion topics that are specifically "in" or "out" of scope

These preparatory materials can be presented to the team members at the meeting using slides or handouts. These materials should be reviewed and updated for each additional workshop to reflect the decisions made by the use case team.

Use Case Workshops

A lesson that has been learned from earlier applications of the IntelliGrid use case process is to have a formal indoctrination of the stakeholders in the overall requirements capture process. The size of the project will dictate how best to introduce the team members to the use case process. A focused training session involving all project participants can be used, or the training can occur in the initial use case workshop.

The use case workshops should be structured to engage the team members to participate, keeping in mind that a workshop may have people with widely varying backgrounds and skill sets. A sample workshop presentation is:

- Review and validation of the use case narrative
- Validation of key use case actors and roles
- Discussion of scenarios to be included within the use case
- Discussion of goals for the day's workshop including scenarios to be completed
- General ground rules for the session
- For second and following sessions…a review of outcomes of the prior session(s) and updates on any issues, action items, and parking lot items documented previously

The use case team leader provides overall strategic direction during the course of the workshop sessions. The facilitator provides agenda and process management. The workshop discussion generates proposed scenario steps. Upon general agreement the scenario steps are adopted and the discussion continues until the scenario is completed. The following guidelines can be used to ensure scenario completeness:

- **W**hat, not how. Concentrate on **what** needs to be done, not the technology or network that will make it happen. You don't want to limit the design too early in the process.
- **A**ctor's point of view. Are you looking at the system from the primary actor's (usually the customer's) point of view, or as a designer of the system? The wrong viewpoint can lead to usability problems.
- **V**alue for the actor. Are the steps you're discussing going to help the primary actor accomplish its goal? Are you getting sidetracked?
- **E**ntire scenario. Have you gone far enough back to find the beginning of the scenario, and are you sure you've reached the goal?

The scenario steps should be evaluated by the group to identify functional and non-functional requirements resulting from the step. The requirements also result in the identification of potential quantifiable or non-quantifiable business benefits that can be made possible by the scenarios included in the use case and should be documented.

The results of the use case workshop should be disseminated to the team members and reviewed for accuracy. Questions and issues that arise during the workshop should be addressed by the architecture team and the answers should be included in the post workshop notes. The workshop process is repeated until the use case is complete.

Writing Good Requirements

A requirement is an expression of a ***perceived*** need that something be accomplished or realized. Note that this definition is intended to encompass ***all*** possible requirements for a project. Be aware that in the real world, a "requirement" may merely be something that someone wants – "***desirements".***

The following items help to define "What's a *Good* Requirement?"

- Binding
  - Makes it clear what is optional and what is not
  - Creates a "contract" with the reader
- Shows Responsibility
  - Identifies what component must take action
  - Implies whose job it is to ensure it happens
- Consistent in Level
  - May be customer, strategic, functional, design, test, etc.
  - Should not "jump ahead" to the next level
- Measurable
  - To be usable later in the process
  - Maybe not by a customer, but by ***someone***
- Testable
  - So you can determine whether the requirement has been met

Components of a Good Requirement

Good requirements development utilizes a consistent structure defined as follows:

- Requirements are best expressed as complete sentences
- Subject-Verb-Object-Qualifier, just like in school
- Don't use "and" because that's linking two requirements together that may not actually be linked. Use two sentences.

- Subject and Object
  - Must be well-known parts of the system
  - Try not to use "the system" – too vague
  - Define your terms ahead of time
  - If you involve people, make them ***specific roles*** if possible
  - **GOOD**: "operator", "administrator", "maintenance worker"
  - **NOT AS GOOD**: "user", or "client"
- Verb
  - Proceeded by a ***binding*** word: "must" is okay, "shall" is best
  - Can use "may optionally" to identify alternatives
  - Use "will" only to provide extra info: "this will ensure that…"
  - Use an ***action*** word
  - ***Passive voice is forbidden***! It is <u>designed</u> to <u>avoid</u> ownership!
  - Be as ***precise*** as possible
  - **GOOD**: "transmit", "display", "activate", "print", "notify", "connect"
  - **BAD**: "is", "be", "have", "contain", "process", "handle", "support"
  - "permit" is a good action word for user interfaces that puts the responsibility on the system providing the interface
- Qualifier
  - Specifies constraints or performance
  - Must be ***measurable***
  - Include a qualifier as often as you can

Classes of Requirements

Two types of requirements are developed for the system – 1) Functional and 2) Non-functional:

- Functional Requirements
  - What the system must ***DO***
  - Actions in response to events, or performed autonomously
  - Operations and features provided
- Non-Functional Requirements
  - What the system must ***BE***
  - Also called "constraints", "behavior", "criteria", "performance targets", etc.
  - Sets limits or controls on how well the system performs the functional requirements.

– These are the "..itys" and "…ances": reliability, security, usability, upgradeability, expandability, scalability, compatibility, safety, performance, conformance, etc.

Use Case Analysis

The goal of the use case analysis is to produce a coherent set of use cases that can be used for subsequent architecture development. The use case analysis process should begin while the workshop process is still underway. The architecture team should review the output of the workshops to evaluate the preliminary requirements and provide feedback. The architecture team can address questions and issues posed by the use case teams and also identify and address scenario gaps or overlaps among different use case teams.

Global Actor List

The workshop process will produce a list of actors and their roles. The names and definitions of these actors should be reviewed to create a standardized list of actor names and roles. The iterative nature of the workshops and the different views that use case teams may hold will cause the creation of duplicate, redundant and conflicting actors. The standardization process should resolve all of these discrepancies.

Activity Diagrams

Activity diagrams are a graphical method to display the events occurring in a use case scenario. The use of this UML tool can provide several benefits. Displaying a use case scenario in a graphical form can allow users to better understand the sequence of events that are occurring and delineate which actors are performing which tasks. The diagram can also reveal points where the textual list of events is insufficient to describe possible outcomes that should be considered in the scenario. The diagram is also useful for indicating interfaces between actors which can also be captured in the UML sequence diagram. (See Figure 3-3).

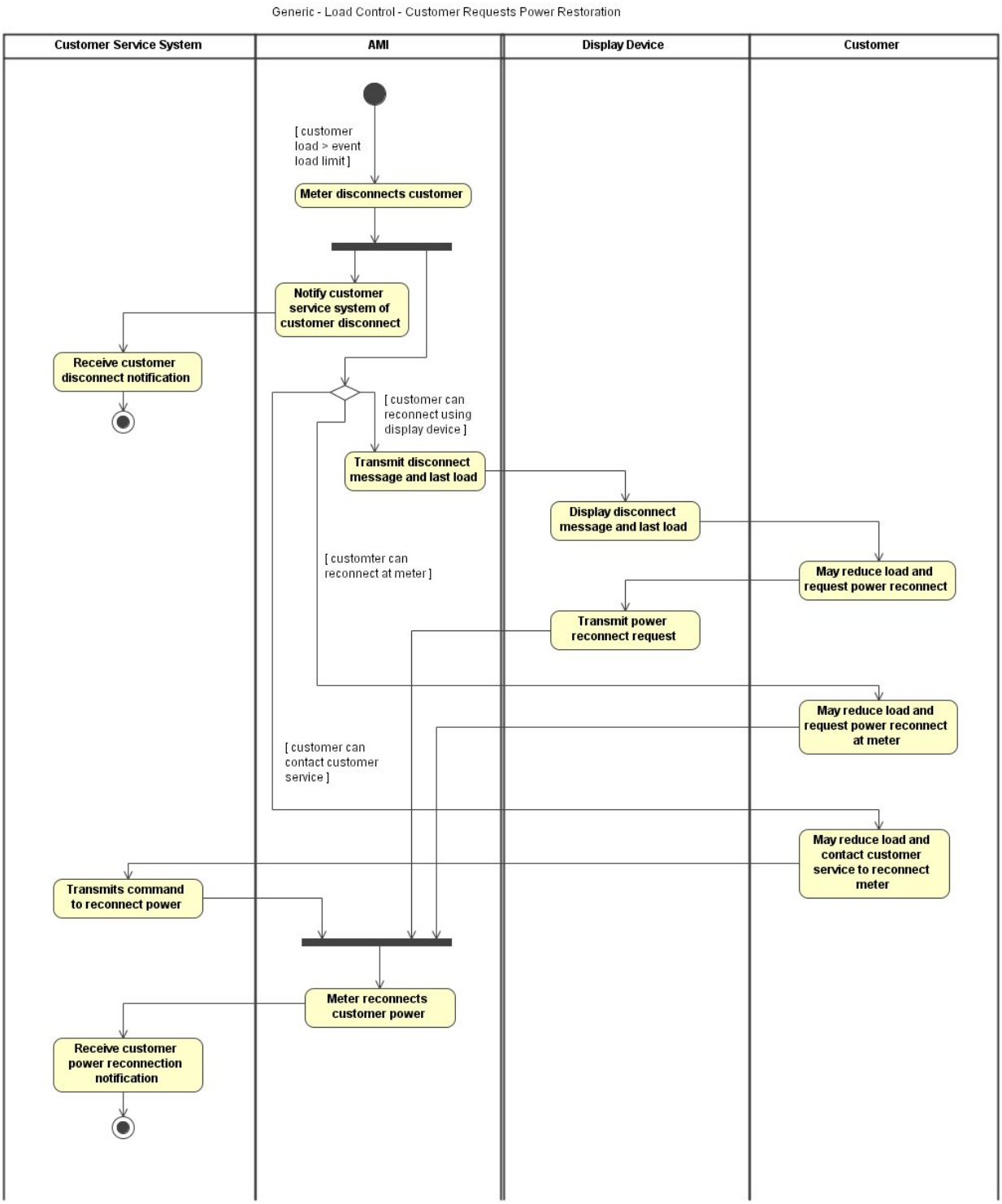


Figure 3-3
Example of an Activity Diagram

Interface Diagrams

The purpose of the interface diagram is to provide a single conceptual picture that can be used to express the flow and sequence of data within the system. The interface diagram can be derived from the interactions among the actors indicated by the activity diagram. A preliminary interface diagram can be created during the use case workshops by the architecture team to provide a high level conceptual view. The preliminary diagram should use accepted design patterns and should be responsive to changes required by the use case workshops. There is no defined UML diagram for interface diagrams but the Yourdon dataflow diagram has been used with success in previous projects. (See Figure 3-4).

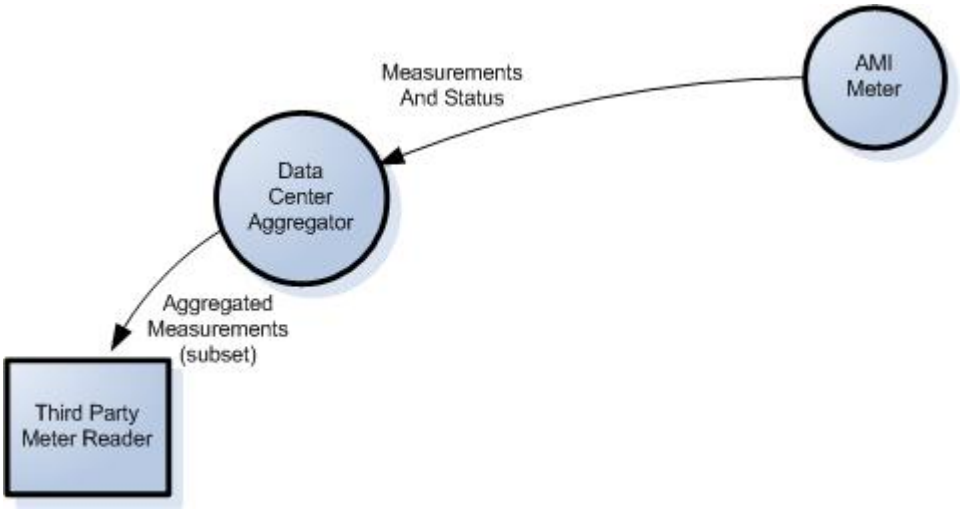


Figure 3-4
Interface Diagram Example

Message Sequence Diagrams

The message sequence diagram is a standard UML sequence diagram that illustrates the step-by-step interactions between the actors in a scenario. The message exchanges indicate where interfaces between actors exist and the types and frequency of data that are exchanged. The message sequence diagram can be derived from the use case scenarios or from activity diagrams. Checking that the scenarios, activity diagrams and message sequence diagrams are consistent ensures that the use case data has been correctly captured by the diagrams. The messages should also be entered into a spreadsheet or database to facilitate the entry of additional information about the message exchanges and to aid the architecture team in the system analysis. (See Figure 3-5).

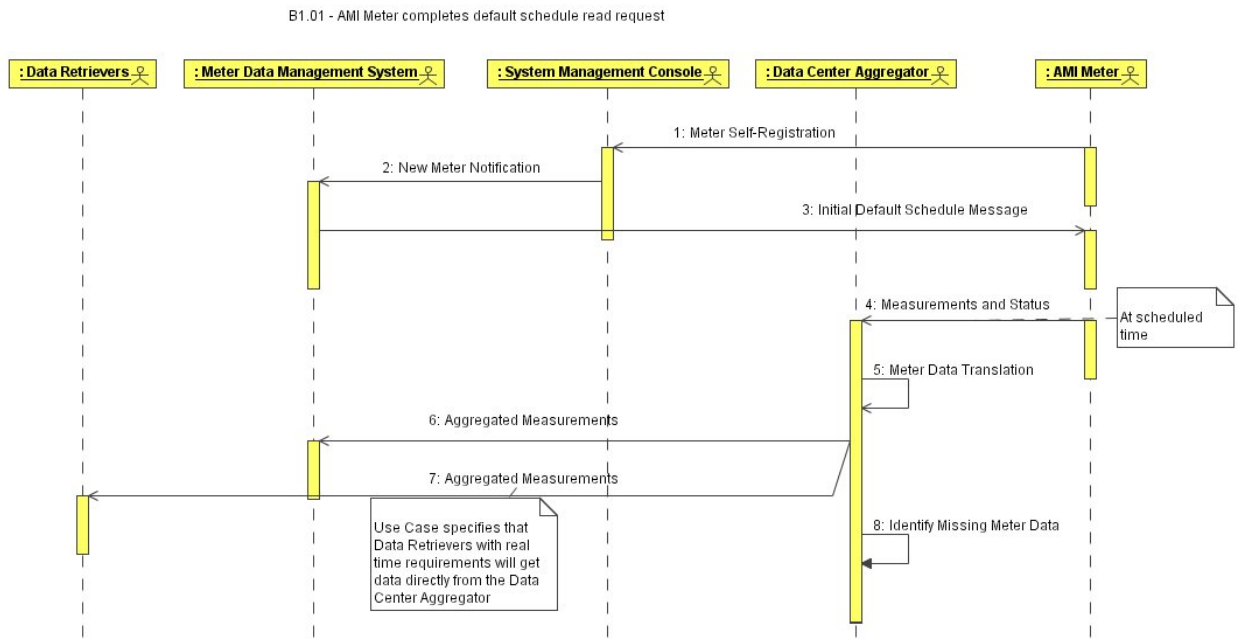


Figure 3-5
Message Sequence Diagram Example

Use Case Interaction Diagrams

Use case interaction diagrams are versions of the interface diagram for each use case which include only the actors and interfaces involved in the use case. These diagrams are useful to illustrate the core parts of a particular use case and to make comparisons between use cases.

Refining Requirements

Refining requirements is the process of reviewing, classifying and consolidating the requirements. The review process should begin during the use case workshop by the architecture team. The architecture team can provide feedback to the use case teams that the requirements that they are generating are of sufficient depth to satisfy the needs of the project. When the use case workshops are complete the final set of requirements can by classified into groups so that similar requirements can be compared for consistency or removed if deemed redundant. The classification can be done by system component or by interface. Non-functional requirements generated by different use cases may also specify the same metric to differing levels of performance. Evaluation of the associated costs and values will determine which level of performance will be specified as a requirement. The documentation of assumptions made by use case teams as requirements should also occur during this phase so that the assumptions are documented and validated against other system requirements.

4
GENERATING PEV COMMUNICATION REQUIREMENTS THROUGH USE CASES

High Level PEV Communications Requirements

- Supports secure two-way communication with the Energy Services Communication Interface (i.e., Utility)
- Supports time- or price-based charging preferences based on current electric rate/tier
- Supports vehicle charging at any voltage
- Support vehicle load correlation (end use metering of the PEV)
- Support Demand Side Management Integration
- Support vehicle charging regardless of utility metering and/or communication availability
- Supports vehicle roaming and unified billing infrastructure
- Supports Customer override/opt-outs
- PEV-to-Utility communications technology based on open standards

Use Case Priorities

Key elements include the following:

- Device Provisioning/Enrollment
  - i.e. Install, Authentication, Validation, Registration,
  - General enrollment process, customer awareness
  - Specific Enrollment process to specific utility programs (see below), customer awareness
- PEV Startup (Joining the network)
- Binding and Rebinding
- Connection Variations
  - 120V AC Cordset EVSE
  - 240V AC Premise EVSE
  - DC Premise EVSE

- EVSE Complexities
  - Single Port
  - Multiple Ports
- Connection Locations and Billing
  - Home (same service territory where the PEV is enrolled)
  - Another Home (same service territory where the PEV is enrolled)
  - Another Home (different service territory where the PEV is enrolled)
  - Public Charging, curbside charging, multifamily charging, workplace charging
- Utility Applications
  - Messaging
  - Demand Response/Load Control
    i.e. Load Control Message, Consumer Response
  - Payment Structures
    i.e. Flat Rate Structure, TOU, Pre-Pay, Real-time Pricing (15 mins, day ahead, etc.), CPP, Discrete Events (Direct Load Control)
  - PEVs (Pluggable Electric Vehicles)
    i.e. Charging, Monitoring

Table 4-1
Use Case Summary – Identifying Key Elements

J2847-1	Use Cases for Communication between Plug-in Vehicles and the Utility Grid	
1	Utility Programs (Enrollment and Specific Charging)	
	1.1	Time of Use (TOU)
	1.2	Discrete Event (DLC/DDC)
	1.3	Periodic/Hourly Pricing (RTP)
	1.4	Active Load Management
	1.5	Critical Peak Pricing (CPP)
2	Connection Variations	
	2.1	120V AC Cordset EVSE
	2.2	240V AC Premise EVSE
	2.3	DC Premise EVSE
3	EVSE Complexities	
	3.1	Single Port
	3.2	Multiple Ports
4	Connection Locations	
	4.1	Home
	4.2	Another's Home (inside utility territory where PEV is enrolled)
	4.3	Another's Home (outside utility territory where PEV is enrolled) Work
	4.4	public location, Multi family Dwelling, and Workplace infrastructure

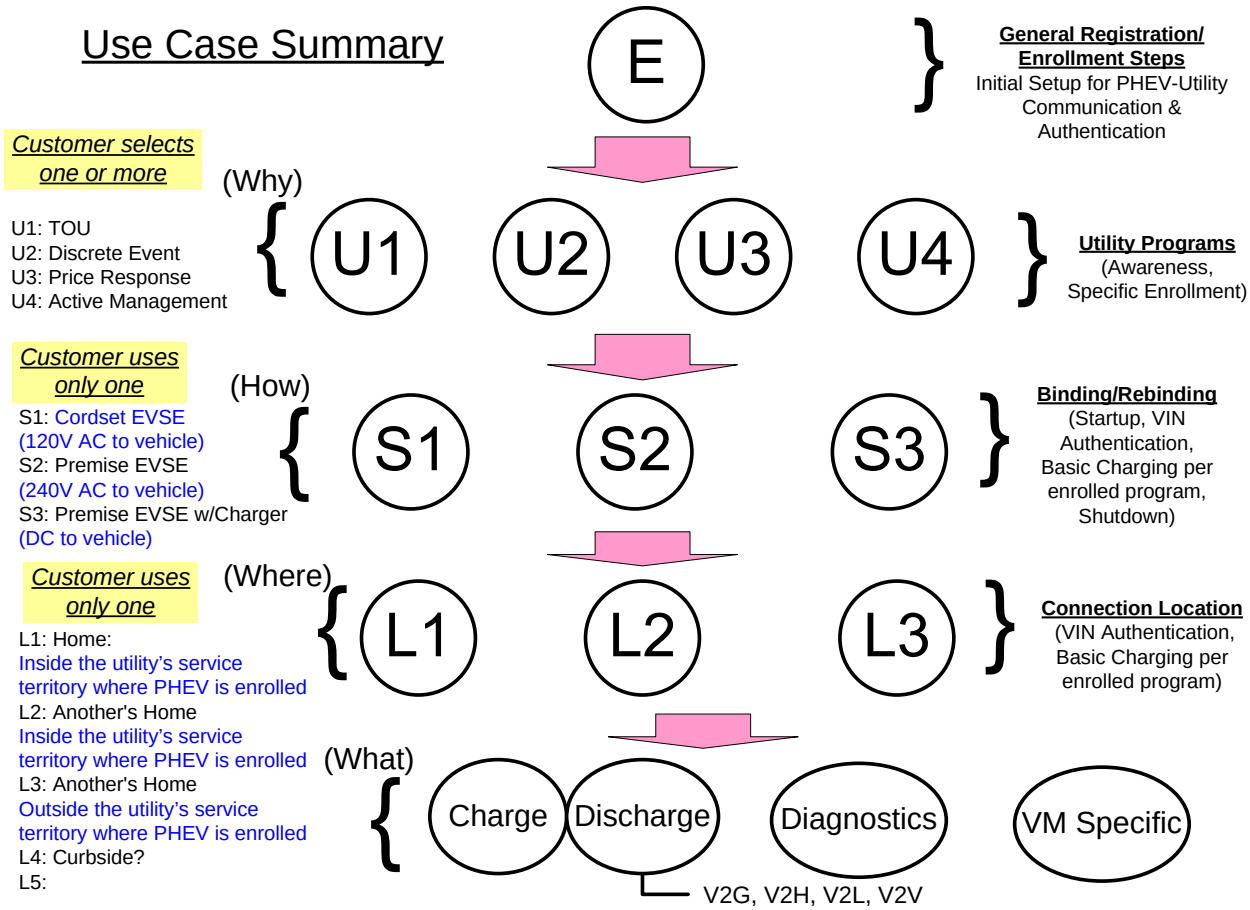


Figure 4-1
Requirement Extraction – A High Level View to Identify Key Elements

Use Case Development

Each use case developed as part of this activity comprising of several key components:

- Brief written description of the use case, its actors, functions of the actors, and intended purpose.
- Scenario matrix, specifying required and optional use case attributes.
- Equipment diagram, depicting actors and physical components of the use case.
- Communication path diagram, depicting communication transports and components.
- Activity diagram, depicting the interactions among use case actors.
- Sequence diagram, depicting the sequence of message flows in the use case.
- Tables to extract the Functional and non-Functional requirements

Several of these concepts – notably, actors, and the activity and sequence diagrams were derived from EPRI Intelligrid methodology, described in the previous chapter, which in turn is based on Unified Modeling Language (UML)[12]

Use Case Activity Currently Underway

Following use case have been developed as part of this effort:

- **E: Utility provides services to Plug-in Electric Vehicle (PEV) Customer: Enrollment Process**
  - Primary Scenario 1: Customer enrolls in PEV program and completes initial setup for PEV – Utilities communications
- **U1: Enrollment Process to Time of Use (TOU) Program**
  - Primary Scenario 1: Customer enrolls in TOU program. The vertically integrated utility provides bundled residential premise services exclusively and that TOU is available on a self-selected basis
  - Primary Scenario 2: Customer enrolls in TOU program – Customer Taking Commodity from ESCO
- **U2: Enrollment Process to Direct Load/Device Control (DDC) Program**
  - Primary Scenario 1: Customer enrolls in Discrete Event Demand Side Management Program. The vertically integrated utility provides bundled residential premise services exclusively and that DDC is available on a self-selected basis
  - Primary Scenario 2: Customer enrolls in Discrete Event Demand Side Management Program. Customer Taking Commodity from ESCO
- **U3: Enrollment Process to Real Time Pricing (RTP) or Hourly/Periodic Pricing Program**
  - Primary Scenario 1: Customer enrolls in RTP program. The vertically integrated utility provides bundled residential premise services exclusively and that RTP is available on a self-selected basis
  - Primary Scenario 2: Customer enrolls in RTP program – Customer Taking Commodity from ESCO
- **U4: Enrollment Process to Active Load Management Program**
- **U5: Enrollment Process to Critical Peak Pricing (CPP) or Hourly/Periodic Pricing Program**
  - Primary Scenario 1: Customer enrolls in CPP program. The vertically integrated utility provides bundled residential premise services exclusively and that RTP is available on a self-selected basis
  - Primary Scenario 2: Customer enrolls in CPP program – Customer Taking Commodity from ESCO

[12] http://en.wikipedia.org/wiki/Unified_Modeling_Language

- **S1: Vehicle Use Case: Customer connects vehicle to premise using Cordset EVSE**
  - Primary Scenario 1: Customer connects PEV to premise (home, another premise inside the enrolled utility's territory, workplace, and another premise outside the enrolled utility's territory). Key elements captured here include: Binding and Rebinding, Vehicle Startup, VIN Authentication, Basic Charging per utility program, shutdown
- **S2: Vehicle Use Case: Customer connects vehicle to premise using Premise Mounted EVSE**
  Primary Scenario 1: Customer connects PEV to premise (home, another premise inside the enrolled utility's territory, workplace, and another premise outside the enrolled utility's territory). Key elements captured here include: Binding and Rebinding, Vehicle Startup, VIN Authentication, Basic Charging per utility program, shutdown
- **S3: Vehicle Use Case: Customer connects vehicle to premise using Premise Mounted EVSE w/Charger (DC to vehicle)**
  Primary Scenario 1: Customer connects PEV to premise (home, another premise inside the enrolled utility's territory, workplace, and another premise outside the enrolled utility's territory). Key elements captured here include: Binding and Rebinding, Vehicle Startup, VIN Authentication, Basic Charging per utility program, shutdown
- **L: Customer connects Plug-In Electric Vehicle to premise energy portal**
  - Scenario L1: Customer connects PEV to energy portal at their premise location
  - Scenario L2(A): Customer connects PEV to energy portal at another premise and premise customer pays for energy use
  - Scenario L2(B): Customer connects PEV to energy portal at another premise and PEV customer pays for energy use
  - Scenario L3: Customer connects PEV to energy portal at another premise outside the enrolled Utility's service territory
  - Scenario L4: Customer charges PHEV at public location, Multi family Dwelling, and Workplace infrastructure
- **PR (Charge): Customer enrolls in a Plug-In Electric Vehicle Demand Side Management Program**
  - Scenario PR1: Customer is enrolled in a TOU Program
  - Scenario PR2: Customer is enrolled in a PEV Discrete Event demand side management program (Direct Load Control) and PEV (and/or PEV customer) receives and responds to discrete demand response events (specific charging)
  - Scenario PR3: Customer is enrolled in a Periodic/Hourly Pricing Price Response program and PEV receives and responds to periodic/hourly energy prices at a day-ahead schedule (specific charging)

Additional usecase to be developed as part of this effort include

- Customer charges PHEV at public location, Multi family Dwelling, and Workplace infrastructure
- Communication failures/exceptional cases related to failures
- Manage PHEV charge for the health of the grid (mainly distribution
- Customer uses Plug-In Electric Vehicle for advanced applications
- Security requirements
- PHEV Vehicle Manufacturer Diagnostic Monitoring and Reporting
- Islanding (Microgrid Support – utility perspective)
- Coordination with upstream protection
- Coordination with upstream feeder / substation loading limits (sensors)
- Customer Manages PHEV Preferences

5
UTILITY PROGRAMS

Introduction

This section provides an overview of the most common retail electric rate structures, ranging from simple static rate structures that are updated relatively infrequently to more complicated structures that involve prices that change more frequently, some as often as every day or hour. A wide variety of pricing structures or plans are utilized to provide retail service. The rate structures reflect an assembly from terms and conditions that determine all aspects of the service, including:

- ***Eligibility and contract terms***
  - Residential vs. non-residential customers
  - Minimum or maximum load requirements
  - Delivery voltage level
  - Contract length, early termination rights, and penalties
- **The rate structure -** defines the how service delivery measured and the applicable prices or rates for each applicable rate component. Standard rate components include a customer charge, energy charge, demand charge, etc. For more complex structures, these components can vary by season, time of day, or during system conditions specified in the tariff. Others include provisions for varying price or availability based on exigent circumstances.
- **How service delivery is measured**
  - Simple kWh meter, demand meter, or interval meter
  - Estimated vs. actual meter reads

All retail rate plans can induce price response, but they vary considerably in terms of the time frame over which an adjustment is undertaken.[13] A change in a uniform rate ($/kWh for all energy consumed) will cause consumers to reevaluate how they use electricity, and depending upon the degree to which there are substitutes, a rate increase will result in decreased usage, and vice versa. Time-differentiated rate schedules differentiate consumption by the time of day or season of the year in occurs.

[13] For an overview of the theory and empirical evidence price response measures see: Neenan, B., Eom, J. January 2008. Price Elasticity of Demand for Electricity: A Primer and Synthesis. EPRI, Palo Alto, CA: 2007. EPRI Report No. 1016264.

Moving from a uniform to a time-of-use (TOU) rate effectively imposes a rate change (lower off-peak price, higher on-peak price) that will cause a readjustment of the load profile commensurate with the customer's ability to make that substitution profitably. Dynamic pricing plans like real-time pricing (RP) and Critical Peak Pricing (CPP) are more surgical in their impact since they involve infrequent and higher price increases of relatively short duration.

Simple, Static Rate Structures

Simple rate structures include: a flat, fixed bill per month, an energy rate which is a fixed volumetric rate (per kWh), a demand rate (which adds a charge for the highest hourly consumption during the billing period), and a graduated volumetric rate which can include a declining or increasing rate for higher levels of energy consumption. Under traditional rate structures, rates for energy (kWh), demand (kW) and other charges (customer charge) are established for a specified period of time, generally a year or more. The rates, once posted, apply to all consumption without restriction to the amount of that consumption, except as specified in the rate.

Retail price structures are established to collect embedded capital and energy supply costs from customers equitably and effectively. Rates are generally based on the estimated costs of serving customers' load, based on historical load patterns.

Flat or Fixed Monthly Bill

A fixed bill assesses a single charge for the entire month's usage, regardless of the amount of energy used or maximum demand achieved. There are two types of fixed bills, a levelized bill and a flat, fixed bill.

Levelized Bill

Levelized (also called "budget billing") was introduced years ago to help customers better manage their electricity costs by making the monthly expenditures more predictable. To establish a levelized bill, the total cost for service for the customer is estimated and 1/12 of the annual total is simply assessed each month, resulting in a bill that is not sensitive to that month's usage. However, eventually the total amount paid reflects metered consumption. To derive the fixed monthly charge, the customer's monthly energy usage is estimated, and tariff rates are applied to the estimates. A balancing account compares the monthly assessment to the bill associated with actual consumption and periodically the levelized amount is adjusted (up or down) to eliminate the balance.

Flat or Fixed Bill

Unlike a levelized bill a flat bill is invariant to that month's actual usage. A single amount ($/month) is assessed for monthly service, regardless of the level of measured energy and maximum demand. The amount is set for each participant is based on historical usage, current rates and a risk premium. Participants whose usage increases may find that the next contract includes a higher fixed bill to reflect the growth. A similar adjustment may be made if usage declines.

Energy or Volumetric Rates ($/kWh)

Energy rates may be flat or vary by levels (blocks) of consumption.

Flat Energy Rates

A single price ($/kWh) applies to all metered energy (kWh) consumption during each billing period. The simplest rate structures include a flat energy rate and a customer charge, a fixed dollar amount. This simple rate structure is most common for residential and small commercial customers.

Block Energy Rate Structures

For block rates, the rate ($/kWh) varies by the volume consumed during the billing period. Variations on the block rate include the following:

- ***Inclining block rate*** – a single rate applies to the first block of kWh, and a higher rate applies to additional kWh.
- ***Declining block rate*** – one rate applies to the first block of kWh, and a lower rate applies to additional kWh.

Three or more blocks can be defined; California residential electricity provided by the three major utilities is sold under a five-tier block rate structure. . The block structure may differ by season (inclining in summer and declining in winter), or the block sizes can vary seasonally (i.e., the first block might be 400 kWh in summer, but 600 kWh in winter).

Demand-Based Rates

Some rate structures include a demand charge ($/kW), in addition to customer charges and energy rates. Demand is the highest level of usage in the month. Demand is usually the kW measured over the highest hour of use, but can be measured over shorter intervals (15 or 30 minutes). Demand charges were developed to reflect the fact that some larger customers can have loads that spike to very high levels, but might have a low load factor[14] if they don't run their processes very long. If large, low-load factor customers were only charged energy rates, they would not pay their fair share of the capacity costs under conventional embedded cost rates. Adding a demand charge to the structure solves this problem.

A demand charge usually only applies to larger commercial and industrial customers and requires demand meters which can keep track of the customers' hourly usage. For billing purposes several different types of demand are relevant: billing demand, ratcheted demand, volumetric block demand, and contract demand.

[14] Load factor is the ratio of average use to the monthly maximum demand.

Billing Demand

Billing demand is the demand level that is used in calculating the demand to be billed bill in that month. A ***coincident demand*** is the customer's maximum demand during the hours in the month (for example, between 12:00 p.m. and 6:00 p.m. weekdays) that are coincident with when the utility system peak occurs. A non-coincident demand is customer's highest level of demand at any time in the month, regardless of when it occurs.

Ratcheted Demand

Ratcheted demand is the higher of the current month's maximum demand, or the highest measured maximum demand in a specified number (often 12) of previous consecutive months.

Volumetric Block Demand

Different demand charges apply to different levels of measured demand. For example, an initial rate applies to the first kW block, and another rate to all additional measured kW. Demand block rates ($/kW) can be inclining or declining. In addition, they can involve two or more blocks of demand and include a ratchet.

Contract Demand

Contract demand is a consumer-specified level of demand to which a base demand charge ($/kW) applies. A higher rate usually applies to demand levels above the contract demand. These types of provisions are common in rate structures for supplemental and backup service.

Dynamic Rate Structures

Dynamic rate structures are structures that are designed to change over time. In Figure 1, dynamic rates are mapped onto a time scale of years (for system planning) to months, days and hour ahead (the time frame for system operations). The traditional, non-time varying rates discussed in Section 2 are typically established at least a year ahead. The dynamic rate structures begin with time of use rates, as illustrated in the Figure 5-1 below.

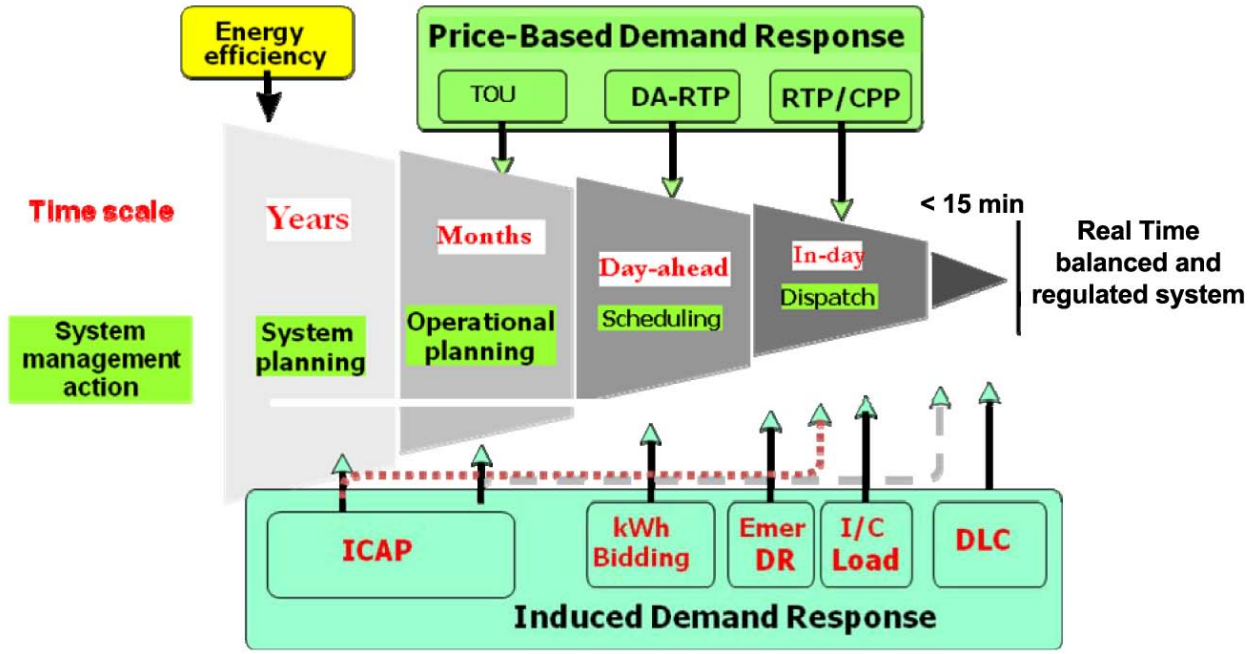


Figure 5-1
Electricity Rate Structures as They Relate to the Different Time Dimensions for System Planning and Operations

Notes to Figure 5-1: TOU = time of use; DA-RTP = day-ahead real-time pricing; CPP = critical peak pricing; DR = demand response; I/C = interruptible/curtailable; DLC = direct load control.

Dynamic rate structures can have some or all of the rate components listed above for simple, static rate structures: energy charges, customer charges and demand charges. The difference is that the time frames over which the charges apply are more variable. The types of dynamic pricing described here include: Time of use rates, critical peak pricing, variable peak pricing, real-time pricing, and a block and swing design.

Time of Use (TOU) Rate Structures

The simplest form of a time of use rate would involve energy prices that vary by time of day. They often vary by season of the year as well, but for simplicity we're only focusing on the designs that vary by hours in the day.

Figure 5-2 shows a simple TOU design with an on-peak period of 14 hours and a 10-hour off-peak period. This design has a long on-peak period and a relatively low peak to off-peak price ratio: the peak price is 1.5 times the off-peak price. This particular design is common among older TOU rates, but has several disadvantages if the utility is trying to encourage demand response. The long on-peak period makes it difficult for many customers to shift load to the off-peak period, and the relatively low peak/off-peak price ratio doesn't provide a very large incentive for customers to try to do so. For that reason, a number of utilities are experimenting with TOU designs that include shorter (7-hour) on-peak periods and higher (1.75 to 2.0) peak to off-peak prices. (See the TOU 3 and TOU 2S designs in Figure 5-2.)

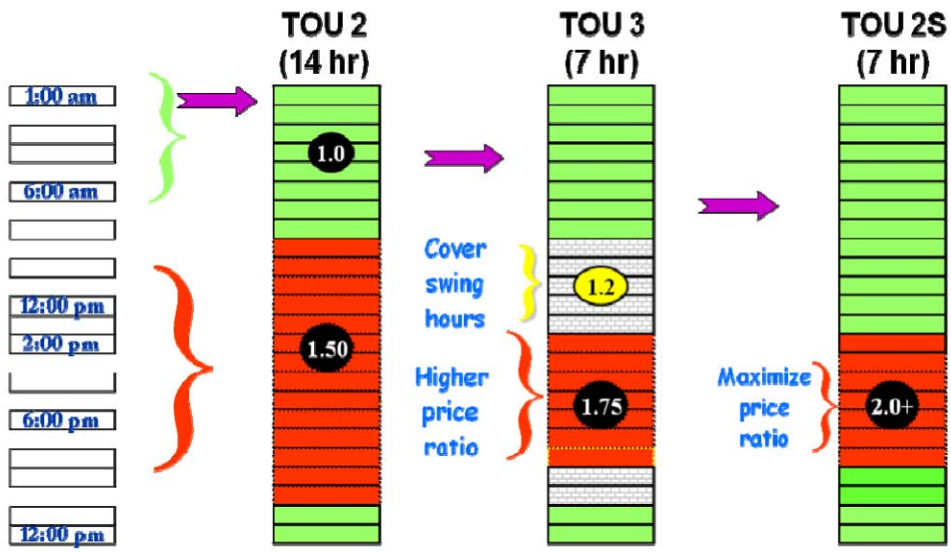


Figure 5-2
Three Alternative TOU Design Concepts

Notes to Figure 5- 2: TOU 2 is a TOU rate with 2 periods; TOU 3 has three periods (peak, off-peak and shoulder period; TOU 2S is a two-period design with a shorter (7 hour) on-peak period.

Alternative Dynamic Pricing Structures

Other variations on the basic TOU structure include critical peak pricing (CPP), variable peak pricing (VPP) and real time pricing (RTP). These alternative designs are illustrated graphically in Figure 5-3. Critical peak pricing is a mechanism whereby normal flat or (in this example) TOU rates are in effect except for certain peak days, when pre-specified higher prices are superimposed on the normal TOU rate. CPP prices are used during system contingencies or during periods of high wholesale electricity prices for a limited number of days or hours per year.

Variable Peak Pricing is a structure where the peak period price is directly tied to the day-ahead wholesale market, while the shoulder and off-peak prices are set ahead of time and maintained according to the underlying rate structure. Variable peak pricing provides the customer with an opportunity to purchase energy during the on-peak period at prices that vary according to the energy market.

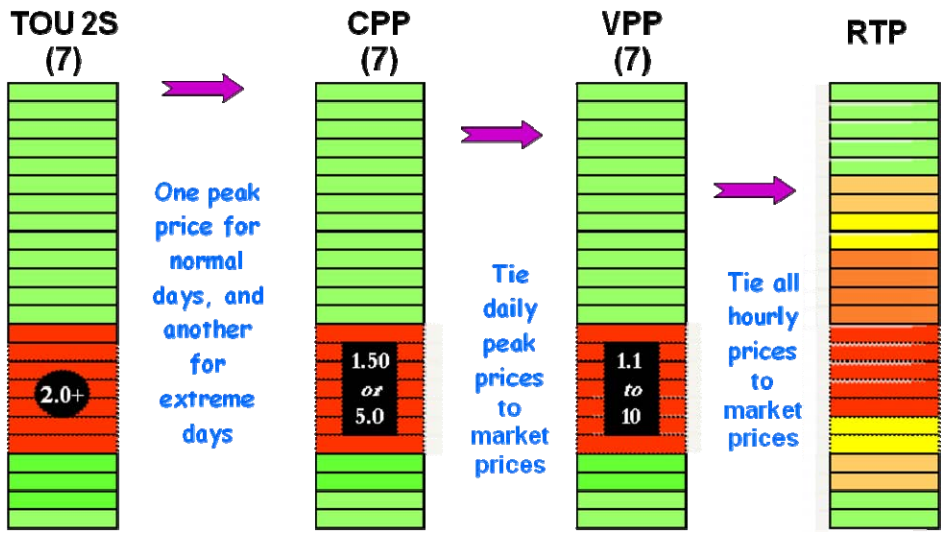


Figure 5-3
Alternative Dynamic Pricing Rate Structures (TOU, CPP, VPP and RTP)

Under real-time pricing (RTP), electricity prices are specified for each hour to reflect varying supply costs. Hourly prices are typically posted day-ahead or hour-ahead, and reflect the utility's cost of generating electricity at the margin or purchasing electricity from the wholesale market. Comparing these four dynamic pricing rates structures, TOU rates provide the most advance notice of price levels (year-ahead is common) and real-time price provides the least amount of advance notice (day ahead or hour ahead).

The last rate structure to be described here is a "block and swing" rate design that is a hybrid TOU/RTP rate, illustrated in Figure 5-4. Under this design, the customer can hedge their supplies by nominating a level of peak and off-peak consumption, which they will buy at a fixed (TOU) price. Variations are settled at the real time price. Consumption above the nominated blocks is purchased at the RTP price. Consumption below the nominated blocks is credited at 1) the RTP 2) the TOU price, or 3) some other 'swing' or settlement price.

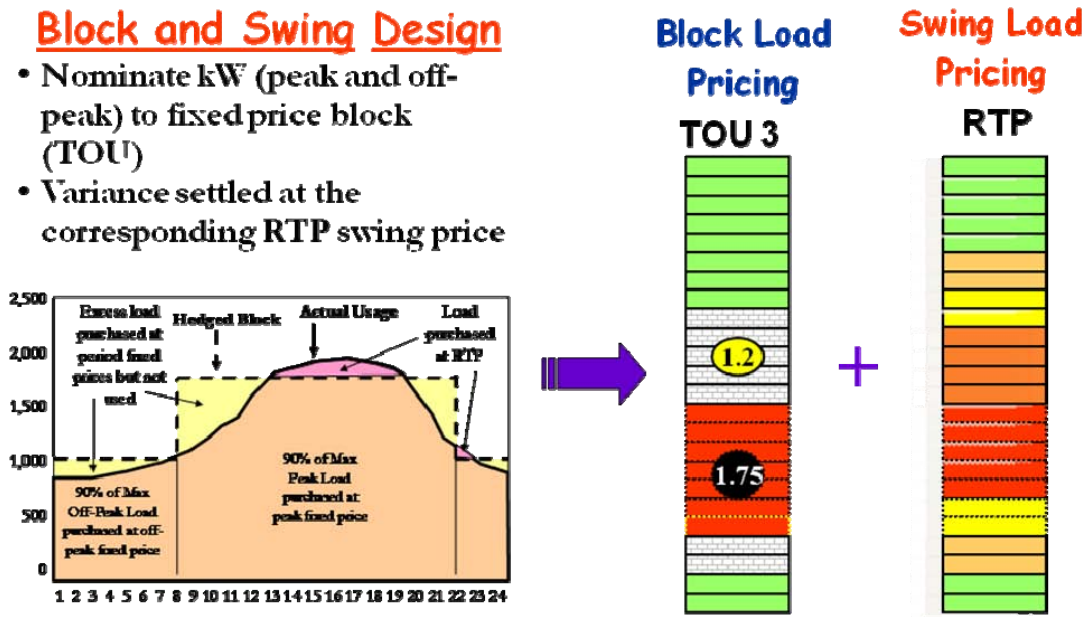


Figure 5-4
Block and Swing Design

6
PEV USE CASE DEVELOPMENT

Business Rules and Assumptions

- PEV Customer has an account with utility and electrical service at a premise served by the utility.
- PEV and utility have communications capabilities, enabled by utility provided Energy Services Communication Interface (ESCI).
- The customer awareness of the utility and vehicle programs is prompted by both the utility providers and the vehicle manufacturers.
  - The utility offers PEV programs and services for its customers and will provide the necessary support processes for enrollment, communications, and billing
  - The Vehicle manufacturers would provide information to the customer about fuel and/or emission gains of the vehicles offered and promote the utility and convenience of connecting to the grid
- Utility shall maintain information on all Customers and PEVs enrolled in the PEV programs, including demand side management programs, associated PHEV IDs, customer IDs, and premise IDs
- In the absence or failure of PEV-utility communications, or if PEV ID validation fails, PEV charging will always proceed; however, without the incentive rates and with all energy charges accruing to the premise customer according to the premise customer's default rate/service plan.
- The actual PEV charging processes, including scenarios for intra- and inter- utility roaming, are covered in use case P2.
- End Use Measurement Device (EUMD) is always available for PEV charging. If not available, charging will proceed without incentive rates and with all energy charges accruing to the premise customer. This may or may not prevent certain charging status indicators / metrics being available to customer for presentation/display purposes.
- EUMD function can be inclusively located anywhere in a zone from the PEV and the branch circuit panel connection.
- To allow for possibility of the EUMD being a part of/within the PEV, PEV is a sub-meter to the primary utility billing meter at any premise (as opposed to being a separate service account with dual meter socket adapter)
- The PEV & Utility will communicate to implement one or more the following Utility programs (details of which are covered in PR)

- Time of Use (TOU) pricing demand side management programs are when the customer has agreed to limit charges to the utility schedule for load balancing. (e.g., off-peak, mid-peak, on-peak, etc.).
- Discrete Event demand side management program (Direct Load Control)
- Periodic/Hourly Pricing Price Response program (RTP)
- Active Load Management program
- Critical Peak Pricing (CPP)

Actors

Actor Name	Actor Type (person, device, system etc.)	Actor Description
Customer	Person	Customer is the operator of a PEV and an electric customer of the home utility. Customer enrolls in an electric utility PEV program and has selected a PEV rate tariff. Customer is responsible for connecting PEV to an Energy Portal for charging.
PEV	System	Plug-in Electric Vehicle (PEV). Plugs into an Energy Portal (see actor definition below) at a premise to charge vehicle. Capable of two-way communications with the utility through the Energy Services Communications Interface (ESCI).
Energy Portal (EP)/Smart Energy Portal (SEP)	Device	Energy Portal is any charging point for a PEV. At a minimum, the Energy Portal is a 120V, 15A outlet but can also be a 240V Electric Vehicle Supply Equipment (EVSE) outlet connected to the premise circuit.
Utility	Organization	Utility typically refers to a collection of systems, business functions, and organizations' which make up the electric utility that include the Customer Information System (CIS), the Advanced Metering Infrastructure (AMI), Rates and Revenue Services, etc.
Energy Services Communication Interface (ESCI)	System	Energy Services Communication Interface (ESCI) The ESCI is the communication device between the vehicle and the utility ESCI The Energy Services Communication Interface (ESCI) shall exist at the customer premise and be capable of securely communicating between the Utility and PHEV to facilitate exchange of demand side management information PEV shall be capable of communicating to the Utility through an ESCI

Actor Name	Actor Type (person, device, system etc.)	Actor Description
		ESCI shall report all PEV charging session information and energy usage to Utility ESCI communicates with and exchanges information between utility, PEV, and End Use Measurement Device (EUMD). ESCI shall provide PEV charging session information to the utility – PEV ID, interval kWhr consumption. Passes energy information, including price signals, schedules, event messages, configuration, and security data from the utility to the PEV. This interface may or may not be facilitated by an Advanced Metering Infrastructure (AMI) that includes a Home Area Network (HAN). ESCI shall employ appropriate security policies when communicating demand side management program-related messages
End Use Measurement Device (EUMD)	Device	End Use Measurement Device (EUMD) is the device that measures and communicates energy usage information payload to Energy Services Communication Interface (ESCI). PEV EUMD shall provide PEV charging session info – PEV ID, Premise ID, interval kWhr consumption. PEV EUMD Receives configuration information (e.g., interval for metering kWhr consumption) from utility. EUMD function can be located anywhere in a zone from the PEV and the branch circuit panel connection End Use Measurement Device shall employ appropriate security policies when communicating demand side management program-related messages End Use Measurement Device (EUMD) is always available for PEV charging. If not available, charging will proceed without incentive rates and with all energy charges accruing to the premise customer. This may or may not prevent certain charging status indicators / metrics being available to customer for presentation/display purposes

Actor Name	Actor Type (person, device, system etc.)	Actor Description
Electric Vehicle Supply Equipment	Device	PEV connects to the grid using an Electric Vehicle Supply Equipment (EVSE). Electric Vehicle Supply Equipment (EVSE) is the physical electrical cord and connectors that are specified by applicable SAE standards (e.g., SAE 2293, SAE 1772, SAE J2836, etc.) that provide transfer of electrical energy from energy portal to PEV. This can be 120V or 240V AC depending upon connection. Two type of connection include 1) EVSE cordset and 2) Premise Mounted version. It is expected to have the cordset stay with the vehicle and used in both home and public applications. The cordset would be used for convenience charging that is expected to connect to either a 15A or 20A 120V outlet. Vehicles that include a 1.5 kW or 2 kW on-board charger could use this cordset connected to the respective 15A or 20A outlets (Energy Portals - EP) but also connect to the grid using the premise mounted EVSE. The premise mounted EVSE is expected to be higher power levels using a 240V supply. The premise EVSE would be used for higher power levels than a Cordset EVSE and is expected to be permanently connected to a 240V premise source that is capable of delivering up to 80A. Vehicles with larger on-board chargers may primarily connect using the premise mounted EVSE but also use the cordset to obtain lower power levels from the Energy Portals EVSE may or may not have communication capability. EVSE may or may not have EUMD and/or ESCI communications capability. Details of the EVSE and it's Pilot circuit is included in SAE J1772. The pilot circuit is used to wake up the vehicle, then start it's PWM generator to establish the initial signals from the vehicle and the EVSE. The following sequence describes these basic steps in this process: 1. When the EVSE has power from the grid, it sends a 12V signal on the pilot circuit.

Actor Name	Actor Type (person, device, system etc.)	Actor Description
		2. When the EVSE is then connected to the vehicle, this 12V signal is reduced to 9V thru a vehicle resistor. 3. The pilot signal wakes up the vehicle for it to latch on vehicle power. 4. This reduction to 9V tells the EVSE a vehicle is connected. It is also used by the EVSE that is also detecting the output of this circuit to start its PWM generator. 5. The PWM generator magnitude is then transitioning from +9V to -12V magnitude and the rate matches the chart for Available Line Current (ALC) identified in J1772. 6. The vehicle reads this PWM signal and if the on-board charger can draw more current, it will scale back to this ALC to overload the circuit on the premise. (i.e. a 15A EP provides 12A and the PWM is 20%, 240V power levels are higher PWM rates). 7. If additional communication is expected between the vehicle and the grid, the PWM changes from the ALC value, to a 5% PWM rate. This is an expected state for a premise mounted EVSE but not for a cordset version. The cordset would either provide a 20% PWM for a 15A outlet or a 26.6% PWM for a 20A 120V outlet. 8. When the vehicle is ready to accept energy, another resistor is switched into the pilot circuit that drops the +9V to either 6V or 3V. 6V means the EVSE does not have to turn on ventilation at the premise and 3V means it does. This voltage drop signals the EVSE to close it's switches and allow power to flow to the vehicle. 9. When the vehicle charge is complete, it opens the "vehicle ready switch" and the EVSE opens it's power switches. The vehicle powers down and the EVSE returns to the state in item 1 above.
Roaming Utility	Organization	Electric Service Provider that is supplying energy to PEV when PEV is outside of the Customer’s Utility service territory

Actor Name	Actor Type (person, device, system etc.)	Actor Description
Clearinghouse	Organization	Organization that provides global PEV account services. Maintains information necessary to facilitate account validation and billing transaction when Customer is charging PEV at a location not served by the Utility that the Customer is enrolled with.
Customer Energy Management System	System	Customer Energy Management System can provide communication interface to PEV for communication of PEV status information (e.g. charging state, state-of-charge, charging rate, time to complete charge) on Customer viewable displays.
Customer Account	System	Customer Account is assigned to Customer to collect charges for billing of energy usage
Guest	Person	Guest is a friend or family member who has permission to use a Customer Premise for charging a PEV. May be liable for PEV charging costs depending upon Customer preferences set up within PEV program.
ESCO	Organization	competitive supplier of commodity service

USE CASE "E" – Utility Provides Services to Plug-in Electric Vehicle (PEV) Customer: Enrollment Process

Use Case Summary

Customers are interested in fueling vehicles with electricity. Electric Vehicles (EV) and Plug-in Electric Vehicles (PEV) are emerging transportation options for consumers. Electric utilities desire to support these emerging loads with electricity at "off peak" times when energy costs are low and generation and power delivery assets are underutilized. PEV manufacturers are interested in working with utilities to develop customer rates/programs which could provide consumers with an increased incentive to purchase a PEV. To enable utility customer rates/programs specifically to customers with PEVs, the utility must offer special services for these customers. These services include the ability to enroll, register, and initially setup communications between a PEV and the utility (one-time setup), the ability to repeatedly re-establish communications for each PEV charging session (repeat communications/re-binding), the ability to provide PEV charging (and other) status information to customer information channels (e.g. web, display devices), and the ability to correctly bill PEV customers according to their selected rates/programs.

Use Case Detailed Narrative

Customers are interested in fueling vehicles with electricity. Electric Vehicles (EV) and Plug-in Electric Vehicles (PEV) are emerging transportation options for consumers. Electric utilities desire to support these emerging loads with electricity at "off peak" times when energy costs are low and generation and power delivery assets are underutilized. PEV manufacturers are interested in working with utilities to develop customer rates/programs which could provide consumers with an increased incentive to purchase a PEV. To enable utility customer rates/programs specifically to customers with PEVs, the utility must offer special services for these customers. These services include the ability to enroll, register, and initially setup communications between a PEV and the utility (one-time setup), the ability to repeatedly re-establish communications for each PEV charging session (repeat communications/re-binding), the ability to provide PEV charging (and other) status information to customer information channels (e.g. web, display devices), and the ability to correctly bill PEV customers according to their selected rates/programs.

Within a utility service territory, the consumer can plug in a PEV to receive a charge of electrical energy at their premise or plug in at another premise location. The vehicle can connect to the grid using either of the following:

- Electric Vehicle Supply Equipment (EVSE) Cordset – The cordset (described in J1772) would be used for convenience charging that is expected to connect to either a 15A or 20A 120V outlet
- Electric Vehicle Supply Equipment (EVSE) at the premise – It is expected that a premise mounted EVSE would be connected to a 240V service
- DC Premise Electric Vehicle Supply Equipment (EVSE)

The Utility may offer the Customer a PEV tariff that provides a low rate for off-peak charging and a higher rate for on-peak charging. The utility must provide services to support energy supplied to customer PEV. These services include enrollment into a PEV program, PEV communications session binding, PEV energy billing, and PEV information services. The utility will implement an enrollment system for Customers with a PEV including registration and commissioning. The utility's Energy Services Communication Interface (ESCI) shall allow for the establishment of a communications session (communications binding), at a premise location each time a PEV plugs in for charging. Energy supplied to the PEV is reported to the utility for billing and presentation to the Customer. Information related to utility PEV programs, energy usage, and PEV charging status/information will be made available to the Customer for viewing via a website or other customer provided display equipment. This use case covers the following scenarios:

- Customer enrolls in PEV program and completes initial setup for PEV – Utilities communications
- PEV and Utility establish/re-establish communications session at the time of charging
- Utility provides billing services for PEV charging to Customer
- Utility provides Customer access to PEV charging and status information

Primary Scenario: Customer Enrolls in PEV Program (Basic Enrollment) and Completes Initial Setup for PEV – Utilities Communications

This scenario describes the most common sequence (basic process) of the utility enrolling a PEV customer into a utility program/ service specifically for customers with PEVs. As described in the main Narrative section, the customer is enrolling in a PEV program /service that may provide for the opportunity to fuel a vehicle at a lower cost during off-peak periods based on one of the utility programs enumaerated in the main Narrative section. This scenario involves both enrollment of the PEV and steps needed to establish an initial communications session with the utility.

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The Customer acquires a PEV and contacts the Utility to enroll in a PEV program	*Customer*	*Customer has a PEV and wishes to enroll in PEV program; Utility offers PEV Programs to its customers. Customer connects the vehicle to premise*	*The Utility has successfully enrolled a Customer PEV in a PEV Program and PEV has established initial communications session with the utility.*

Steps for This Scenario

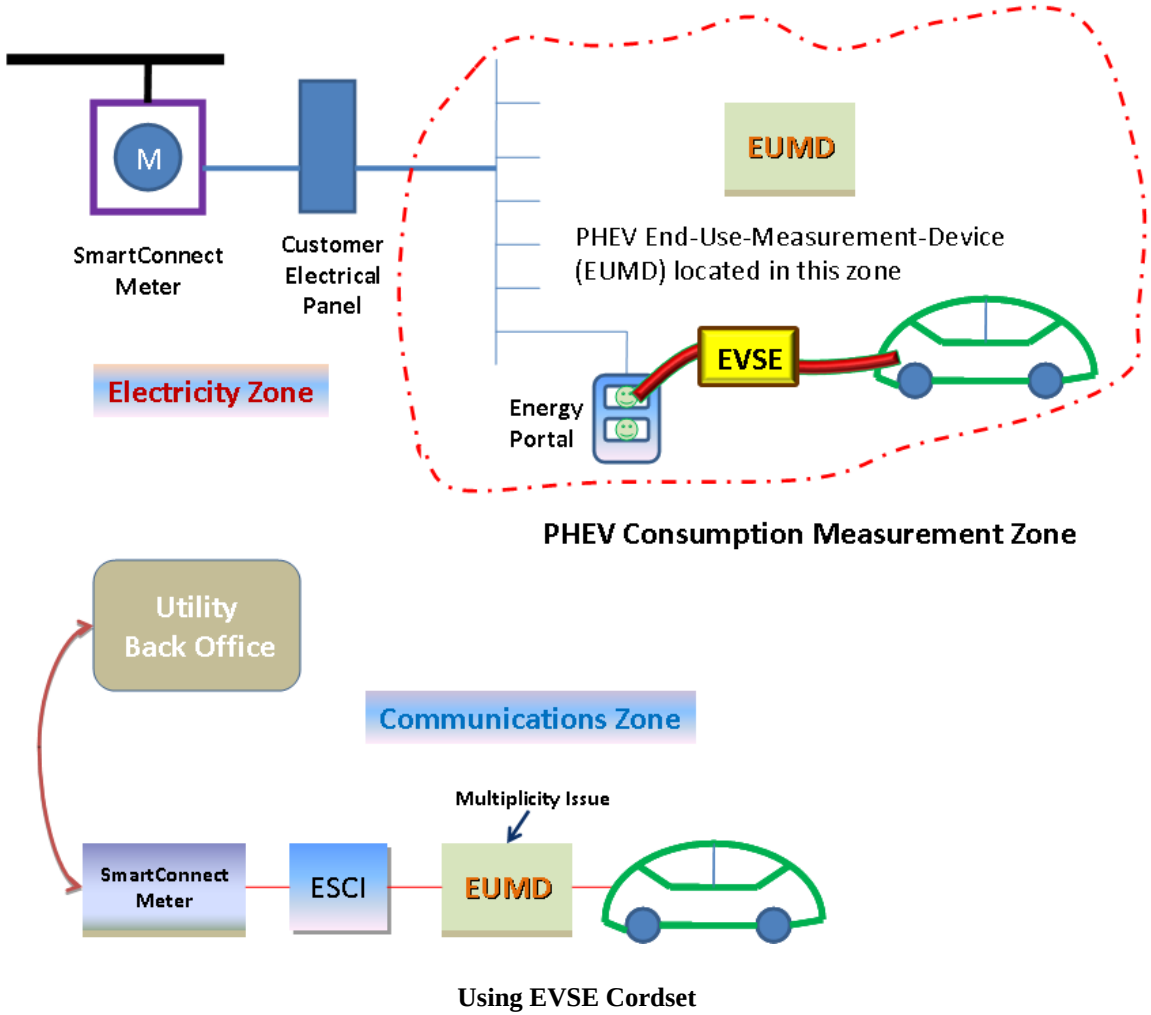
Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..*
1	Customer	Customer initiates request to enroll PEV in a PEV Program by contacting Utility and provides Customer and PEV information (i.e. Customer Account information, PEV ID, etc.).	Customer uses phone, Internet, or other communications channel. Preference for PEV is PEV VIN #
2	Utility	Utility authenticates Customer, Customer account, and Premise information, and collects PEV information including PEV ID.	
3	Utility	Utility presents Customer with PEV Program information and PEV Program selections.	
4	Customer	Customer selects PEV Program and Service Plan, sets PEV program parameters (i.e. guest charging, allow roaming, etc.). The Customer and PEV are now enrolled in a utility PEV program.	
5	Customer	Customer connects at their premise location.	The connection could be using either EVSE corset or Premise EVSE. In this scenario we will consider that PEV is connected through EVSE cordset
6	PEV/ Energy Services Communications Interface (ESCI)	PEV and Energy Services Communications Interface (ESCI) initiate a secure communications session.	Implementation could have PEV or ESCI as initiator of session.

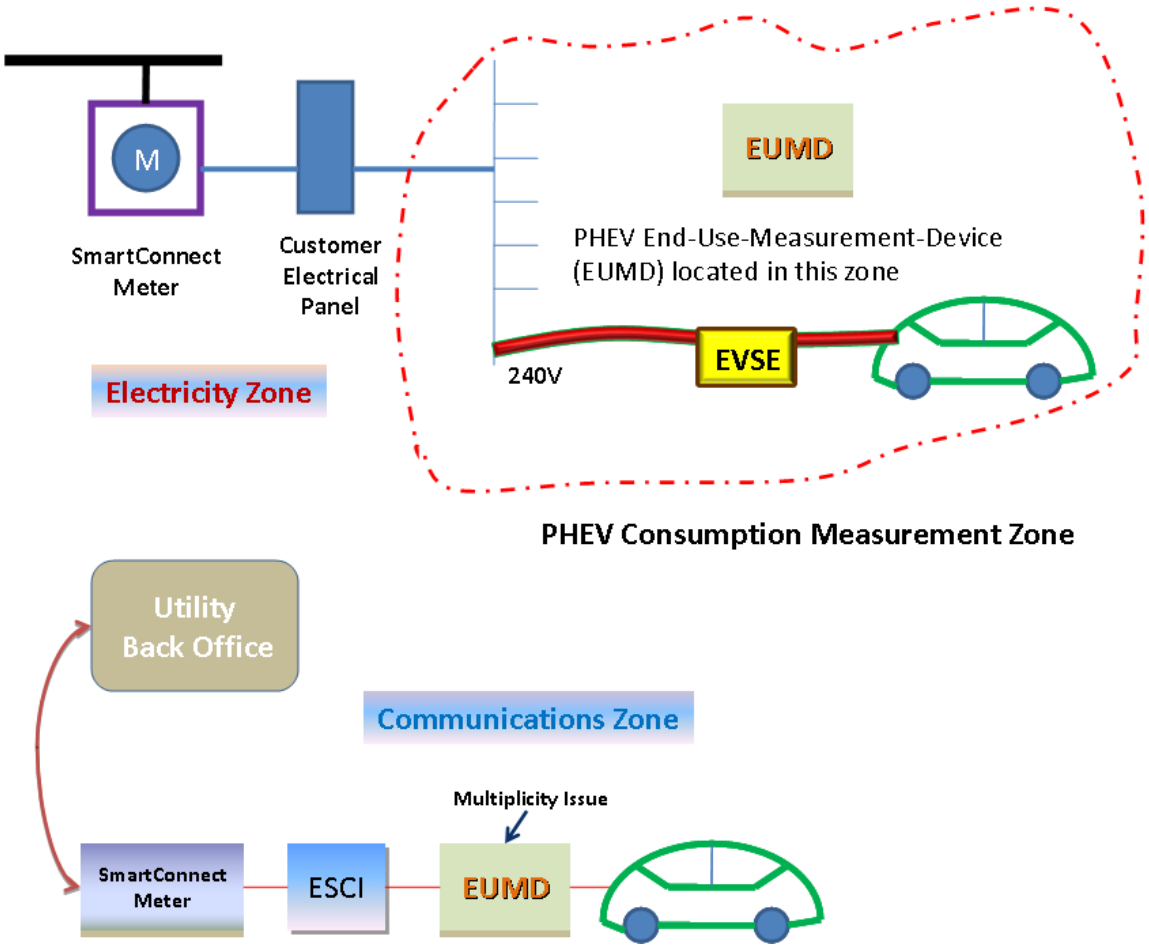
Step #	Actor	Description of the Step	Additional Notes
7	PEV	PEV ID is transmitted to ESCI.	Unique PEV ID will ultimately support portability of charging, among other purposes.
8	ESCI	ESCI maintains communication session and security between PEV and Utility. ESCI transmits request for validating PEV ID to Utility, includes Premise ID.	
9	Utility	Utility identifies and authenticates PEV ID and Premise ID.	PEV binds with utility
10	Utility	Utility transmits confirmation message via ESCI to PEV indicating successful binding with premise ESCI. Confirmation message includes authentication parameters for PEV.	Authentication parameters would include utility rate program information.
11	PEV	PEV receives confirmation message and sets authentication parameters.	
12	PEV	PEV transmits via ESCI message to Utility acknowledgement of receipt of valid confirmation message and setting of authentication parameters.	
13	Utility	Utility transmits message via ESCI to discover EUMD at Customer Premise; message includes authentication parameters for EUMD.	Authentication parameters would include utility rate program information (e.g. interval size, etc.).
14	EUMD	EUMD receives discovery message and sets authentication parameters.	
15	EUMD	EUMD transmits via ESCI message to Utility acknowledgement of receipt of valid discovery message and setting of authentication parameters.	

Step #	Actor	Description of the Step	Additional Notes
16	ESCI	ESCI transmits confirmation message to PEV indicating successful communication session binding of PEV to Utility, meaning that charging can proceed according to enrolled PEV program.	Authentication between Utility and PEV is now complete and charging can proceed according to the enrolled PEV program criteria
17	PEV	PEV prepares for charging based on Customer-selected preferences and enrolled PEV program. Charging may be delayed based upon Customer preferences or grid reliability criteria (e.g., off-peak economy charging, demand response event underway, short, randomized charging delay to promote grid stability, etc.)	

Diagram

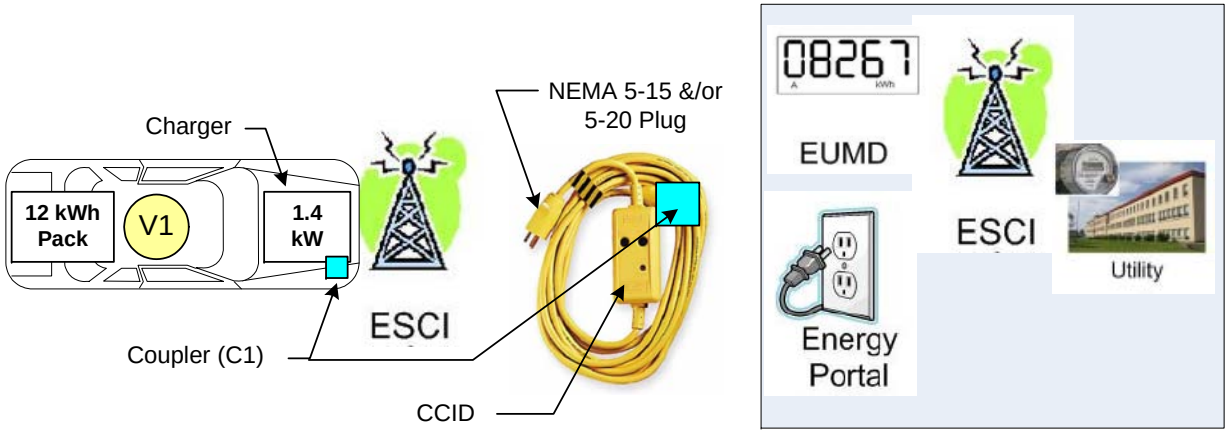
System Diagram



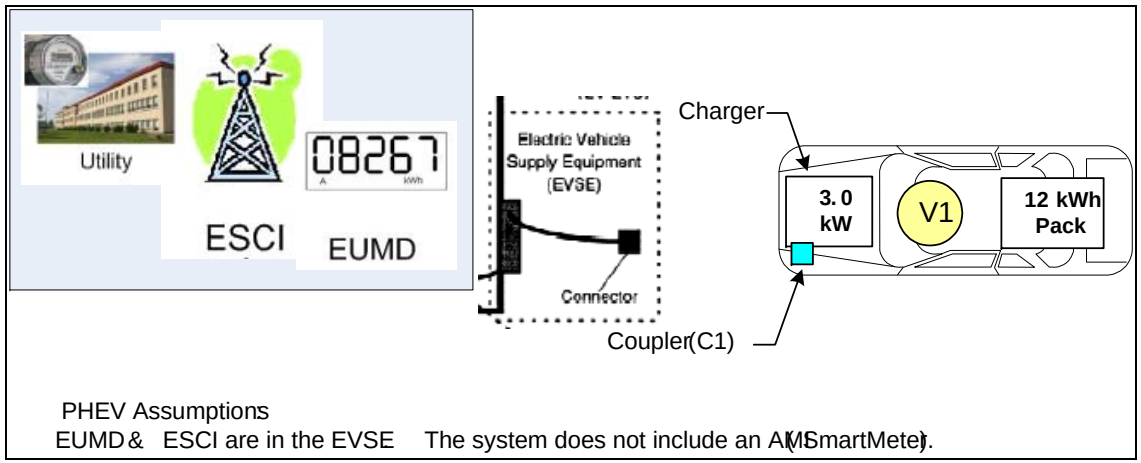


Using Premise Mounted EVSE

Equipment Diagram

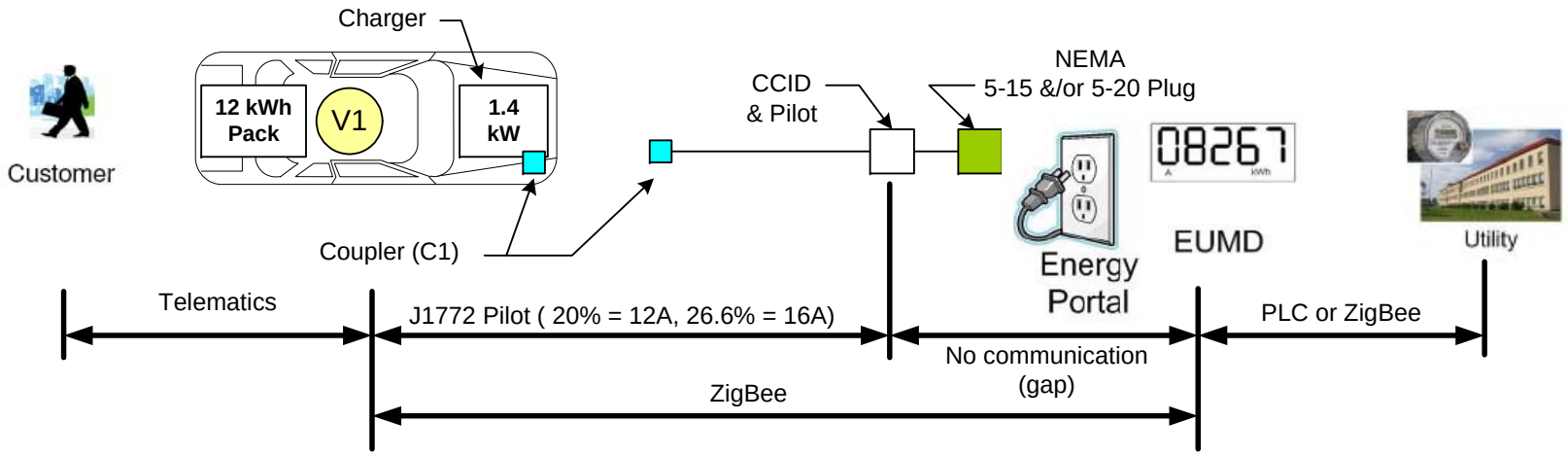


Using EVSE Cordset

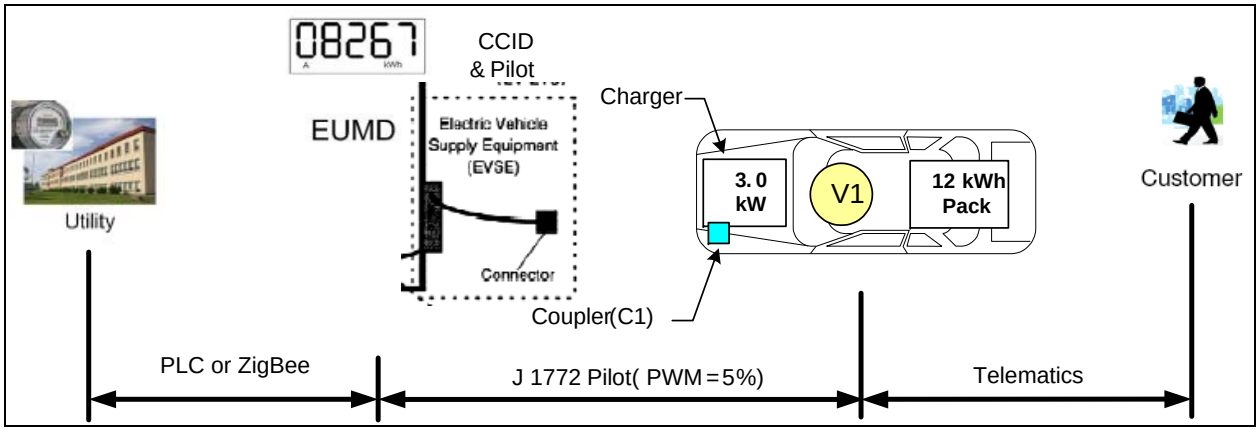


Using Premise Mounted EVSE

Communication Path Diagram

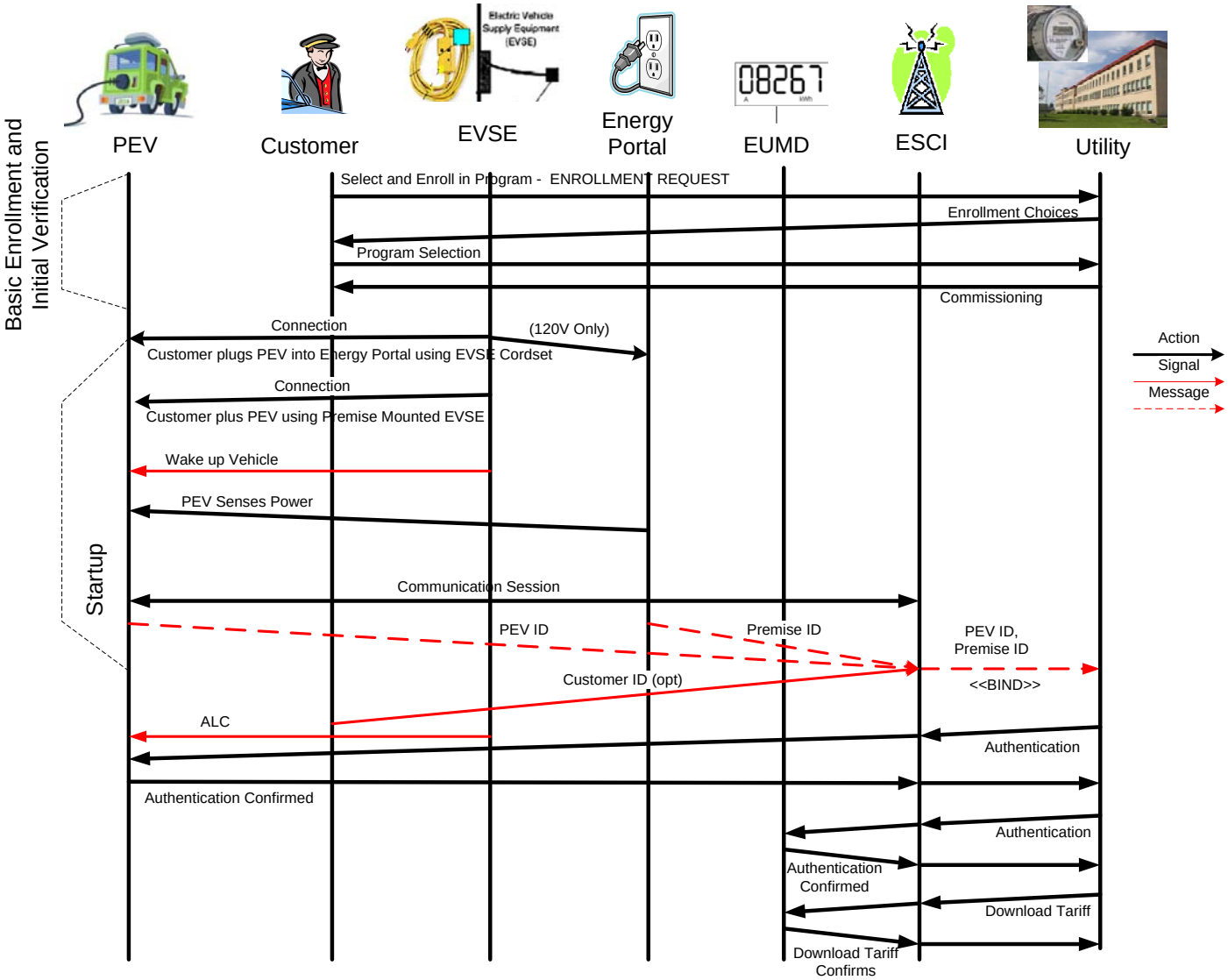


Using EVSE Cordset



Using Premise Mounted EVSE

Sequence Diagram



USE CASE "U1" - Enrollment Process to Time of Use (TOU) Program

Primary Scenario (U1-A): Customer Enrolls in TOU Program. The Vertically Integrated Utility Provides Bundled Residential Premise Services Exclusively and That TOU Is Available on a Self-selected Basis

This scenario describes the steps of the utility enrolling a PEV customer into Time-of-Use (TOU) pricing demand side management program (e.g., off-peak, mid-peak, on-peak, etc.). Assumes that a single, vertically integrated utility provides bundled residential premise service exclusively, and that TOU is available on a self-selected basis (voluntary that is TOU is not mandatory, it is an option). Default rate is an old traditional/conventional flat rate.

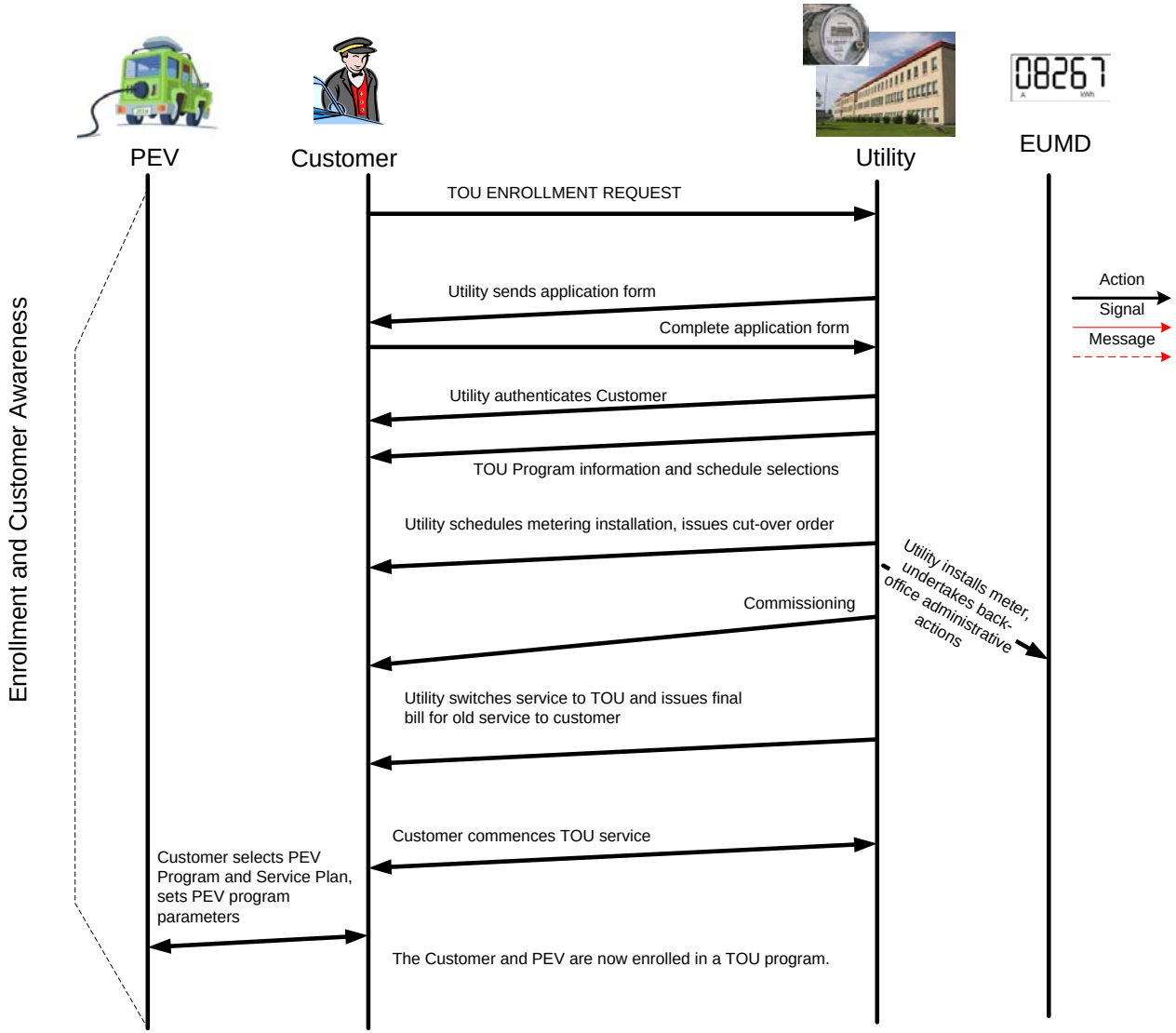
Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The Customer acquires a PEV and contacts the Utility to enroll in a TOU program	Customer	Customer has a PEV and wishes to enroll in TOU program; Utility offers PEV Programs to its customers. Assumes that a single, vertically integrated utility provides bundled residential premise service exclusively, and that TOU is available on a self-selected basis	The Utility has successfully enrolled a Customer PEV in a TOU Program and PEV has established initial communications session with the utility.

Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..*
1	Customer	Customer initiates request to enroll PEV in a TOU Program by contacting Utility and provides Customer and PEV information (i.e. Customer Account information, PEV ID, etc.).	Customer uses phone, Internet, or other communications channel. Preference for PEV is PEV VIN #
2	Utility	Utility sends application form via web or mail	
3	Customer	Customer completes enrollment form, returns to utility via web or mail	
4	Utility	Utility make a decision if the customer is eligible or not. Not eligible he notifies the customer	
5	Utility	For eligible customers, utility notifies customer of in-service date	
6	Utility	Utility authenticates Customer, Customer account, and Premise information, and collects PEV information including PEV ID.	
7	Utility	Utility presents Customer with TOU Program information and schedule selections	
8	Utility	Utility schedules metering installation, issues cut-over order (internal process order, billing, parameters of billing, financial network), notifies customer of meter installation (in-service) date	

Step #	Actor	Description of the Step	Additional Notes
9	Utility	Utility installs meter, undertakes back-office administrative actions	TOU Recording Meter are preprogrammed based on TOU. It can have either two or three registers (peak, off-peak, shoulder peak). If the customer has AMI meter, utility informs the meter on the new data (two-way communication. It will change the instruction set. The cut in order will take the back office to cumulative in on-peak or off-peak
10	Utility	Utility switches service to TOU and issues final bill for old service to customer	
11	Customer	Customer commences TOU service Customer selects PEV Program and Service Plan, sets PEV program parameters (i.e. guest charging, allow roaming, etc.). The Customer and PEV are now enrolled in a utility TOU program.	Same schedule applies till a rate case or rate change takes place, (TOU structure typically does not change). Nominal prices are subject to change based on utility supply cost (eg. fuel price).

Sequence Diagram



Primary Scenario (U1-B): Customer Enrolls in TOU Program – Customer Taking Commodity From ESCO

This scenario assumes customer choice to enrolling a PEV customer into Time-of-Use (TOU) pricing demand side management program (e.g., off-peak, mid-peak, on-peak, etc.). Assumes that customer can have unbundled residential premise service. He gets the wired service from the utility and commodity service from ESCO. If customer takes bundle service, then process is the same as previous case. Otherwise, the illustrated processes are involved. Utility sets TOU meter

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The Customer acquires a PEV and contacts the Utility to enroll in a TOU program	Customer	Customer has a PEV and wishes to enroll in TOU program; Gets wires services from the utility and commodity service from ESCO.	ESCO has successfully enrolled a Customer PEV in a TOU Program and PEV has established initial communications session with the utility.

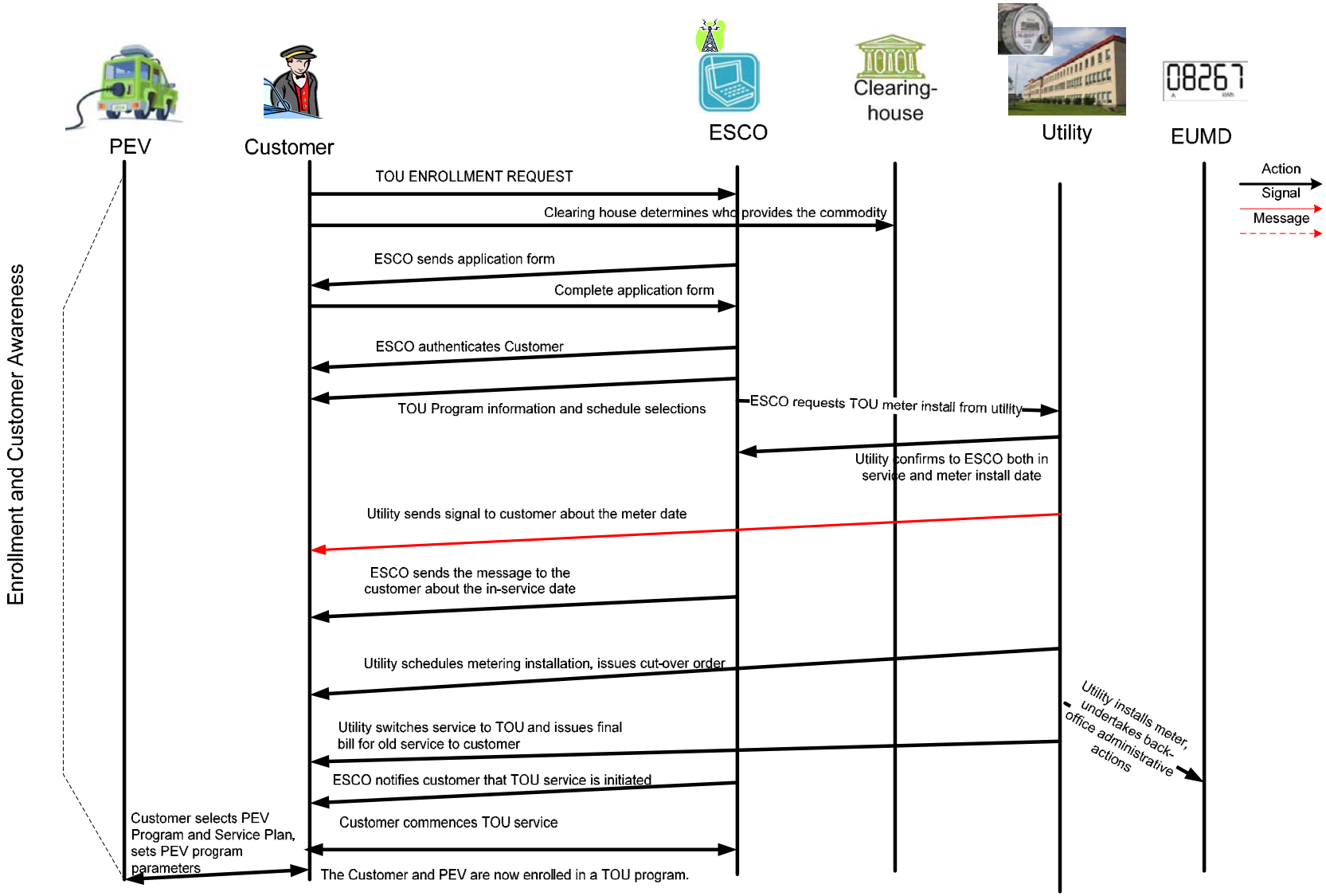
Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..*
1	Customer	Customer initiates request to enroll PEV in a TOU Program by contacting ESCO and provides Customer and PEV information (i.e. Customer Account information, PEV ID, etc.).	Customer uses phone, Internet, or other communications channel. Preference for PEV is PEV VIN #
2	Clearing House	Clearing house determines who provides the commodity	If the commodity is bundled then use the previous scenario, if the service is unbundled then utility is informed but the utility does not have to take any action
3	ESCO	ESCO sends application form via web or mail	
4	Customer	Customer completes enrollment form, returns to ESCO via web or mail	
5	ESCO	ESCO make a decision if the customer is eligible or not. Not eligible he notifies the customer	
6	ESCO	For eligible customers, ESCO notifies customer of in-service date	
7	ESCO	ESCO authenticates Customer, Customer account, and Premise information, and collects PEV information including PEV ID.	

Step #	Actor	Description of the Step	Additional Notes
8	ESCO	ESCO presents Customer with TOU Program information and schedule selections	
9	ESCO	ESCO requests TOU meter install from utility	
10	Utility	Utility confirms to ESCO both in service and meter install date	
11	Utility	Utility sends signal to customer about the meter date	
12	ESCO	ESCO sends the message to the customer about the in-service date	
13	Utility	Utility schedules metering installation, issues cut-over order (internal process order, billing, parameters of billing, financial network)	
14	Utility	Utility installs meter, undertakes back-office administrative actions	TOU Recording Meter are preprogrammed based on TOU. It can have either two or three registers (peak, off-peak, shoulder peak). If the customer has AMI meter, utility informs the meter on the new data (two-way communication. It will change the instruction set. The cut in order will take the back office to cumulative in on-peak or off-peak

Step #	Actor	Description of the Step	Additional Notes
15	Utility	Utility switches service to TOU and issues final bill for old service to ESCO	
16	ESCO	ESCO notifies customer that TOU service is initiated	
17	Customer	Customer commences TOU service Customer selects PEV Program and Service Plan, sets PEV program parameters (i.e. guest charging, allow roaming, etc.). The Customer and PEV are now enrolled in TOU program.	Same schedule applies till a rate case or rate change takes place, (TOU structure typically does not change). Nominal prices are subject to change based on utility supply cost (eg. fuel price).

Sequence Diagram



USE CASE "U2" - Enrollment Process to Discrete Event Demand Side Management Program (Direct Load Control)

Primary Scenario: Customer Enrolls in Discrete Event Demand Side Management Program

- Direct device control (DDC) service involves a Call Option on one or more devices on the premises.
- A single price schedule applies to total premise metered service (uniform or TOU if that was selected). A discount is applied to the base service for each device enrolled in DDC. Prices are firm, but service is not.
- The retailer exercises its Call Option by first notifying the participant that a event has been declared for the nest day. The DDC service plan specified when such notice must be delivered to become effective
- The retailer exercises it Call Option by sending a signal that either shuts off electricity to the device (or devices) or restricts its usage during the event.

The enrollment is similar to TOU except that the utility install a control device on specified devices, as depicted on the next slide). Enrollment to an ESCO program is the same as with TOU where the customer takes commodity form an ESCO except the meter change out is replaced with the installation of a control device or devices

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The Customer acquires a PEV and contacts the Utility to enroll in a Direct Load Control program	Customer	Customer has a PEV and wishes to enroll in DDC program; Utility offers PEV Programs to its customers. Assumes that a single, vertically integrated utility provides bundled residential premise service exclusively, and that DDC is available on a self-selected basis	The Utility has successfully enrolled a Customer PEV in a DDC Program and PEV has established initial communications session with the utility.

Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..*
1	Customer	Customer inquires about DDC Program availability by contacting Utility and provides Customer and PEV information (i.e. Customer Account information, PEV ID, etc.).	Customer uses phone, Internet, or other communications channel. Preference for PEV is PEV VIN # (customer has to apply from his default rate or TOU rate to the DCC Rate)
2	Utility	Utility sends application form via web or mail	
3	Customer	Customer completes enrollment form, returns to utility via web or mail	
4	Utility	Utility make a decision if the customer is eligible or not. Not eligible he notifies the customer	
5	Utility	For eligible customers, utility notifies customer of in-service date	
6	Utility	Utility authenticates Customer, Customer account, and Premise information, and collects PEV information including PEV ID.	
7	Utility	Utility presents Customer with DDC Program information	

Step #	Actor	Description of the Step	Additional Notes
8	Utility	Utility schedules control device installation, issues cut-over order (internal process order, billing, parameters of billing, financial network), notifies customer of control device installation (in-service) date	
9	Utility	Utility installs control device	
10	Utility	Utility switches service to DDC and issues final bill for old service to customer	
11	Customer	Customer commences DDC service Customer selects PEV Program and Service Plan, sets PEV program parameters (i.e. guest charging, allow roaming, etc.). The Customer and PEV are now enrolled in a utility DDC program.	Same schedule applies till a rate case or rate change takes place, (TOU structure typically does not change). Nominal prices are subject to change based on utility supply cost (eg. fuel price).

USE CASE “U3” - Enrollment Process to Real Time Pricing (RTP) Program

Primary Scenario: Customer Enrolls in RTP Program

RTP-DA (day-ahead) service provides daily price schedules (one price ($/kWh) per hour,) to participants the day before they are effective.Once delivered, the prices are firm – they are not subject to revision. The hourly prices are applied to the corresponding hour’s metered energy usage (kWh).

The enrollment steps are identical to those to TOU for bundled utility and unbundled EPSO service). Each day, the Retailer (utility or ESCO) prepares and delivers the price schedule for the next day to the participant (by a specified time), and participant acknowledges receipt of the schedule (by a specified time).

USE CASE “U5” - Enrollment Process to Critical Peak Pricing (CPP) Program

Primary Scenario: Customer Enrolls in CPP Program

CPP day-ahead service set prices based on system conditions

- Normal conditions – the base rate schedule (a uniform rate, or TOU if the customer selected that option) applies for all metered usage except when the retailer provider (utility or ESCO) exercises its Call Option rights
- Call Option conditions - the retailer revokes the base rate schedule for a specified period of hours for the next day and imposes the Call Option price schedule by notifying the participant that an event has been declared. The Call Option price schedule (which specifies the hours that comprise the event and the price ($kWh) during that event) is predetermined and fixed for the contract period (for example, a year) so the notification needs only to convey the declaration of an event. The Call Option must be declared by a specified time the day prior to be effective.

The enrollment steps are identical to those to TOU for bundled utility and unbundled EPSO service). The Retailer (utility or ESCO) prepared and delivers the price schedule for the next day to the participant (by a specified time), and participant acknowledges receipt of the schedule (by a specified time).

USE CASE "S1" – Vehicle Use Case: Customer Connects Vehicle to Premise Using Cordset EVSE

Use Case Detailed Narrative

The vehicle connects to the grid using an Electric Vehicle Supply Equipment (EVSE) Cordset, as described in J1772. It is expected to have the cordset stay with the vehicle and used in both home and public applications. The cordset would be used for convenience charging that is expected to connect to either a 15A or 20A 120V outlet. Vehicles that include a 1.5 kW or 2 kW on-board charger uses this cordset connected to the respective 15A or 20A outlets (Energy Portals - EP).

Primary scenario is the customer connects an EVSE cordset to the PHEV and Energy Portal, at home to charge the PHEV. The customer wants to take advantage of one or more of the utility programs.

Alternate scenario is the customer connects an EVSE cordset to the PHEV and Energy Portal, at other locations that include another home or public locations to charge the PHEV. The customer wants to take advantage of one or more of the utility programs.

Primary Scenario

- Customer connects an EVSE cordset to the PHEV and Energy Portal at home
- Customer connects an EVSE cordset to the PHEV and Energy Portal at another home.
- Customer connects an EVSE cordset to the PHEV and Energy Portal at a public location.

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
Customer connects EVSE cordset to Energy Portal and PHEV.	*Customer*	*Customer has enrolled PHEV with home utility*	*The utility has a record of the energy agreement related to the customer premise and the associated PHEV ID. PHEV binds or rebinds with utility.*

Steps for This Scenario

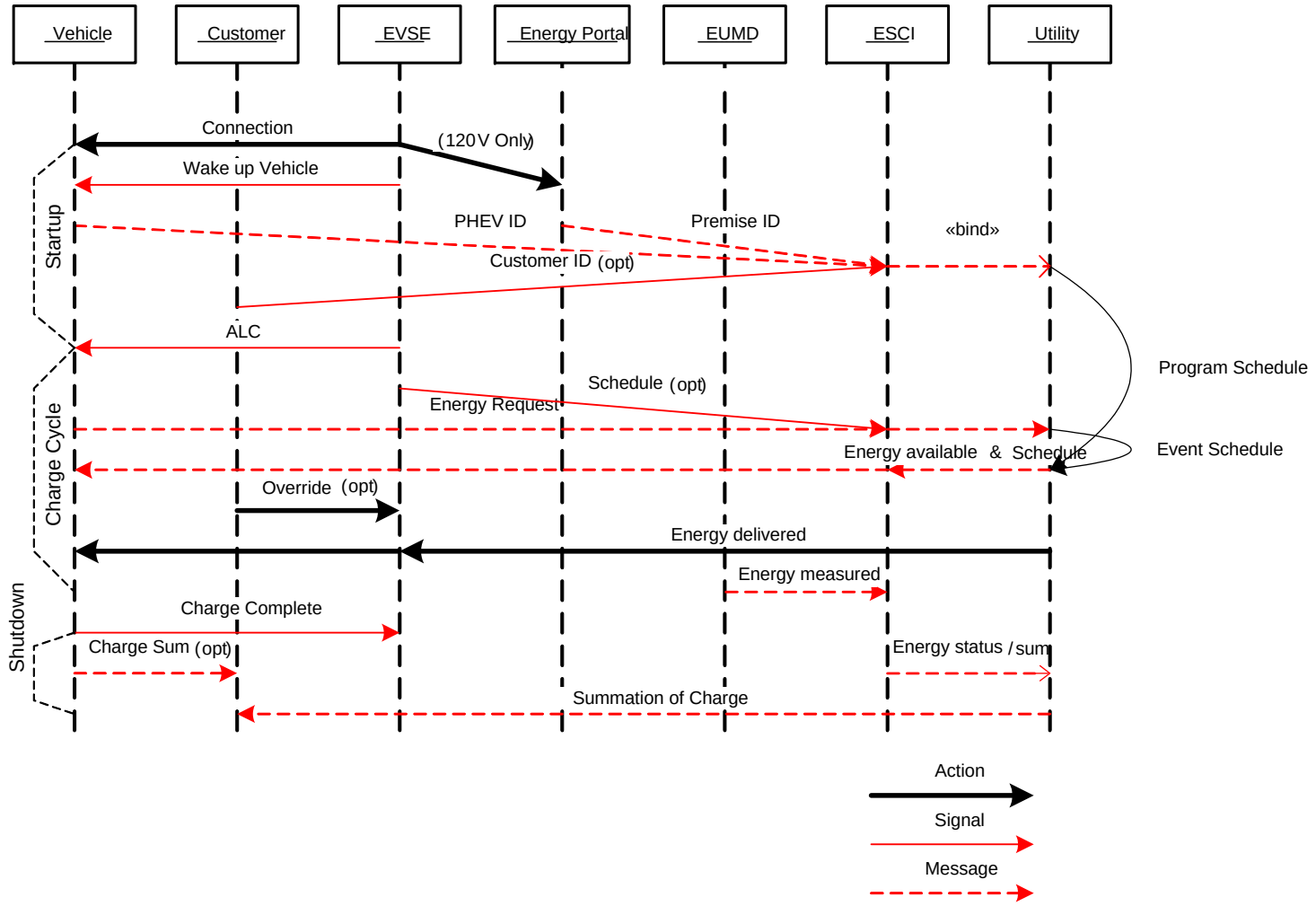
Step #	Actor	Description of the Step	Additional Notes
1	Customer	Customer connects EVSE cordset to Energy Portal at Premise.	When the EVSE has power from the grid, it sends a 12V signal on the pilot circuit to the PHEV.
2	Customer	Customer connects EVSE cordset to PHEV.	When the EVSE is then connected to the PHEV, this 12V signal is reduced to 9V thru a vehicle resistor on the PHEV.
3	PHEV	PHEV wakes up.	The pilot signal wakes up the vehicle for it to latch on vehicle power.
4	EVSE	EVSE monitors pilot voltage drop from 12V to 9V.	This reduction to 9V tells the EVSE a vehicle is connected. It is also used by the EVSE that is also detecting the output of this circuit to start its PWM generator.
5	EVSE	EVSE starts Available Line Current (ALC) PWM generator.	The PWM generator magnitude is then transitioning from +9V to -12V magnitude and the rate matches the chart for Available Line Current (ALC) identified in J1772
6	PHEV	PHEV prepares for charging rate (charger size or ALC, whatever is lowest).	The vehicle reads this PWM signal and if the on-board charger can draw more current, it will scale back to this ALC to overload the circuit on the premise. (i.e. a 15A EP provides 12A and the PWM is 20%, 240V power levels are higher PWM rates).
7	PHEV/ESCI	PHEV and Energy Services Communications Interface (ESCI) initiate a secure communications session.	Implementation could have PHEV or ESCI as initiator of session.
8	PHEV	PHEV sends VIN	Utility authenticates PHEV is connected and implements program criteria.

Step #	Actor	Description of the Step	Additional Notes
8a	PHEV	PHEV sends Billing Request	This would confirm PHEV billing at premise (customer's home). Optional billing requests may be request if connecting to another Utility territory or public premises. These options would have been transmitted to the utility during the enrollment or could have been agreed to at public sites (i.e. curbside, etc).
9	PHEV	PHEV sends Energy Request (amount & rate)	Amount is total (based on RESS SOC). Rate is the lesser of ALC or charger size. Utility compares request with available and confirms or adjusts for message back to PHEV.
9a	PHEV	PHEV sends schedule for energy request	Based on TOU program.
9b	PHEV	PHEV sends request for discrete event info.	Based on Discrete Event demand side management program.
9c	PHEV	PHEV sends customers predetermined pricing info to utility	Based on Periodic/Hourly Pricing Price Response program.
9d	PHEV	PHEV sends …	Based on Active Load Management program.
10	Utility	Utility verifies PHEV ID (premise ID and/or customer ID) to ESCI	PEV binds (or rebinds) with utility
11	Utility	Utility transmits confirmation message via ESCI to End Use Measurement Device (EUMD) indicating successful binding with premise ESCI.	EUMD is required for revenue metering of electricity

Step #	Actor	Description of the Step	Additional Notes
12	Utility	Utility sends Energy Available (amount & rate)	Amount is total (based on RESS SOC). Rate is the lesser of ALC or charger size. Utility compares request with available and confirms or adjusts for message back to PHEV.
12a	Utility	Utility sends schedule for energy available (time spread energy will be delivered)	Based on TOU program. Schedule is Connection Time, Full Charge Time and Balance Charge Time.
12b	Utility	Utility sends discrete event alerts.	Based on Discrete Event demand side management program.
12c	Utility	Utility sends periodic/hourly prices.	Based on Periodic/Hourly Pricing Price Response program.
12d	Utility	Utility sends …	Based on Active Load Management program.
13	PHEV	PHEV prepares for charging.	When the vehicle is ready to accept energy, another resistor is switched into the pilot circuit that drops the +9V to either 6V or 3V. 6V means the EVSE does not have to turn on ventilation at the premise and 3V means it does. This voltage drop signals the EVSE to close it's switches and allow power to flow to the vehicle.
14	EUMD	PHEV Charges	EUMD records charging information and energy supplied to PHEV for each charging session. Charging information is included with additional info collected by ESCI (PHEV ID, Premise ID, Date & Time stamp) for each metering interval.

Step #	Actor	Description of the Step	Additional Notes
15	EUMD	EUMD communicates to Energy Services Communication Interface the energy supplied to PEV for each charging session.	This communication could be on a periodic basis during charging, upon vehicle unplug from energy portal, or a combination of the two.
16	ESCI	ESCI transmits Date, time, duration and energy delivered to Utility and Vehicle.	This is the status of the cycle for the Utility, PHEV and Customer information.
17	Utility	Utility records each PHEV charging session for bill generation and reporting to customer account associated with this premise and PHEV ID.	

Sequence Diagrams



USE CASE "S2" – Vehicle Use Case: Customer Connects Vehicle to Premise EVSE

Use Case Detailed Narrative

The vehicle connects to the grid using a cord that is included in the premise mounted Electric Vehicle Supply Equipment (EVSE), as described in J1772. These are expected to be available in both home and public applications.

The premise EVSE would be used for higher power levels than a Cordset EVSE and is expected to be permanently connected to a 240V premise source that is capable of delivering up to 80A.Vehicles that use this premise EVSE are expected to include on-board chargers.

The premise EVSE could also include more than one cord allowing it to be connected to more than one vehicle at a location. Primary scenario is the customer connects a premise EVSE to the PHEV, at home to charge the PHEV. The customer wants to take advantage of one or more of the utility programs.

Alternate scenario is the customer connects a premise EVSE to the PHEV, at other locations that include another home or public locations to charge the PHEV. The customer wants to take advantage of one or more of the utility programs.

Primary Scenario Description

- Customer connects an EVSE to the PHEV at home.
- Customer connects an EVSE to the PHEV at another home.
- Customer connects an EVSE to the PHEV at a public location.

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
Customer connects premise EVSE cord to PHEV.	*Customer*	*Customer has enrolled PHEV with home utility*	*The utility has a record of the energy agreement related to the customer premise and the associated PHEV ID. PHEV binds or rebinds with utility.*

Steps for This Scenario

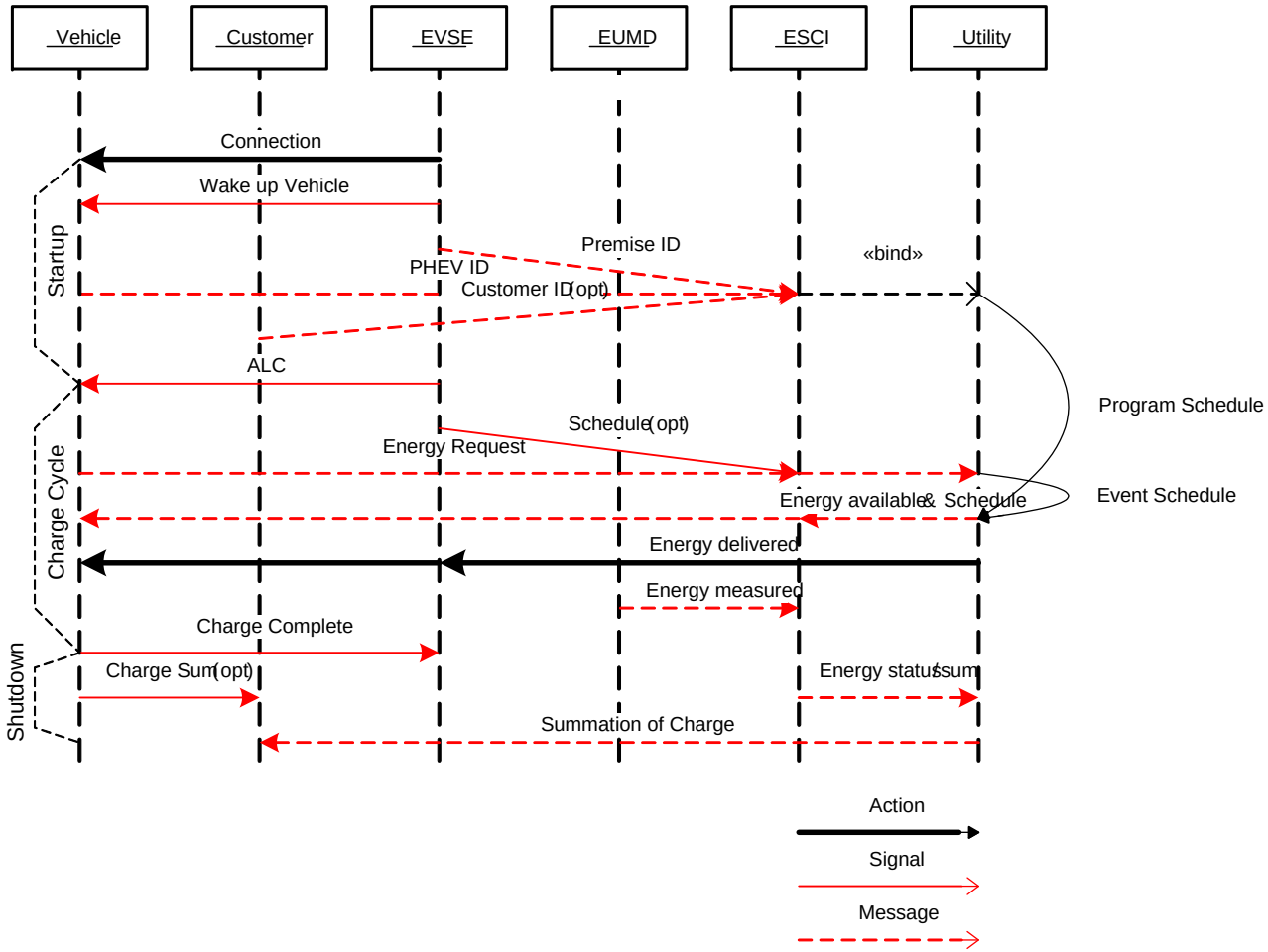
Step #	Actor	Description of the Step	Additional Notes
1	EVSE	When the EVSE has power from the premise, it sends a 12V signal on the pilot circuit.	
2	Customer	Customer connects EVSE cord to PHEV.	When the EVSE cord is connected to the PHEV, this 12V signal is reduced to 9V thru a vehicle resistor on the PHEV.
2a	EVSE	If the EVSE has multiple cords, the customer may have to enter more info at the EVSE.	This may or may not be required at a customer's home.
2b	EVSE	A public EVSE with or without multiple cords may require the customer to enter billing and/or personal info or verify the customer is authorized to connect at this site.	Billing could be for a parking space rather than cost of energy.
3	PHEV	PHEV wakes up.	The pilot signal wakes up the vehicle to a state sufficient to participate in charging.
4	EVSE	EVSE monitors pilot voltage drop from 12V to 9V.	This reduction to 9V tells the EVSE a vehicle is connected. It is also used by the EVSE that is also detecting the output of this circuit to start its PWM generator.
5	EVSE	EVSE starts Available Line Current (ALC) PWM generator.	The PWM generator magnitude is then transitioning from +9V to -12V magnitude and the rate matches the chart for Available Line Current (ALC) identified in J1772

Step #	Actor	Description of the Step	Additional Notes
6	PHEV	PHEV prepares for charging rate (charger size or ALC, whatever is lowest).	The vehicle reads this PWM signal and if the on-board charger can draw more current, it will scale back to this ALC to prevent overloading the circuit on the premise. (e.g. a 40A premise circuit provides 32A and the PWM is 53.3%, whereas a 10 kW charger could draw 41.6A and overload the circuit).
7	PHEV/ESCI	PHEV and Energy Services Communications Interface (ESCI) initiate a secure communications session.	Implementation could have PHEV or ESCI as initiator of session.
8	PHEV	PHEV sends VIN	Utility authenticates PHEV is connected and implements program criteria.
8a	PHEV	PHEV sends Billing Request	This would confirm PHEV billing at premise (customer's home). Optional billing requests may be request if connecting to another Utility territory or public premises. These options would have been transmitted to the utility during the enrollment or could have been agreed to at public sites (i.e. curbside, etc).
9	PHEV	PHEV sends Energy Request (amount & rate)	Amount is total (based on RESS SOC). Rate is the lesser of ALC or charger size. Utility compares request with available and confirms or adjusts for message back to PHEV.
9a	PHEV	PHEV sends schedule for energy request	Based on TOU program. Schedule is Connection Time, Full Charge Time and Balance Charge Time.

Step #	Actor	Description of the Step	Additional Notes
9b	PHEV	PHEV sends request for discrete event info.	Based on Discrete Event demand side management program.
9c	PHEV	PHEV sends customers predetermined pricing info to utility	Based on Periodic/Hourly Pricing Price Response program.
9d	PHEV	PHEV sends …	Based on Active Load Management program.
10	Utility	Utility verifies PHEV ID (premise ID and/or customer ID) to ESCI	PEV binds (or rebinds) with utility
11	Utility	Utility transmits confirmation message via ESCI to End Use Measurement Device (EUMD) indicating successful binding with premise ESCI.	EUMD is required for revenue metering of electricity
12	Utility	Utility sends Energy Available (amount & rate)	
12a	Utility	Utility sends schedule for energy available (time spread energy will be delivered)	Based on TOU program.
12b	Utility	Utility sends discrete event alerts.	Based on Discrete Event demand side management program.
12c	Utility	Utility sends periodic/hourly prices.	Based on Periodic/Hourly Pricing Price Response program.
12d	Utility	Utility sends …	Based on Active Load Management program.

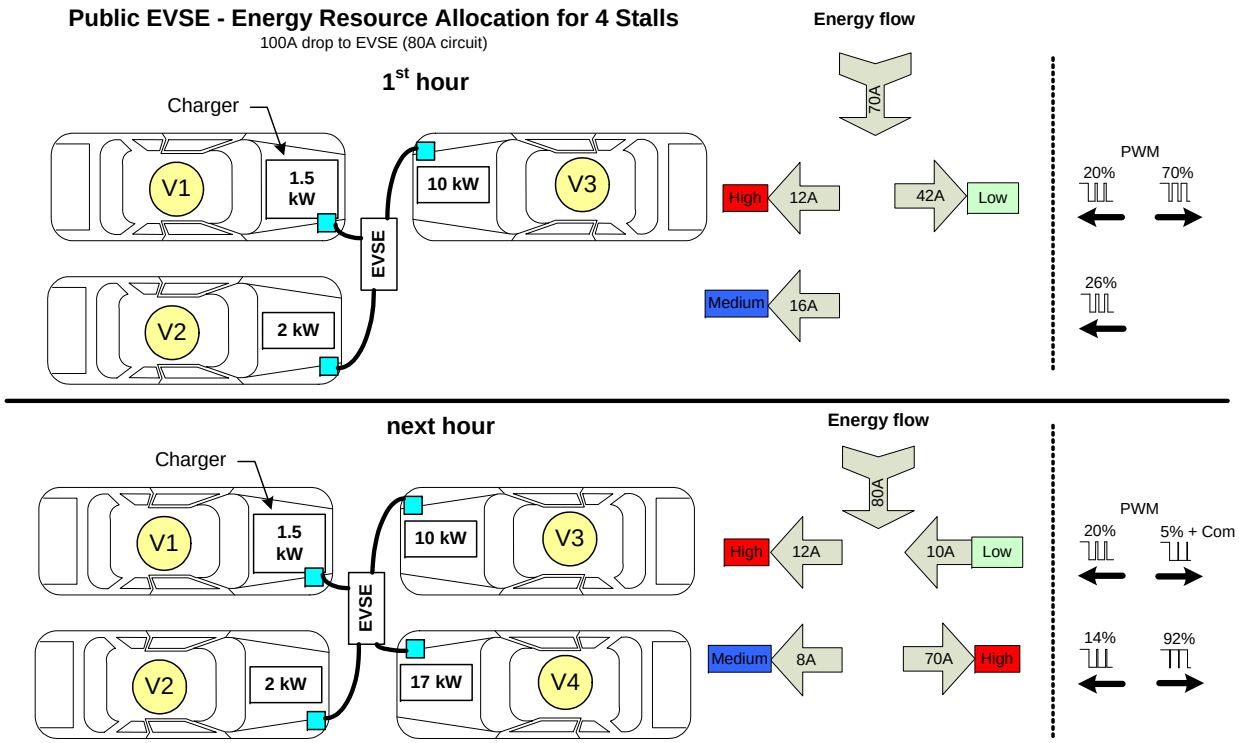
Step #	Actor	Description of the Step	Additional Notes
13	PHEV	PHEV prepares for charging.	When the vehicle is ready to accept energy, another resistor is switched into the pilot circuit that drops the +9V to either 6V or 3V. 6V means the EVSE does not have to turn on ventilation at the premise and 3V means it does. This voltage drop signals the EVSE to close it's switches and allow power to flow to the vehicle.
14	EUMD	PHEV Charges	EUMD records charging information and energy supplied to PHEV for each charging session. Charging information is included with additional info collected by ESCI (PHEV ID, Premise ID, Date & Time stamp) for each metering interval.
15	EUMD	EUMD communicates to Energy Services Communication Interface the energy supplied to PEV for each charging session.	This communication could be on a periodic basis during charging, upon vehicle unplug from energy portal, or a combination of the two.
16	ESCI	ESCI transmits Date, time, duration and energy delivered to Utility and Vehicle.	This is the status of the cycle for the Utility, PHEV and Customer information.
17	Utility	Utility records each PHEV charging session for bill generation and reporting to customer account associated with this premise and PHEV ID.	

Sequence Diagrams



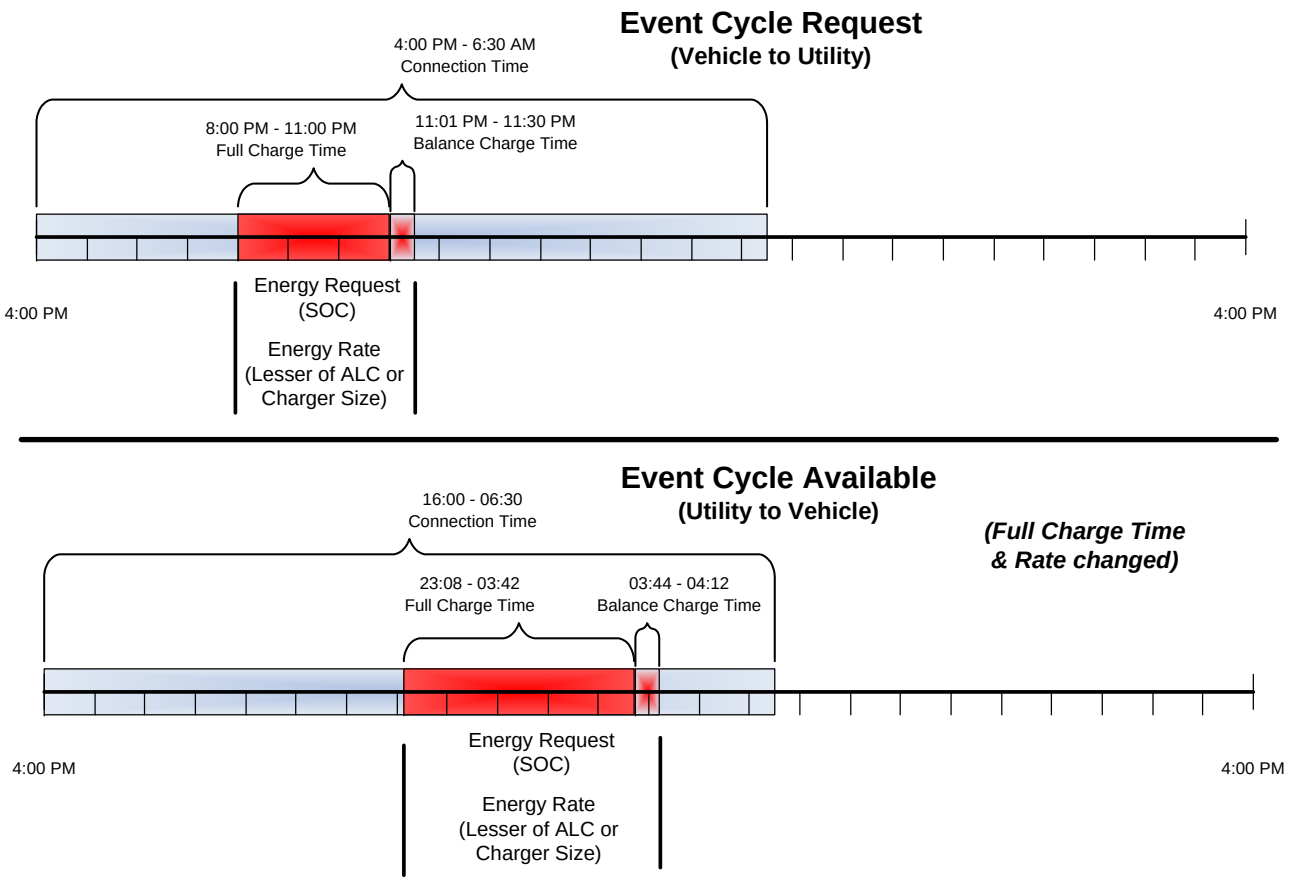
Multiple Port Scenario Diagram

Note: It is expected that some public EVSEs will need to allocate the resources for the combination of EVs and PHEVs that use them during the day. Business centers may include one or more of the following charging stations in their parking lot and are expected to have multiple vehicles use them during the day. One station may only accommodate one EV but will handle up to four PHEVs with the resources allocated.


Public EVSE - Energy Resource Allocation for 4 Stalls
100A drop to EVSE (80A circuit)
1st hour
Charger
V1
1.5 kW
V2
2 kW
EVSE
10 kW
V3
Energy flow
70A
High
12A
42A
Low
Medium
16A
PWM
20%
70%
26%
next hour
Charger
V1
1.5 kW
V2
2 kW
EVSE
10 kW
V3
17 kW
V4
Energy flow
80A
High
12A
10A
Low
Medium
8A
70A
High
PWM
20%
5% + Com
14%
92%

Message Diagram

This diagram shows the primary message requests sent from Vehicle and a potential message reply from the Utility. The Energy request (amount & rate) delivery time is based on the Utility program enrollment programmed into the vehicle or the EVSE. The utility responds with the optimization values for this cycle time.


Event Cycle Request
(Vehicle to Utility)
4:00 PM - 6:30 AM
Connection Time
8:00 PM - 11:00 PM
Full Charge Time
11:01 PM - 11:30 PM
Balance Charge Time
4:00 PM
Energy Request
(SOC)
Energy Rate
(Lesser of ALC or
Charger Size)
4:00 PM
Event Cycle Available
(Utility to Vehicle)
16:00 - 06:30
Connection Time
(Full Charge Time
& Rate changed)
23:08 - 03:42
Full Charge Time
03:44 - 04:12
Balance Charge Time
4:00 PM
Energy Request
(SOC)
Energy Rate
(Lesser of ALC or
Charger Size)
4:00 PM

USE CASE "L" – Location

Primary Scenario (L1): Customer Connects PEV at Their Premise Location Using Either EVSE Cordset or Premise Mounted EVSE

This scenario describes the most common sequence of customer charging their PEV at their own premise. As described in the main Narrative section, the customer is attempting to charge a PEV under a selected PEV rate tariff that may provide an incentive to charge during off peak periods. The utility needs to support customers on the PEV program.

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The customer plugs in the PEV using either EVSE cordset or Premise EVSE for charging	PEV	Customer has enrolled PEV with home utility. Enrollment and Initial Setup steps	The utility has a record of the energy purchased transactions related to the customer premise and the associated PEV ID.

Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..*
1	Customer	Customer connects PEV at his premise location. Customer can plug in his PEV using either EVSE cordset or Premise EVSE for charging	
1a	Customer	Customer connects EVSE **cordset** to Energy Portal at Premise.	Startup steps are provided in S1
1b	EVSE	Customer connects **Premise Mounted** EVSE to PEV.	Startup steps are provided in S2
2	PEV/Energy Services Communications Interface (ESCI)	PEV and Energy Services Communications Interface (ESCI) perform PEV binding and authentication process.	Implementation could have PEV or ESCI as initiator of session.
3	PEV	PEV is able to provide indicator to customer that binding has been successful (and that the PEV will receive incentive rate upon charging, if applicable).	
4	PEV	PEV sends Energy Request (amount and rate) and Schedule (according to enrolled PEV program)	
5	Utility	Utility compares request with available and confirms or adjusts for message back to PEV Utility sends Energy Available (amount and rate) and Schedule (according to enrolled PEV program)	
6	PEV	PEV prepares for charging	

Step #	Actor	Description of the Step	Additional Notes
7	PEV	PEV begins charging based on Customer-selected preferences. Charging may be delayed based upon Customer preferences or grid reliability criteria (e.g., off-peak economy charging, demand response event underway, short, randomized charging delay to promote grid stability, etc.)	The vehicle needs to record the energy delivered as a running total for the event. This would be a reference to be compared with the EUMD total. The EUMD has logged the actual energy flow accumulation for the utility
8	End Use Measurement Device	EUMD records charging information and energy supplied to PEV for each charging session. Charging information includes PEV ID, Premise ID, energy usage, and time stamp for each metering interval.	
9	End Use Measurement Device	EUMD communicates to Energy Services Communication Interface the energy supplied to PEV for each charging session.	This communication could be on a periodic basis during charging, upon vehicle unplug from energy portal, or a combination of the two.
10	Energy Services Communication Interface	Energy Services Communication Interface communicates to Utility the energy supplied to PEV for each charging session. ESCI transmits Date, time, duration and energy delivered to Utility and Vehicle.	This is the status of the cycle for the Utility, PEV and Customer information. J2836 identifies the periodicity of these messages. It may be desired to have this summed on a regular interval (every minute) in case the charge cycle is interrupted prior to the end so the current information (running summation) is not lost
11	Utility	Utility records each PEV charging session for bill generation and reporting to customer account associated with this premise and PEV ID.	

Primary Scenario (L2-A): Customer Connects PEV to Energy Portal at Another Premise and Premise Customer Pays for Energy Use

This scenario describes what happens if a Customer plugs PEV into another premise (not his own, but one serviced by the same utility), where the premise owner is responsible for the cost of energy delivered to the PEV charged at the premise.

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The customer plugs in the PEV using either EVSE cordset or Premise EVSE for charging	PEV	Customer has enrolled PEV with home utility. Enrollment and Initial Setup steps	The utility has a record of the energy purchased transactions related to the customer premise and the associated PEV ID.

Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	What actor, either primary or secondary is responsible for the activity in this step?	Describe the actions that take place in this step. The step should be described in active, present tense.	Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..
1	PEV	PEV connects another customer's premise within the Utility service territory, and the customer at this location is willing to pay for PEV charging energy. Customer can plug in his PEV using either EVSE cordset or Premise EVSE for charging	PEV may display message communicating charging/billing options or information to the Customer
1a	Customer	Customer connects EVSE **cordset** to Energy Portal at Premise.	Startup steps are provided in S1
1b	EVSE	Customer connects **Premise Mounted** EVSE to PEV.	Startup steps are provided in S2
2	PEV/Energy Services Communications Interface (ESCI)	PEV and Energy Services Communications Interface (ESCI) perform PEV binding and authentication process.	Implementation could have PEV or ESCI as initiator of session.
3	PEV	PEV is able to provide indicator to customer that binding has been successful (and that the PEV will receive incentive rate upon charging, if applicable).	
4	PEV	PEV sends Energy Request (amount and rate) and Schedule (according to enrolled PEV program)	
5	Utility	Utility compares request with available and confirms or adjusts for message back to PEV Utility sends Energy Available (amount and rate) and Schedule (according to enrolled PEV program)	

Step #	Actor	Description of the Step	Additional Notes
6	PEV	PEV prepares for charging	
7	PEV	PEV begins charging based on Customer-selected preferences. Charging may be delayed based upon Customer preferences or grid reliability criteria (e.g., off-peak economy charging, demand response event underway, short, randomized charging delay to promote grid stability, etc.)	The vehicle needs to record the energy delivered as a running total for the event. This would be a reference to be compared with the EUMD total. The EUMD has logged the actual energy flow accumulation for the utility
8	End Use Measurement Device	EUMD records charging information and energy supplied to PEV for each charging session. Charging information includes PEV ID, Premise ID, energy usage, and time stamp for each metering interval.	
9	End Use Measurement Device	EUMD communicates to Energy Services Communication Interface the energy supplied to PEV for each charging session.	This communication could be on a periodic basis during charging, upon vehicle unplug from energy portal, or a combination of the two.
10	Energy Services Communication Interface	Energy Services Communication Interface communicates to Utility the energy supplied to PEV for each charging session. ESCI transmits Date, time, duration and energy delivered to Utility and Vehicle.	This is the status of the cycle for the Utility, PEV and Customer information. J2836 identifies the periodicity of these messages. It may be desired to have this summed on a regular interval (every minute) in case the charge cycle is interrupted prior to the end so the current information (running summation) is not lost
11	Utility	Utility records each PEV charging session for bill generation and reporting to customer account associated with this premise and PEV ID.	

Primary Scenario (L2-B): Customer Connects PEV to Energy Portal at Another Premise and PEV Customer Pays for Energy Use

This scenario describes what happens if customer plugs PEV into another premise (not his own, but serviced by the same utility), where the PEV operator is responsible for the cost of energy delivered to the PEV charged at the premise.

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The customer plugs in the PEV using either EVSE cordset or Premise EVSE for charging	PEV	Customer has enrolled PEV with home utility. Enrollment and Initial Setup steps	The utility has a record of the energy purchased transactions related to the customer premise and the associated PEV ID.

Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..*
1	PEV	PEV connects at another customer premise within the Utility service territory. PEV owner will pay for charging. Customer can plug in his PEV using either EVSE cordset or Premise EVSE for charging	PEV may display message communicating charging/billing options or information to the Customer.
1a	Customer	Customer connects EVSE cordset to Energy Portal at Premise.	Startup steps are provided in S1
1b	EVSE	Customer connects Premise Mounted EVSE to PEV.	Startup steps are provided in S2
2	PEV/Energy Services Communications Interface (ESCI)	PEV and Energy Services Communications Interface (ESCI) perform PEV binding and authentication process	Implementation could have PEV or ESCI as initiator of session.
3	PEV	PEV is able to provide indicator to customer that binding has been successful (and that the PEV will receive incentive rate upon charging, if applicable).	
4	PEV	PEV sends Energy Request (amount and rate) and Schedule (according to enrolled PEV program)	
5	Utility	Utility compares request with available and confirms or adjusts for message back to PEV Utility sends Energy Available (amount and rate) and Schedule (according to enrolled PEV program)	
6	PEV	PEV prepares for charging	

Step #	Actor	Description of the Step	Additional Notes
7	PEV	PEV begins charging based on Customer-selected preferences. Charging may be delayed based upon Customer preferences or grid reliability criteria (e.g., off-peak economy charging, demand response event underway, short, randomized charging delay to promote grid stability, etc.)	The vehicle needs to record the energy delivered as a running total for the event. This would be a reference to be compared with the EUMD total. The EUMD has logged the actual energy flow accumulation for the utility
8	End Use Measurement Device	EUMD records charging information and energy supplied to PEV for each charging session. Charging information includes PEV ID, Premise ID, energy usage, and time stamp for each metering interval.	
9	End Use Measurement Device	EUMD communicates to Energy Services Communication Interface the energy supplied to PEV for each charging session.	This communication could be on a periodic basis during charging, upon vehicle unplug from energy portal, or a combination of the two.
10	Energy Services Communication Interface	Energy Services Communication Interface communicates to Utility the energy supplied to PEV for each charging session. ESCI transmits Date, time, duration and energy delivered to Utility and Vehicle.	This is the status of the cycle for the Utility, PEV and Customer information. J2836 identifies the periodicity of these messages. It may be desired to have this summed on a regular interval (every minute) in case the charge cycle is interrupted prior to the end so the current information (running summation) is not lost
11	Utility	Utility records each PEV charging session for bill generation and reporting to customer account associated with this premise and PEV ID.	

Primary Scenario (L3): Customer Connects PEV to Energy Portal at Another Premise Outside the Enrolled Utility's Service Territory

This scenario describes what happens if customer plugs PEV into another premise (not his own, and not serviced by the same utility (i.e.. roaming utility), where the PEV operator is responsible for the cost of energy delivered to the PEV charged at the premise.

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The customer plugs in the PEV using either EVSE cordset or Premise EVSE for charging	PEV	Customer has enrolled PEV with home utility. . Enrollment and Initial Setup steps Both home and foreign/roaming utility participate in inter-utility clearinghouse.	The foreign/roaming utility and the clearinghouse have record of the energy purchased transactions related to the customer premise, the PEV ID, the Customer ID, and the Utility ID.

Steps for This Scenario

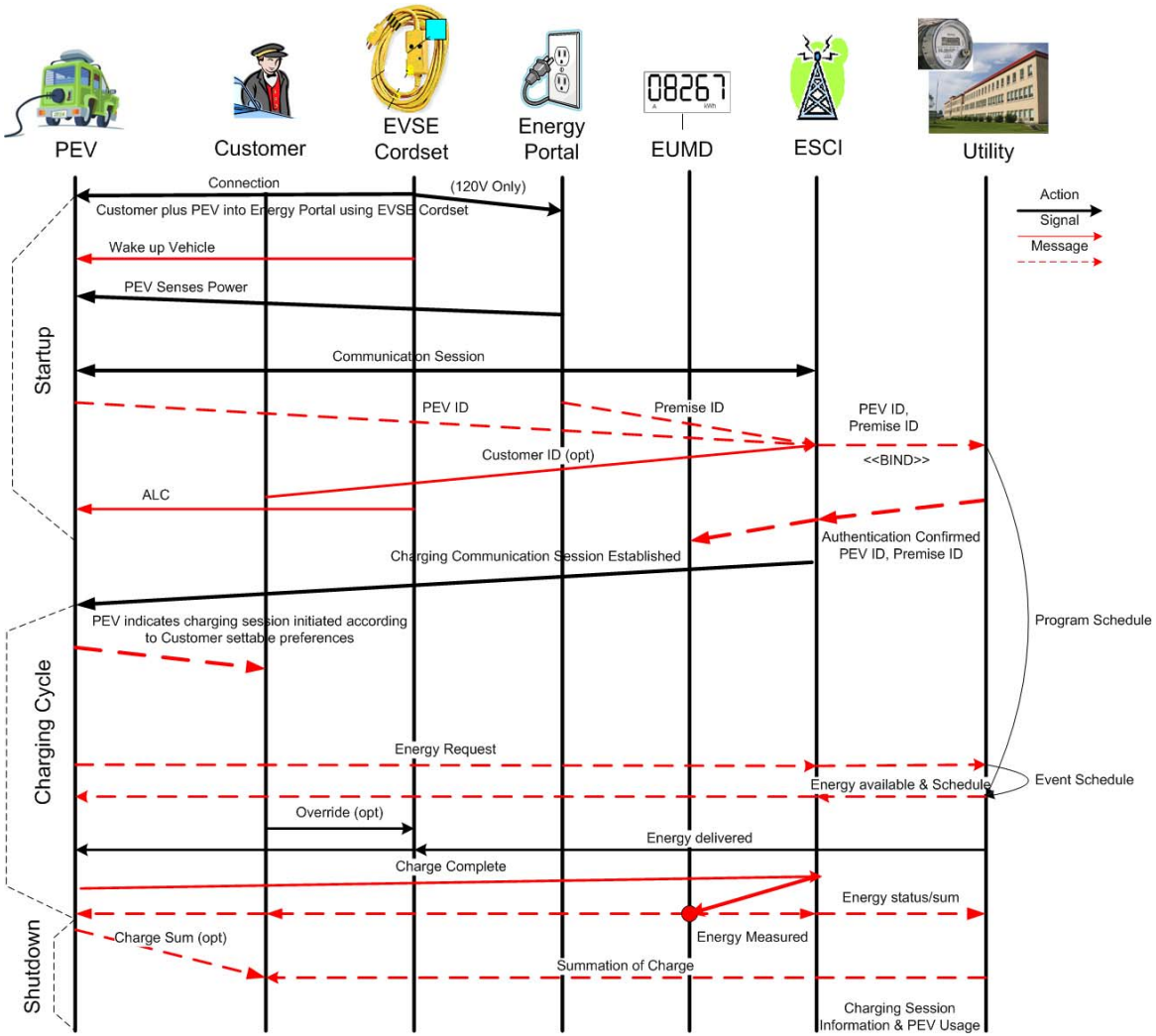
Step #	Actor	Description of the Step	Additional Notes
#	What actor, either primary or secondary is responsible for the activity in this step?	Describe the actions that take place in this step. The step should be described in active, present tense.	Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..
1	PEV	PEV connects PEV at a location outside of the home Utility service territory. PEV owner will pay for charging. Customer can plug in his PEV using either EVSE cordset or Premise EVSE for charging	PEV may display message communicating charging/billing options or information to the Customer.
1a	Customer	Customer connects EVSE **cordset** to Energy Portal at Premise.	Startup steps are provided in S1
1b	EVSE	Customer connects **Premise Mounted** EVSE to PEV.	Startup steps are provided in S2
2	PEV	PEV prepares for charging rate (charger size or ALC, whatever is lowest). PEV senses power to on-board charging unit and activates 'On Plug' state.	
3	PEV/ Energy Services Communications Interface (ESCI)	PEV and Energy Services Communications Interface (ESCI) perform PEV binding and authentication process	Implementation could have PEV or ESCI as initiator of session.
4	PEV	PEV ID is transmitted to ESCI.	Unique PEV ID will ultimately support portability of charging, among other purposes.
5	ESCI	ESCI maintains communication session and security between PEV and Roaming Utility. ESCI transmits request for validating PEV ID to Roaming Utility, including Premise ID.	

Step #	Actor	Description of the Step	Additional Notes
6	Roaming Utility	Roaming Utility checks PEV ID and Premise ID against internal database. When not found (because PEV is registered with home utility), Roaming utility forwards PEV ID and Roaming Utility ID to Clearinghouse for verification.	
7	Clearinghouse	Clearinghouse checks PEV database for PEV ID and finds corresponding Home Utility ID, and Home Utility Account/Premise ID.	Underlying assumption is that PEV has been registered with home utility and that both utilities participate in the clearinghouse.
8	Clearinghouse	Clearinghouse transmits confirmed message to Roaming Utility, including PEV ID, Home Utility ID, and Home Utility Account/Premise ID.	
9	Roaming Utility	Roaming Utility transmits confirmed message via ESCI to End Use Measurement Device (EUMD) indicating successful binding with premise ESCI.	
10	ESCI	ESCI transmits confirmation message to PEV indicating successful communication session binding of PEV to Roaming Utility at PEV program tariff. PEV is able to provide indicator to customer that binding has been successful (and that he will receive incentive rate upon charging, if applicable).	
11	PEV	PEV sends Energy Request (amount and rate) and Schedule (according to enrolled PEV program)	
12	Utility	Utility compares request with available and confirms or adjusts for message back to PEV Utility sends Energy Available (amount and rate) and Schedule (according to enrolled PEV program)	

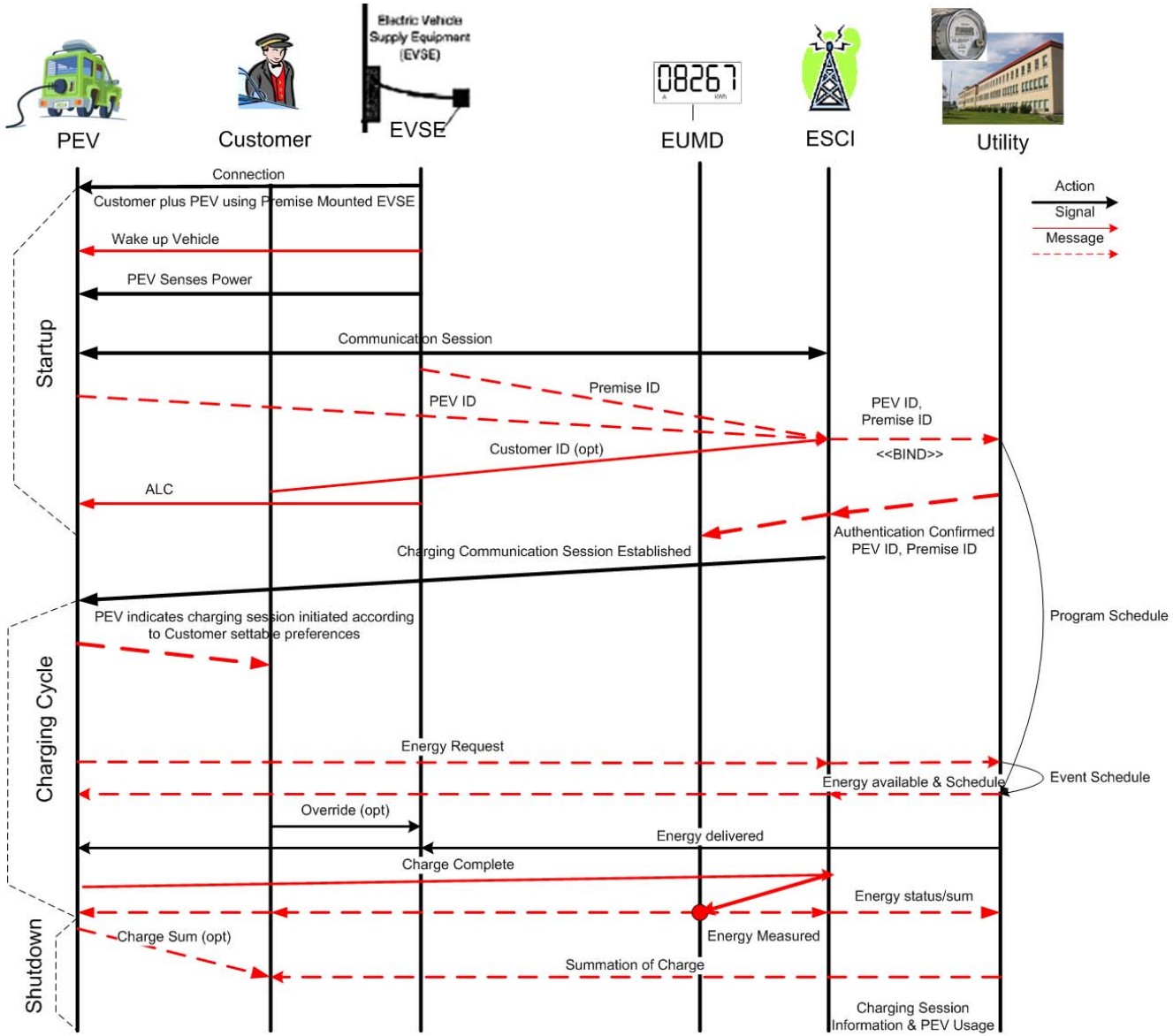
Step #	Actor	Description of the Step	Additional Notes
13	PEV	PEV prepares for charging	
14	PEV	PEV begins charging based on Customer selected preferences. Charging may be delayed based upon Customer preferences or grid reliability criteria (e.g., off-peak economy charging, demand response event underway, short, randomized charging delay to promote grid stability, etc.)	The vehicle needs to record the energy delivered as a running total for the event. This would be a reference to be compared with the EUMD total. The EUMD has logged the actual energy flow accumulation for the utility
15	End Use Measurement Device	EUMD records charging information and energy supplied to PEV for each charging session. Charging information includes PEV ID, Premise ID, energy usage, and time stamp for each metering interval.	
16	End Use Measurement Device	EUMD communicates to Energy Services Communication Interface energy supplied to PEV ID for each charging session.	This communication could be on a periodic basis during charging, upon vehicle unplug from energy portal, or a combination of the two.
17	Energy Services Communication Interface	Energy Services Communications Interface (ESCI) communicates to Roaming Utility energy supplied to PEV for each charging session.	This is the status of the cycle for the Utility, PEV and Customer information. J2836 identifies the periodicity of these messages. It may be desired to have this summed on a regular interval (every minute) in case the charge cycle is interrupted prior to the end so the current information (running summation) is not lost
18	Roaming Utility	Roaming Utility records each PEV charging session for reporting to Clearinghouse. Customer account associated with this roaming utility premise will be credited for energy supplied for this charging session.	

Step #	Actor	Description of the Step	Additional Notes
19	Roaming Utility	Roaming Utility forwards transaction to Clearinghouse for energy supplied to PEV including PEV ID, Customer ID, Home Utility ID, and interval based charging session information.	
20	Clearinghouse	Clearinghouse receives energy charge transaction from Roaming Utility for posting charges to PEV operator's home utility Customer account.	

Sequence Diagram: Scenario L1, L2-A, L2-B

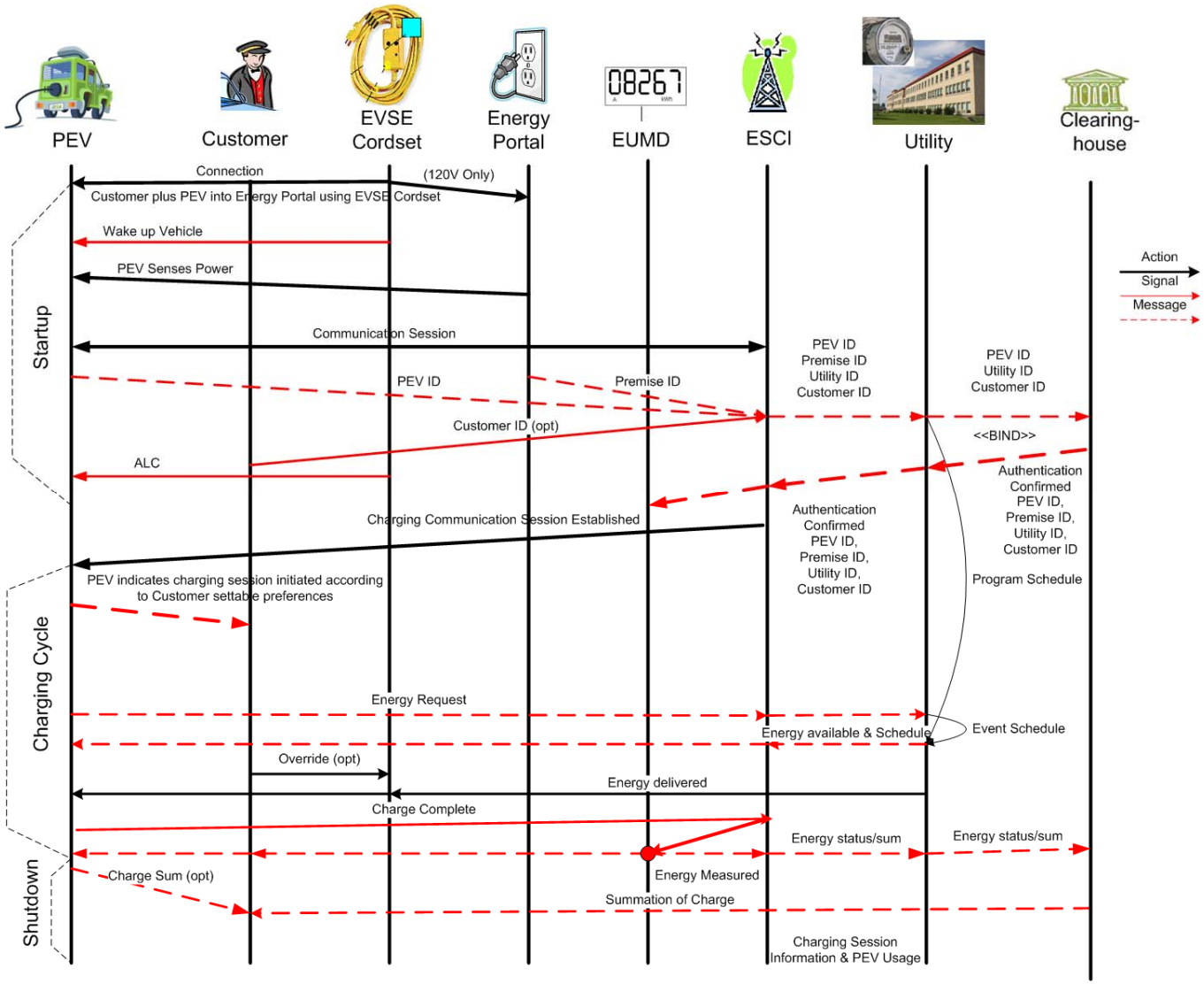


Using EVSE Cordset

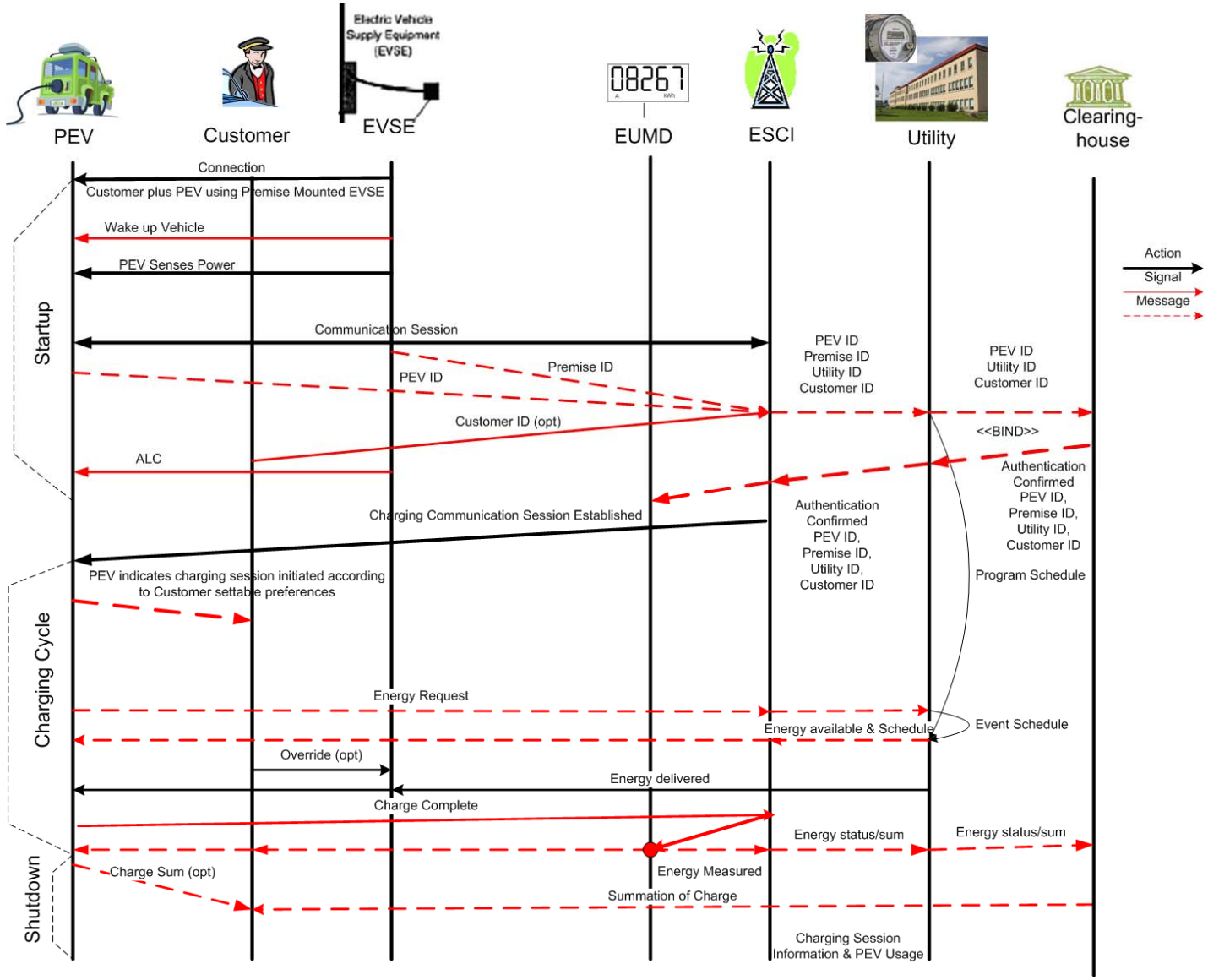


Using Premise Mounted EVSE

Sequence Diagram: Scenario L3



Using EVSE Cordset



Using Premise Mounted EVSE

USE CASE "PR" – Charging

Primary Scenario (PR1): Customer Is Enrolled in a TOU Schedule

For those customers enrolled in a PEV Time-of-Use (TOU) pricing demand side management program, applicable energy prices and rate periods (e.g., off-peak, mid-peak, on-peak, etc.) will be made known to the Customer and PEV. PEV initiates charging based on Customer-defined preference settings (considering peak/off-peak rate periods) in the PEV. PEV may not receive demand response discrete event notifications; however, some Customers enrolled in PEV TOU demand side management programs could also enroll in a Discrete Event demand side management program. Because no regular periodic communications between PEV and vehicle is required to support a basic PEV TOU pricing demand side management program, an explicit scenario for this option was not included in this use case. However, Utility-to-PEV communications for PEVs enrolled in a TOU demand side management program does offer other benefits (e.g., updated rates displayed in PEV).

Primary Scenario (PR2): Customer Is Enrolled in a PEV Discrete Event Demand Side Management Program (Direct Load Control) and PEV (and/or PEV customer) Receives and Responds to Discrete Demand Response Events

For those customers enrolled in a PEV discrete event demand side management program (possibly in exchange for special PEV tariffs or other incentives), this program allows the utility to request an automated load reduction at the customer site by issuing event information to the PEV. The customer can override and/or opt-out of the request in exchange for a reduced incentive. Typically, PEV demand response events are downloaded at least 24 hours ahead, however they could be provided day-of in the case of a grid reliability emergency

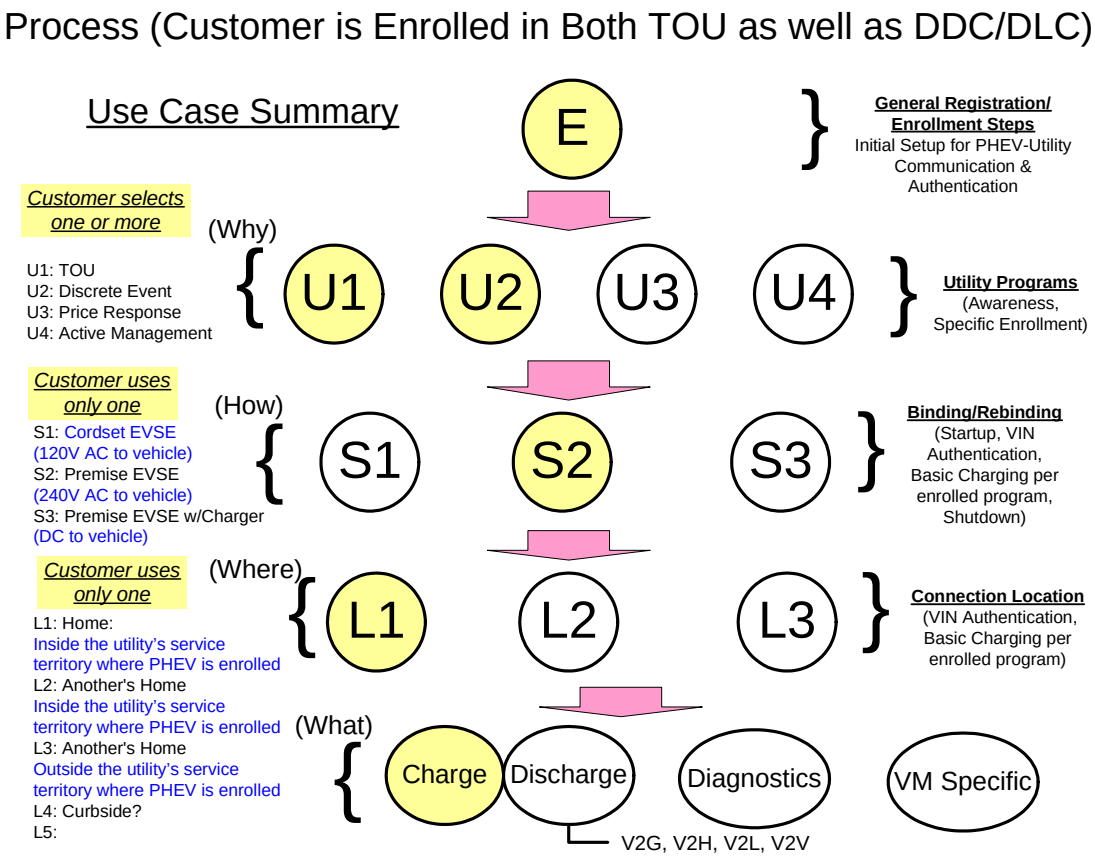
- Utility shall be able to transmit discrete demand response event messages to an ESCI and onward to PEV.
- Utility shall track Customer preference for remote notification of PEV Demand Response (DR) events.
- Utility shall transmit PEV Demand Response event alerts to Customer via Customer-designated communication channel(s).
- Customer shall have the ability to override and/or opt-out of discrete demand response events.
- PEV shall charge based on Customer-configurable preferences and shall take appropriate action based upon discrete demand response events.
- PEV shall send Customer opt-out notification message to Utility.
- Pre–event notification shall be sent to customers in advance in a range from one minute in an emergency up to 24 hours for normal/planned discrete demand response events

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
As electrical system approaches overload and/or resources become constrained	PEV	Customer has subscribed to a PEV demand side management discrete event program.	Conditions that led to constrained resources have abated or been mitigated. Customer returns to normal PEV load operation.

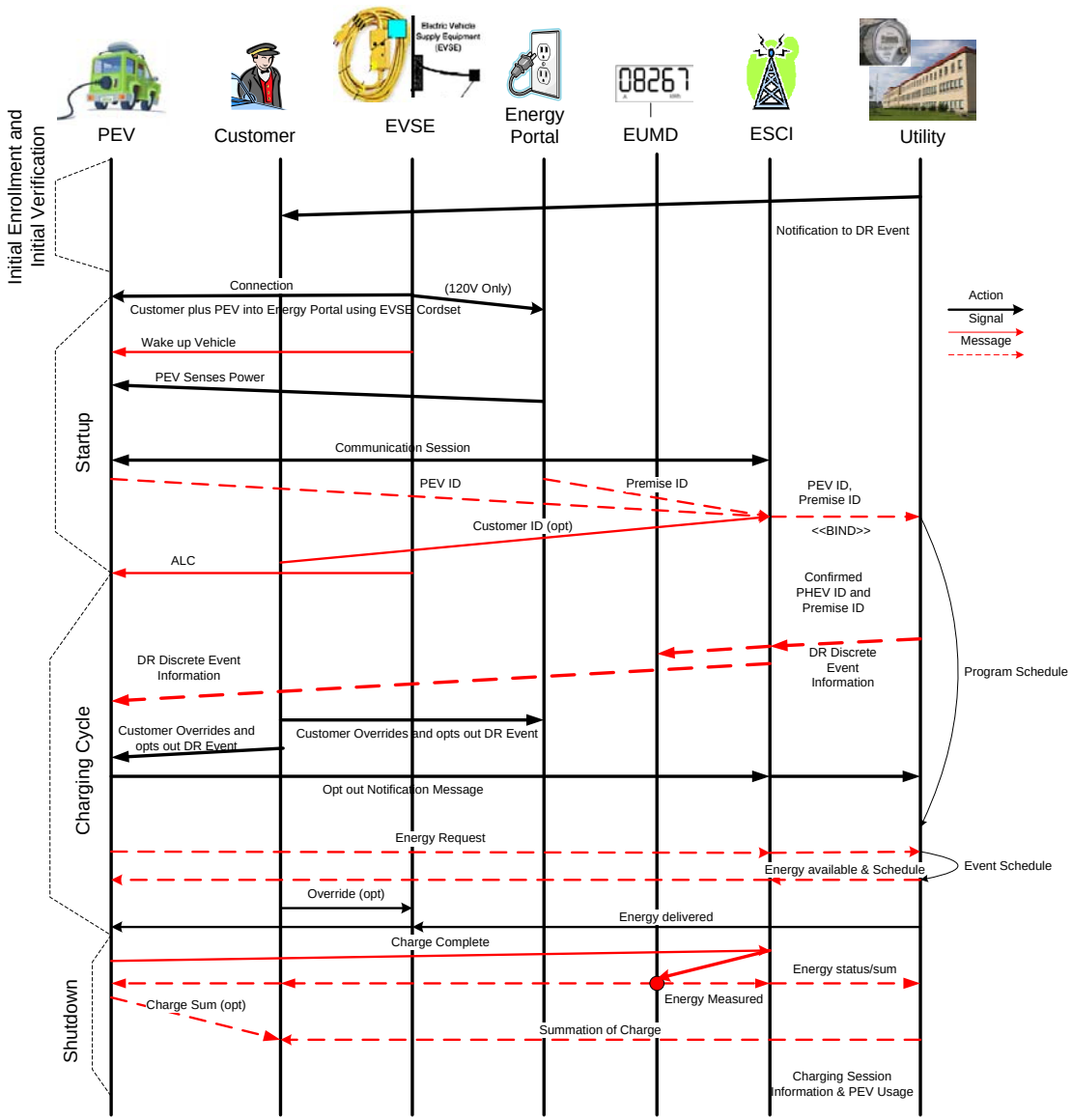
Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..*
1	Utility	At least 24 hours prior to event, Utility sends out remote notification to PEV Customers enrolled in PEV DR programs indicating demand response action.	
2	Utility	Utility shall transmit PEV Demand Response event alerts notification via pager, e-mail, text message on cell phone, web page, etc.	
3	Utility	Utility shall track Customer preference for remote notification of PEV Demand Response (DR) events	
4	Customer	Customer selects/adjusts demand side management preference(s) on PEV (if necessary) and connects PEV to energy portal at his local premise.	
5	Utility	Utility downloads demand response discrete event information to PEV via ESCI. Message includes event information or load reduction request notification.	
6	PEV	PEV charging proceeds based on Customer defined preferences (which considers receipt of demand side management information).	
7	Customer	Customer has the ability to override and/or opt-out of demand response event using Customer-configurable preferences in the PEV. Customer may receive a reduced incentive for exercising this option.	Other means of indicating override or opt-out (e.g., outside of vehicle) may also be considered here.

Process Example



Sequence Diagram



Primary Scenario (PR3): Customer Is Enrolled in a Periodic/Hourly Pricing Price Response Program and PEV Receives and Responds to Periodic/Hourly Energy Prices (day-ahead schedule)

For those customers enrolled in a hourly price demand side management program, this program will download a schedule of 24 hours critical peak pricing for the next day, at least 24 hours ahead, based upon a prediction of energy shortages.

- The utility will download day-ahead 24 hour prices for each hour to the PHEV. PHEV charging proceeds based on Customer-selected preference settings in the PHEV
- Utility shall be able to transmit periodic/hourly pricing tables to an ESCI and onward to PHEV.
- Utility shall apply correct rate structure for accurate customer billing considering any enrolled PHEV demand side management programs and the benefits for compliance or charges for overrides and opt outs which are included in those programs.
- PHEV shall charge based on Customer-configurable preferences and shall take appropriate action based upon a periodic/hourly price table.
- PHEV shall send Customer opt-out notification message to Utility

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
Utility determines day-ahead periodic/hourly pricing	PEV	Customer has subscribed to a PEV periodic/hourly pricing demand side management program.	Conditions that led to constrained resources have abated or been mitigated. Customer return to normal PEV load operation.

Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	What actor, either primary or secondary is responsible for the activity in this step?	Describe the actions that take place in this step. The step should be described in active, present tense.	Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..
1	Utility	Utility determines periodic/hourly prices for the next day, based on forecasts.	
2	Utility	In the case of abnormally high hourly prices, Utility may send out remote notification to PEV Customers enrolled in this type of PEV DR Program advising demand response action. Notification can be via pager, e-mail, text message on cell phone, web page, etc.	
3	Customer	Customer selects/adjusts demand side management preference(s) on PEV (if necessary) and connects PEV to energy portal at his local premise.	See Issue 1.0 (Section 6)
4	Utility	Utility downloads day-ahead periodic/hourly pricing rate table to PEV via ESCI. Table includes periodic/hourly prices for each period in the next day, or current day if table not yet downloaded for current day.	
5	PEV	PEV charging proceeds based on Customer-defined preferences (which considers current hourly/periodic pricing table). Customer may set or adjust limits for acceptable price for charging.	

Primary Scenario (PR4): Non-enrolled PEV (or Customer with non-communicating PEV) Connects to Energy Portal

This scenario describes what happens if an unenrolled PEV can communicate with local area network (e.g., LAN, HAN, PAN) or Customer has PEV that cannot communicate or cannot communicate with a specific Utility's network.

Triggering Event	Primary Actor	Pre-Condition	Post-Condition
(Identify the name of the event that start the scenario)	*(Identify the actor whose point-of-view is primarily used to describe the steps)*	*(Identify any pre-conditions or actor states necessary for the scenario to start)*	*(Identify the post-conditions or significant results required to consider the scenario complete)*
The customer plugs in the PEV using either EVSE cordset or Premise EVSE for charging	PEV	Customer has a PEV, but is unenrolled in a Utility PEV program, has a non-communicating PEV, or both.	No communication session established with Utility network or devices. PEV charges successfully with all energy charges accruing to charging premise account.

Steps for This Scenario

Step #	Actor	Description of the Step	Additional Notes
#	*What actor, either primary or secondary is responsible for the activity in this step?*	*Describe the actions that take place in this step. The step should be described in active, present tense.*	*Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column..*
1	PEV	PEV connects at any customer location. This could be in the PEV operator's home utility service territory or in a foreign utility service territory. Customer can plug in his PEV using either EVSE cordset or Premise EVSE for charging	
1a	Customer	Customer connects EVSE **cordset** to Energy Portal at Premise.	Startup steps are provided in P1 S1 (Steps 5a through Step 10)
1b	EVSE	Customer connects **Premise Mounted** EVSE to PEV.	Startup steps are provided in P1 S2 (Steps 5a through Step 10)
2	PEV	PEV prepares for charging rate (charger size or ALC, whatever is lowest). PEV senses power to on-board charging unit and activates 'On Plug' state	
3	PEV/ Energy Services Communications Interface (ESCI)	PEV (if communications enabled) and Energy Services Communications Interface (ESCI) initiate a secure communications session.	Implementation could have PEV or ESCI as initiator of session. If PEV does not have communications capability (or if communication is disabled), charging will commence with all energy charges accruing to premise customer at default rate for customer account.
4	PEV	PEV ID is transmitted to ESCI	

Step #	Actor	Description of the Step	Additional Notes
5	Utility	Utility checks PEV ID, Premise ID against internal database. If not found (because PEV is roaming outside of home utility), utility forwards PEV ID to Clearinghouse for verification.	
6	Utility/Clearinghouse	Neither utility nor clearinghouse has record of the PEV ID	Utility will have PEV ID of unenrolled PEV, should it desire to identify it and contact operator regarding potential enrollment in utility program.
7	PEV	PEV begins charging based on Customer selected preferences. All energy charges accrue to premise account.	

7
TRANSLATING REQUIREMENTS INTO INDUSTRY ACCEPTED INFORMATION MODELS: INTEROPERABILITY WITH APPLICATION LAYER STANDARDS

Challenges

The challenges faced by the industry in application level communications include the integration of work from various fields of expertise and focused efforts. This challenge also includes getting the work into a standardized structure and format that can be applied across the power industry. Achieving interoperable systems and those that can be effectively managed over their life cycle includes taking an architecture perspective on systems integration. For dynamic customer and electric vehicle integration this includes the integration of communication standards under development for advanced power systems automation. For critical components of field equipment operations the power industry must drive toward a consistent standards based architecture for real-time operations.

As enumerated in the previous chapters, utilities and system operations personnel have been developing electric vehicle integration "use cases" and requirements, the electric vehicle in simple form appears as a mobile form of "customer systems" combined with distributed energy resource integration. The electric vehicle support for both demand response and power injection with grid operations means that vehicle to grid communications now take into account the appropriate integration with utility transmission and distribution (T&D) field equipment operations. The majority of grid power injection integration effort is related to the necessary integration with the utility distribution system automation and protection systems.

The challenges to develop information models from the Utility-PEV communication requirements include:

1. Develop real time price rate structures and control signals in formats that are used in the industry
2. Can be interoperable with existing objects and application layer standards
3. Can easily and seamlessly incorporate added control or communication parameters into existing objects.

EPRI Report "*Common Objects for Pricing and Control Communications*" proposes draft real time pricing objects and demand response communications in a structure and format consistent with the International Electrotechnical Commission (IEC) 61850 Standard for real time

communications with advanced field equipment. IEC 61850 is proposed for carrying messages for both demand response (including pricing and direct load control) as well as integration of power injection. In this way the power system application level infrastructure for T&D field operations is consistent with vehicle to grid application level communications.

IEC 61850 is an International Standard for advanced utility field equipment automation. It is proposed for both Transmission and Distribution systems field equipment and represents the next generation of communications standards for automation equipment. The 61850 Standard has a structured and robust approach to standardized application level communications for widespread use. Complex data and device models and behaviors can be developed for meeting the requirements of next generation utility field equipment automation. The standard has been developed for key areas important to utility field operations including substation automation, integration of distributed energy resources and is now developing for advanced distribution automation and customer communications. This standard is also backed by an active user group under UCA International and is now being implemented world wide.

The communication "objects" proposed in EPRI Report "*Common Objects for Pricing and Control Communications*" can be carried over any physical communications media that meets the requirements of the supported applications. It does not require broadband communications. It should be noted that the application level elements of the IEC 61850 standard are independent of underlying networking and physical communications media. The structured messages can be carried over any emerging standards based communications media.

The use of the IEC 61850 standard is now under development for this purpose and is appropriate for communications with any DER equipment both mobile and stationary. The energy industry needs a consistent application level approach to forward pricing and control signals to customer equipment. EPRI Report "*Common Objects for Pricing and Control Communications*" builds upon prior work to format real time pricing rate structures and control signals to consumer equipment and vehicles.

Factors Affecting Retail Pricing

First plug-in Hybrids are announced and will be in production in 2010 (GM) or sooner (Fisker, etc). These vehicles are expected to be charged overnight at home most of the time, but with the cordset and on-board charger, they can potentially charge from any standard outlet. It is however, beneficial to the utility and customer that these hybrids be charged at times that offer the best load factor improvement for the utility and cheapest rates for the consumer. Pricing of a unit of electricity (or a kWh) has been seen as a signal for the utility company to provide to consumers, especially the bulk consumers in Commercial and Industrial (C&I) space, to incentivize or disincentivize them from using electricity during certain periods of day, week or year. In order for this to occur, the PHEV somehow needs to have the information about the applicable tariff as a function of time and location during the time it expects to charge the batteries. At present, however, there is no common standard across 50 states around (a) specifying, (b) communicating or (c) accounting for special rates for PHEVs. The existing standards and information around these is scattered and either not relevant (i.e., many regions have flat rates for all times and all loads) or not available across all service territories in the US.

It will become important for utilities to implement special tariffs for PHEV charging for two reasons (a) Regulations around carbon tax may make the pricing of electricity uneven across different times, as well make improving the load factor a priority in carbon-intense electric generation areas of the nation, and, (b) To aid to this, subsidizing PHEV charging may both promote PHEV adoption in the particular service territory as well as enable improvement of the load factor by providing a load that can be charged off-peak.

ISOs/RTOs post day-ahead prices based on market rules that share many common aspects, but that result in vastly different price profiles at times because of different market circumstances. They post day-ahead price schedules (by zone) at their web site, usually about 4:00 p.m. They also maintain web-accessible historical data bases. Some competitive retailers and utilities offer customer other means for acquiring the daily price schedules, but there is no standard for that activity. Most do so because the prices they post to customers contain adjustments from the base wholesale LMP to account for losses, and in some cases recover capacity costs. In general, it is tiresome to pull down daily price schedules from the web page unless you write a software routine to query the site daily and automate the download, which the guys in the Living Lab have done to support the streaming prices we display.

Utility-based RTP programs, where the prices are set by the utility, and therefore reflect their top-of-stack dispatch costs, are generated by a variety of algorithms, some of which have a lot in common with ISO/RTP price formation, and others that diverge substantially.

In other words, the day-ahead prices can vary substantial at customer meters just a few miles apart because of jurisdictional and market rules. This could provide incentives to go into another city or country to fill up (so to speak), just as people travel to avoid paying local sales taxes.

RTP and TOU Standards

These points out the need to work to provide greater standardization of how such retail prices are promulgated and distributed.

When looking for price delivery standards, and one needs to look at what has been done in the EPRI living lab to get those prices from the source to the meter. Daily polling is ok if the data goes to the meter. However, if the data has to go to a mobile load such as a car, that is capable of plugging into any electrical outlet, it can potentially move between service territories with different pricing schedules, which are a function of the demand and supply patterns over the day and over the year.

Another important aspect is that since the demand/supply patterns change very slowly year-over-year in any particular region, it may be possible to store this information as default settings on-board the vehicle, and the changes can either be downloaded via short- or long-range wired or wireless connection, or can be flashed at the dealer as and when they change. Both of these are entirely possible scenarios.

So, in the near-term, if it is possible to (a) replicate the data format and process based on standards to create a data stream, and (b) have a means to communicate this to the car, it may be possible to get the pricing information to the car – either in real-time or in an a-priori fashion.

The challenge here for a plug-in HEV, which is essentially a roaming load, is be that the car will have to be able to determine what electricity market it is in, the price in that market, and the distance to the next, lower cost market, to determine when to charge. If the rate is a time-of-use schedule, then the prices are quite stables, changing only yearly, perhaps. That provides a static schedule that can be loaded into the decision processor and updated only periodically. Better overall (expected) prices will be available if the charging is done on day-ahead market prices, but that involves considerable volatility and the need to update the price schedule database every day. Another thing to keep in mind is that if indeed PHEV were to become common, then under cost-based rates the cost allocation would change, which would result in more costs being assigned to residential customers, which might change their rate, and could effect the rate structure itself.

Approach to Development of a Nationwide Standard to Develop RTP and TOU Objects

All of this discussion points in the direction to try and build a framework for pricing electricity for PHEVs that can (and will be) be uniformly applied across the country. This would be the first effort to consolidate and align retail rates nationally. This is enabled by standardizing communications early in the process, because,

- A consistent Approach to Communications Language is necessary for communications interoperability.
- Vehicles must be able to seamlessly integrate across utility service territories
- This approach must be standardized to enable manufacturers to optimize charging (as well as power injection) for customers
- Infrastructure must include standardized communications/networking management that includes security functions

The vision proffered by the proponents of Automated Metering Infrastructure for success is that it will enable supporting of advanced electricity rate structures, will integrate with home-area networks at the end-use level to transmission and distribution operations' IT systems upstream. It will also support all plausible advanced use cases covering advanced network and systems administration that will engender strong public trust for reliability and security. These obviously will need to be endorsed and integrated into ongoing efforts by SDOs (IEEE, SAE, ASHRAE etc) and Consortia (ZigBee/HomePlug alliance, for example).

As illustrated in the following figure 6-1, the electric power delivery infrastructure of the future is likely to be much evolved over what has been the norm just a few years ago, with transmission and distribution operations supplemented by dynamic systems control, customer integration, advanced metering, all the way to the end use applications such as renewables, distributed generation and storage and PHEV integration into the grid, plus the standard load control of the end use devices. All of these are meant to enable energy efficiency and demand response programs that effectively increase load factor and capacity utilization. However, they need to be architected correctly to integrate across end-use industries and upstream utility operations.

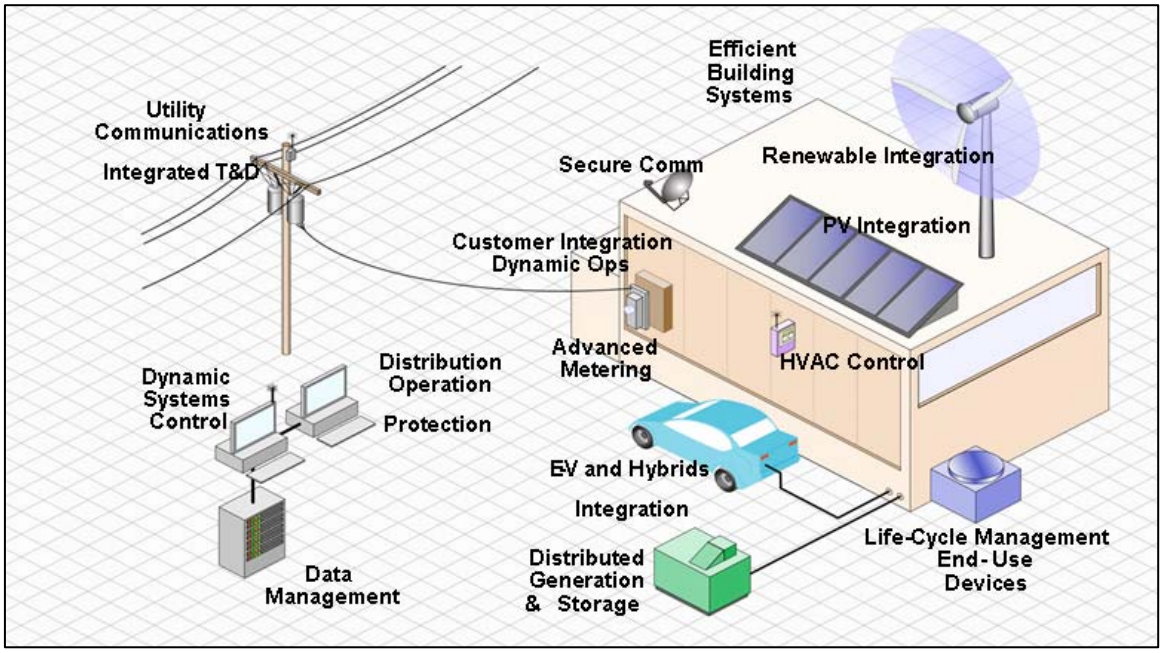


Figure 7-1
Smart Grid Integration with Smart Loads, Storage and Renewables

In 1999, ASHRAE group has published RP1011 report which precipitated a working group under ASHRAE SSPC 135 to work on Utility to Building Integration using BACnet for in-building communications. The work since then has resulted in the development of load control objects. The RTP structures still have yet to be adopted

Communications technology has changed, although unfortunately it has not been converging but diverging into a variety of fragmented splinter groups dozens of physical media and several groups working on application layer communications with little cross pollination. Additionally, there is a need to separate the layers in communications. EPRI's effort has been to strategize on application layer communications that can be one anchor point for interoperability from utility to the intelligent consumer equipment.

Moreover, the end use crosses dozens of industries so there is no dominant player in many of these environments. So, to establish a widespread support, EPRI has been rallying around the IEC Standards based on IEC 61850 Standard part 6 which calls out a structured approach to objects using an XML Schema. This is being used for substations and field equipment including integration of DER. The RP 1011 RTP objects were developed on earlier versions of this standard. The semantics and thought behind the objects are still solid and may/should be expanded based on any new knowledge but the basic work for RTP should be retained and built upon.

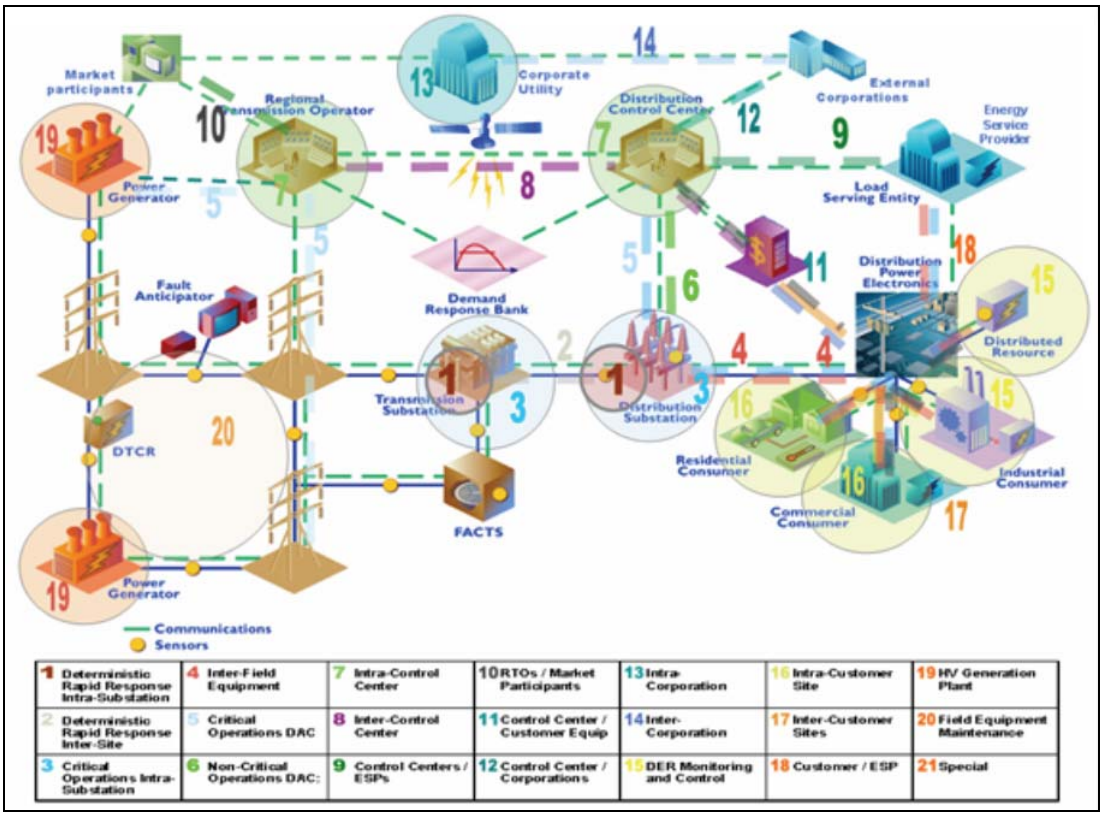


Figure 7-2
Industry-Level Communications Architecture and Computing Environments

Real-Time Pricing is just one of the applications that need to be standardized. When one looks at the entire range of applications that are being considered as a part of a broader picture, a taxonomy is emerging as shown in Figure 7-2, that falls under Charging, Demand Response, Power Injection and Vehicle Management categories. This forms the application-layer that needs to be standardized, and then implemented over a mish-mash of distributed computing environments which are a loosely coupled combination of legacy and state-of-the art information systems covering a patchwork of utility service territories and their transmission, distribution and utilization functions, as shown in Figure 7-3.

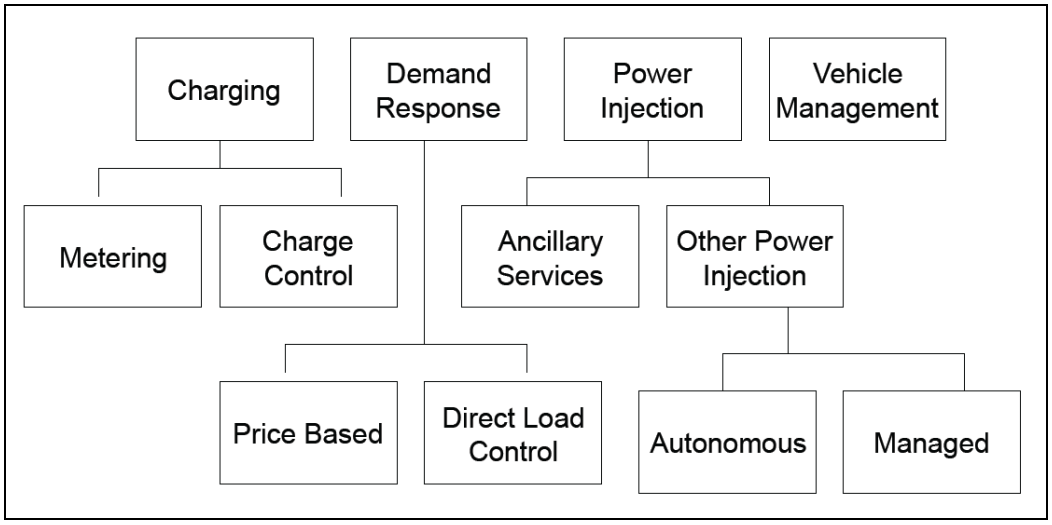


Figure 7-3
Real-Time Pricing and DR Program Taxonomy

The main user group is UCA International that was built around this standard and has split off separate working groups for customer communications. The standard set of objects need some formal SDO home(s) including IEC TC57 (power systems) and ASHRAE (for buildings/HVAC), possibly SAE (for vehicles), ANSI/AHAM for appliances etc.

The entire gamut of standards development organizations (SDOs) involved in defining standards for various aspects of the industry level IntelliGrid infrastructure is overwhelming, and requires careful coordination to ensure that they perform mutually exclusive and collectively exhaustive work on covering industries, applications, technologies and policy, technology, legal and security aspects of the standards. This is no mean task and is currently being facilitated by several projects from CEC, EPRI, DoE, DoD and others, as shown in Figure 7-4 below:

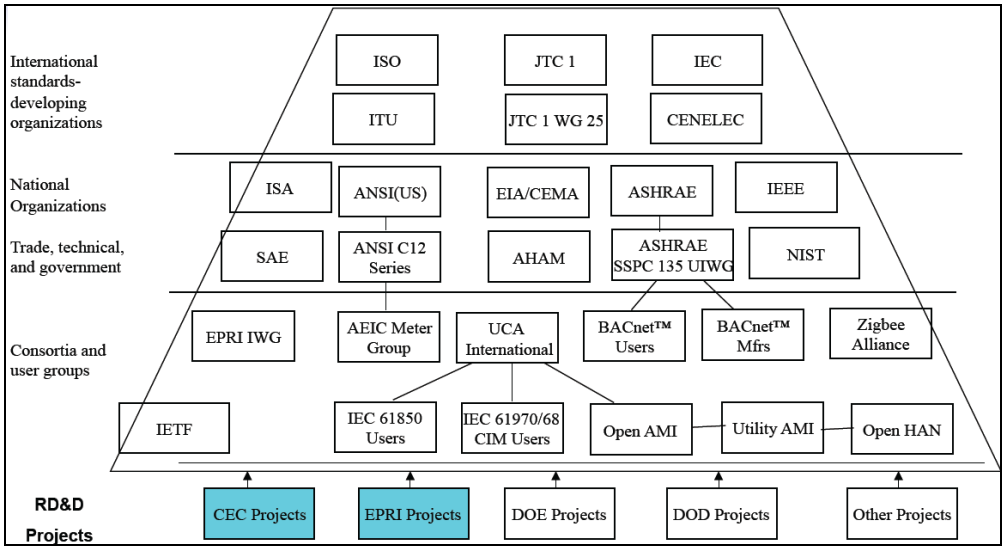


Figure 7-4
Key Standards Development Organizations Involved in Industry Level Infrastructure Development

The latest EPRI-NIST effort is focused on building from the ASHRAE RP 1011 project for structure of the RTP and control objects sent from the energy service provider/utility to the customers. The hope is that various committees working on end use equipment standards such as SAE, AHAM and others would see this as a time saving step to adopt similar messaging structure and semantics to reduce the need for application level translation.

Clearly, ingredients for a successful industry-level interoperable and managed systems development can be conceptualized as the three legs of the 3-legged stool:

- 1: Open, Mature Standards – Protocols, test schemas and object models
- 2: Involved User Community – Interoperability Agreements, Labelling, Testing and Issues Resolution
- 3: Reference Implementations and Designs: Focused Development Projects, Developer tools, standards implementations, test implementations and are open-source.

Again, these standards have to cover integration across both information technology (IT) and field equipment (real-time sense and respond capability). This will require data and application integration among the IT systems that span power procurement and market operations, regional transmission operators, distribution control centers and external corporations, coordinated with Customer and Distributed Energy Resources (DER) integration as well as upstream transmission, substation and distribution automation systems. In terms of applications, this spans enterprise applications, data management, communications infrastructure and sense-and-respond, dynamic system control type real-time applications at the grid operations and load management levels.

Much work needs to be done in order to ensure that central and remote applications have application layers standardized and harmonized to EPRI's vision of Common Information Model (CIM), issues with management and maturity are managed in a manner that results in development of common approaches that are adopted as appropriate. The physical media are either an artifact of the systems traditionally in place, or the required sense/respond technologies to achieve the desired functions, and should be chosen and used as appropriate. Figure 7-5 shows this process.

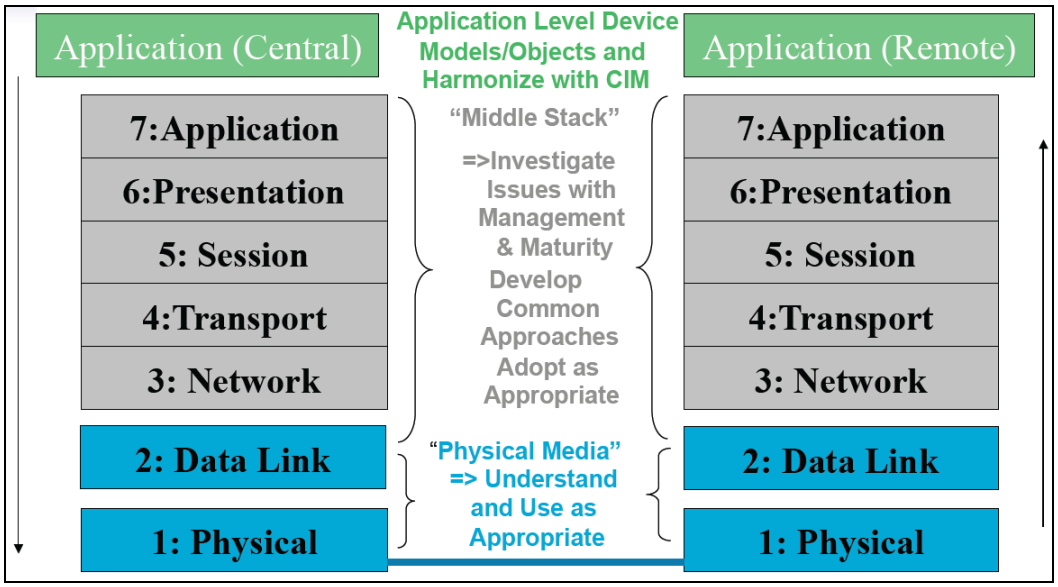


Figure 7-5
Application Layer Standardization as an Enabler to Interoperability

Fortunately, much of the work on infrastructure standardization has taken place and needs to be built upon. This includes IEC 61970-61968 covering Enterprise IT integration and IEC 61850 for Real-Time Field Automation and DER Integration among Generators, Transmission Operators, Substation and Distribution ops control centers and smart loads at C&I and now residential, among the SDOs that span IEC, IEEE (P37.118, IEEE 1547), SAE (for PHEVs), ANSI C12 (revenue metering), ASHRAE / ANSI 135 for Building Automation and ISA for industrial loads.

So, an approach to integrate common communications for a wide variety of RTP and ToU tariffs and other EE and DR communications signals can be conceptually seen as each utility broadcasting a package of information that covers its rate structure program, rate structure schedule and rates/pricing information, as seen by figure 7-6 below:

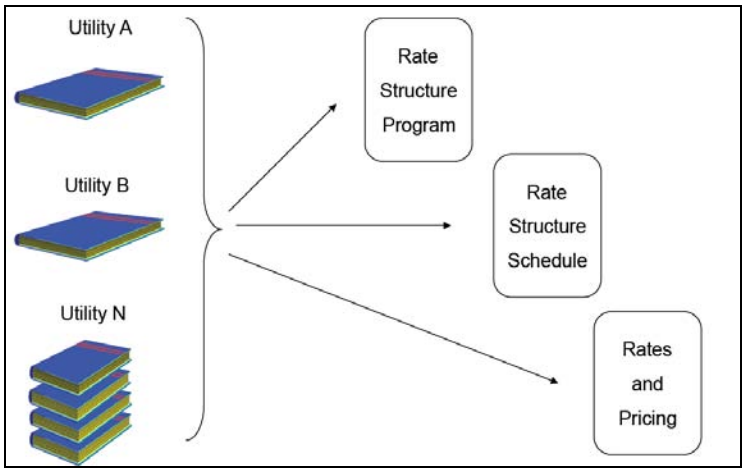


Figure 7-6
Approach to Integrating Common Communications for Wide Variety of Tariffs

In RP1011 domain, this tariff model looks as follows:

Table 7-1
RTPTariff Object Structure

```
Tariff
|__________ID
|__________NumMx
|__________Cmps[1..NumMx]
           |__________Pricing
           |__________Schd
           |__________RefProf
```

Tariff
The complete description of the dynamic electric rate tariffs.
ID
Identifier of tariff. For instance the rate schedule name could serve as an ID.
NumMx
Number of descriptive components of this tariff. For example, a tariff based on consumption pricing and demand pricing would be represented by NumMx of 2.
Cmps[]
An array of RTP component structures each of which describes price components. It uses NumMx as a dimension index of the array.
Pricing
Contains the pricing information of each element of Cmps. It embodies a data structure itself.
Schd
Contains a description of the real-time pricing schedule for the price component.
RefProf
Contains a reference load profile or customer baseline (CBL) for use in computing differential contributions to bill.

And a corresponding Real-Time Pricing communication object, "RTPProgram" has the following structure:

Table 7-2
RTPProgram Object Structure

Object Model: RTPProgram		
Component Name	DataType	Typical Content
Type_RTP (KWH[1],KVAR[2],KW[3])	ENUM8	1
EditMode (ADD[1], DELETE[2], REPLACE[3])	ENUM8	1 (ADD)
ListOfSchedule	Schedule[]	<list of schedule>

Whereas a Real-Time Pricing Communication object for pricing Schedule has this structure:

Table 7-3
RTPSchedule Object Structure

Object Model: RTPSchedule		
Component Name	DataType	Typical Content
Month	INT8U	0 = don't care
Day	INT8U	0
Hour	INT8U	9
Minute	INT8U	0
DayofWeek	DOW	-MTWTF-
DoOnce	BOOL	TRUE
Tier	INT8U	1

In the same fashion, recommended structure for RTP Pricing object ("RTPPricing") per EPRI and UCA Forum Work has been defined to be:

Table 7-4
RTPPricing" Object Structure

Object Model: RTPPricing		
Component Name	DataType	Typical Content
TypeRTP (KWH[1],KVAR[2],KW[3])	ENUM8	1
UnitPrice (CENTS[1],MCENTS[2])	ENUM8	1
NumberBins	INT16	25
PriceArray	OSTRING	UINT16[NumberBins]
OwnerArray	OSTRING	UINT8[NumberBins]

Implementation Pathway

When one looks at the magnitude of challenge that remains to achieve the 'holy grail' of 50-state, interoperable standards that will enable the PHEVs to communicate with the smart grid, it seems daunting. The devil is definitely in the details of implementation, and this implementation needs to be executed at three levels:

- Data Definition for Objects, that cover data semantics, syntax, type, precision, sign, encoding and significant bits, for example
- Coordinated standardization of hardware's ability to communicate, that covers Metering, C&I building automation systems, energy service clients, and customer / end use energy management systems, that cover SDOs such as IEEE PES, ANSI, IEC, ASHRAE, DMTF, SAE J2847/J2836, AHAM, ISA and customer forums such as Utility AMI/Open AMI/OpenHAN, ZigBee/HomePlug alliance, LBL DRAS, AMI SEC etc.

- Coordinated implementation from requirements through commercial rollout, which builds upon standardized definition, coordinated standardization and uses robust systems engineering and product development processes that mitigate risk, ensure high quality and reliability of products and services and deliver these cost-effectively to realize the full potential of the technologies. Figure 7-7 elaborates on this process:

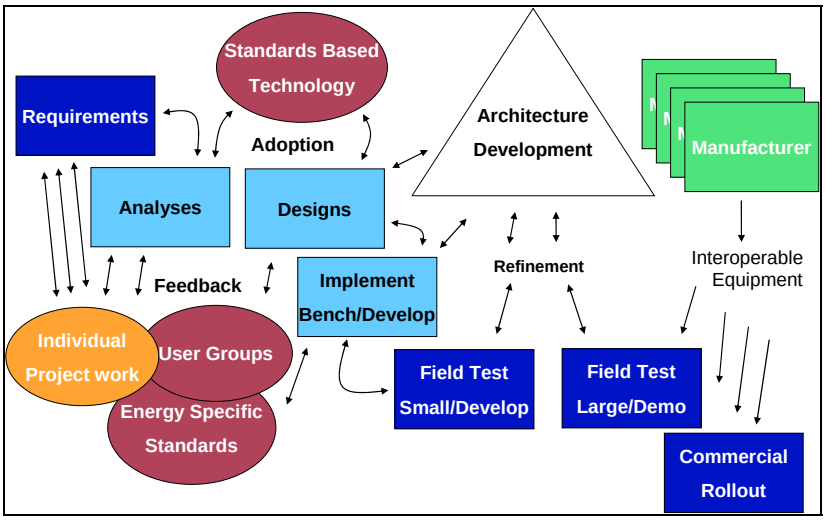


Figure 7-7
Pathway to Implementing Standards-Based Technologies for PEVs and Smart Grid

8
DIFFERENT STANDARDIZATION EFFORTS UNDERWAY

Until recently, a whole host of standards development processes and initiatives have emerged simultaneously and independently. These include:

- The ZigBee alliance[15] have released an application layer specification, named ZigBee Smart Energy Profile v1.0, which addresses communications requirements of smart loads such as PCTs and other devices.
- Simultaneously, HomePlug alliance[16] is in the process of ratifying the IEEE P1901[17] standard and product certification requirements that will address transport and application layer requirements for this broadband over powerline technology
- There is movement to unify the HomePlug and ZigBee alliances (Smart Energy Council Joint Steering Committee comprising of ZigBee, HomePlug, and utilities) making their application layers compliant with Smart Energy Profile 1.0 and the transport layers interoperable through bridging the wired and wireless protocols.
- Separately, EPRI's Electric Transportation group, utilities, and automotive industries are working on developing SAE recommended practices that the auto industry comply to, under J2847 containing use case documentation for utility-vehicle interface and J2836[18] actually containing the communications requirements between automotive industry. The SAE committees have always included participation from other SDOs like NEC[19], UL[20], EAEC[21], ISO[22] & JARI[23] to harmonize requirements.
- There is already a consensus building amongst SAE members that the best way to account for PEV-related communication requirements (PHEV objects) will be for SAE J2836 to use the Smart Energy Profile introduced by the Zigbee Alliance for the Application Layer and provide the necessary enrichment to Smart Energy Profile 1.0 (to create Smart Energy Profile v2.0).

[15] www.zigbee.org
[16] www.homeplug.org
[17] http://grouper.ieee.org/groups/1901/ - IEEE P1901 Draft Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications
[18] http://www.sae.org/servlets/works/committeeHome.do?comtID=TEVHYB6
[19] NEC – National Electric Code
[20] UL – Underwriters Laboratories Inc.
[21] EAEC – European Automotive Engineers Cooperation
[22] ISO – International Organization for Standardization
[23] JARI – Japan Automobile Research Institute

- EPRI's IntelliGrid group is putting together the Common Information Model (CIM) for data exchange between the smart grid (comprising of transmission, distribution and end-use systems) and smart loads such as PCTs and PEVs.
- EPRI's IntelliGrid group is working diligently with other SDOs such as ASHRAE, Bacnet[24] and NIST (National Institutes of Science and Technology) to create interoperable set of CIM objects that span the entire smart grid from transmission to end-use, incorporating ZigBee Smart Energy Profile v2.0 along the way to accommodate communication needs for PEVs.
- EPRI's IntelliGrid group is working on creating the AMI/HAN Interest Group to address the needs of the utility industry pertaining to Demand Response/Energy Efficiency Initiatives. Interest Group brings all the other utilities not represented in the Smart Energy Council as well as provide a formal interface to SAE and AHAM to this work. Additionally, the AMI/HAN Interest Group will provide the standard test procedures for different vendor products.
- EPRI's Infrastructure Working Council (IWC) group is also envisioned to be playing a central role in making appropriate revisions to IEC[25], IEEE[26] and NEC codes and standards.

EPRI's Role and Next Steps

The end vision of the unification and harmonization process amongst different SDOs is that each of the standards will have a unique focus but will cross-reference others where applicable, rather than recreating requirements in each instance. For example, it is envisioned that SAE J2836 will refer to Smart Energy Profile 2.0 and EPRI CIM for definition of the real-time pricing and DR/ load

EPRI's Electric Transportation and EPRI's IntelliGrid groups will need to work closely with various SDOs to ensure that the best practice elements of each of the effort are preserved and propagated with minimum of redundancy and maximum leverage in developing standards so that widely acceptable set of standards can be developed and supply base energized to help proliferate smart grid technologies across a wide spectrum of smart grid systems and smart loads, including PEVs.

Specifically, EPRI will work with SDOs, automotive OEMs, appliance manufacturers and utility organizations to develop interoperable set of standards, with the following specific steps to accelerate this process for PEVs:

[24] http://www.bacnet.org/
[25] IEC – International Electro technical Commission
[26] IEEE – Institute of Electrical and Electronics Engineers Inc.

- Participate in Standards development processes
  - Home Plug / ZigBee Alliance Certification development process
  - J2847/J2836 development process (roadmap in Figure 8-1 and Figure 8-2) and this group to work closely with the Smart Energy Council to establish a standard syntax and semantics for objects representing the attributes of PEV as well as a standard set of dynamic pricing objects and load control messages from the utility side
  - Smart Energy 2.0 Application Specification development process (Figure 8-2 and Figure 8-3)
- Industry-wide testing and validation
  - Work with chip suppliers on vehicle reliability requirements
  - Develop standard test procedures to evaluate advanced meters and AMI/HAN communication solutions
  - Develop, test, and verify message formats and structures
  - Test communications protocol functionality and interoperability with utility HAN/AMI systems
  - Validate Standard Application Layer specifications, certification testing, and J2836 message sets

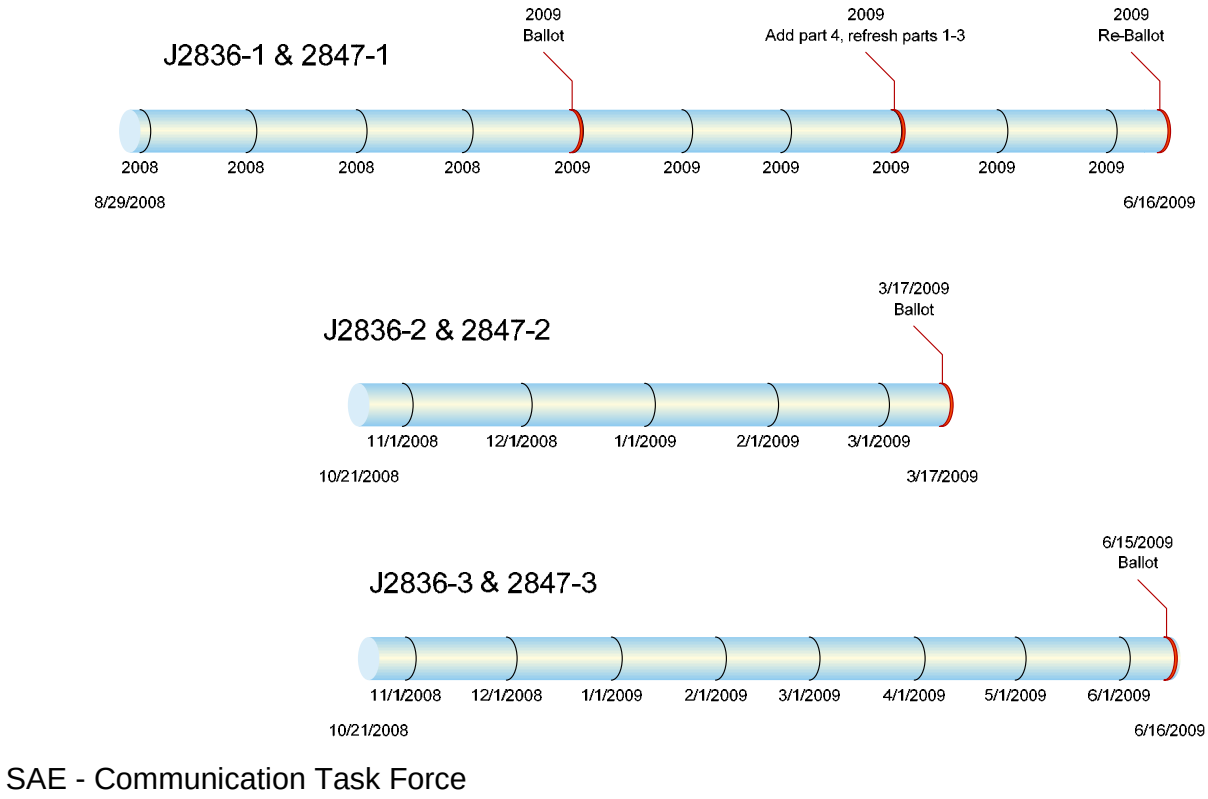


Figure 8-1
SAE J2836 Document Roadmap

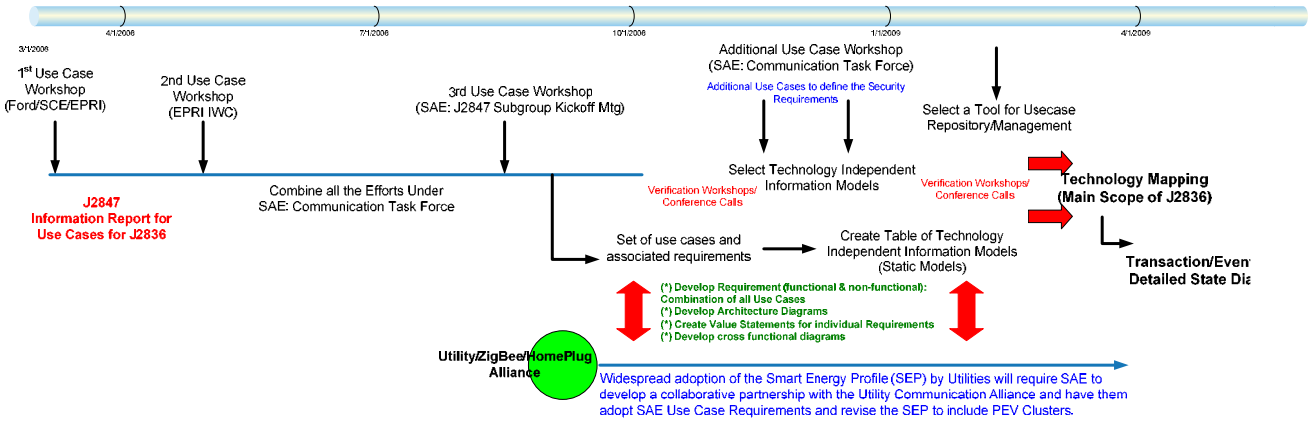


Figure 8-2
SAE J2847 Roadmap

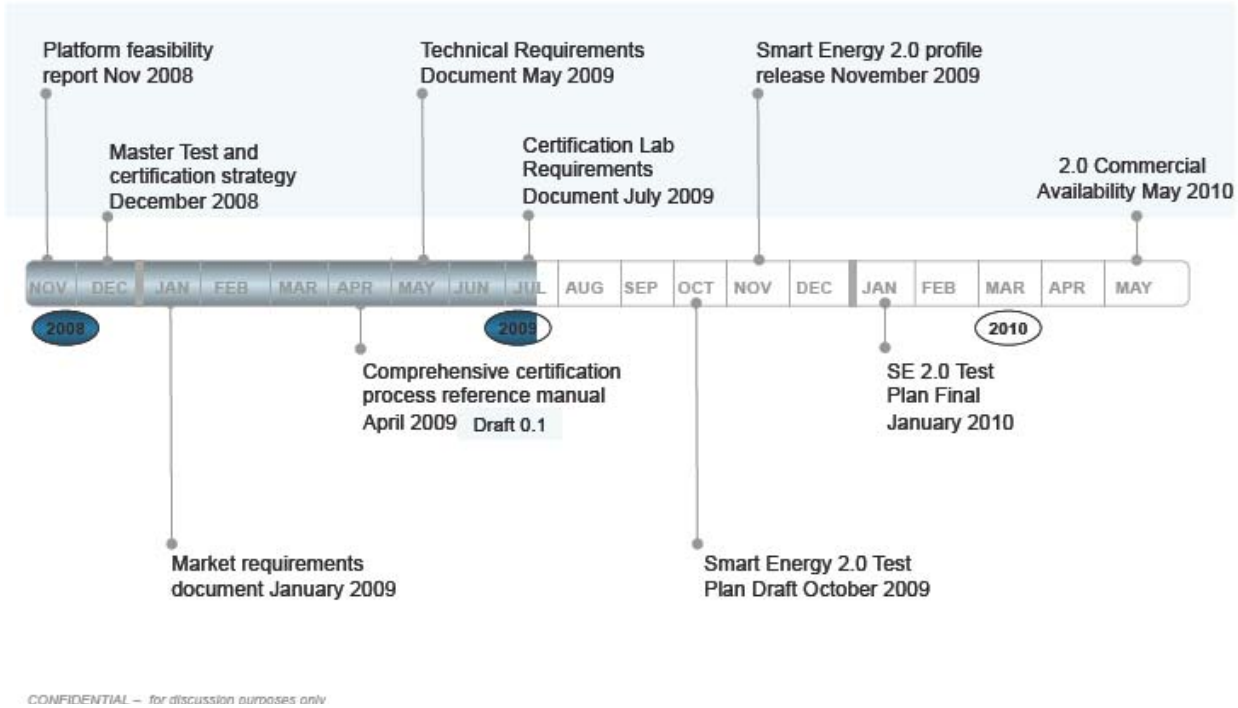


Figure 8-3
Smart Energy Profile 2.0 – High-Level Timeline and Milestones (Source: Smart Energy Council Alliance WorkGroup)

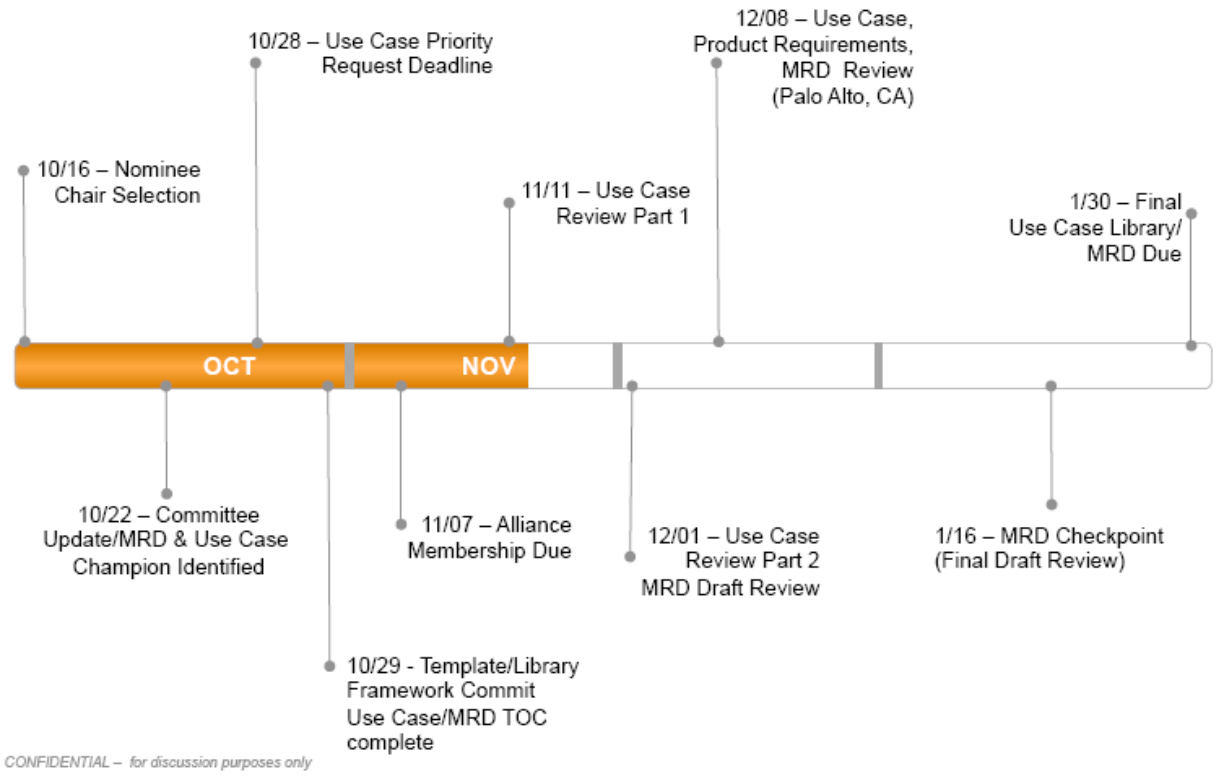


Figure 8-4
Use Case/Market Requirement Document (MRD) Development High-Level Timeline and Milestones (Source: Smart Energy Council Alliance WorkGroup)

A
GLOSSARY

Capacity Service (Demand Response Service Type) – A type of Demand Response service in which demand resources are obligated over a defined period of time to be available to provide Demand Response upon deployment by the System Operator.

Critical-Peak Pricing (CPP) – A type of pricing mechanism whereby normal flat rates or time-of-use (TOU) rates are in effect except for certain peak days, when pre-specified higher electricity usage rate is superimposed on the normal flat rate or TOU rate. CPP prices are used during contingencies or during high wholesale electricity prices for a limited number of days or hours per year.

Curtailment – The act of reducing electricity consumption in response to an event.

Customer Baseline Load or Baseline – The level of electricity usage that the customer would have consumed during a specified duration (event), in the absence of a demand reduction obligation.

Customer/Consumer Class – Customer type classification such as residential, industrial commercial etc.

Customer feedback – Consumption information communicated to the customer, which can be time-delayed or indirect (e.g. standard billing, enhanced billing, or web-based information, etc.), or instantaneous or direct (e.g. real-time consumption displays and monitors, etc).

Demand Bidding/Buyback – Demand Bidding (also called Buyback) programs are programs in which consumers bid on specific load reductions in the electricity wholesale market. A bid is accepted if it is less than the market price. When a bid is accepted, the customer must curtail his load by the amount specified in the bid or face penalties.

Demand Response – A change in a consumer's electricity usage level or profile in response to a change in the price it pays for electricity, or another inducement to do so.

Direct Load Control (DLC) – DLC programs enable utilities to remotely control and/or shut down participating customer equipment on a short notice. In return, participating customers receive upfront incentive payments or rate discounts.

Dispatchable - the extent to which a resource is available to be controlled by the system operator, who is responsible for the real-time physical balancing of the network.

Dynamic Pricing – A pricing mechanism whereby electricity is priced in a way that reflects the time-variation in electricity supply costs. This type of pricing generally provides an incentive to the customer to shift electricity usage from high-price periods to low-price periods.

Economic (Deployment Type) – The Demand Resource is dispatched based on its attributed economic value in the dispatch system it contributes to, helping to minimize the cost to serve scheduled or anticipated energy requirements.

Emergency Response – or Emergency Demand Response – A short-notice program that provides payments to electric customers for load reductions during emergency conditions. During these events, participants are expected (typically not obligated) to either reduce energy consumption or transfer load to an alternate off-grid source.

Emergency Service (Demand Response Service Type) – A type of Demand Response service in which the demand resource is dispatched as a supplemental energy resource to cover extreme circumstances which can compromise the reliability of the electric system.

Enabling Technology – Hardware, software and communication technology that is mandatory for implementing dynamic pricing-based programs. Examples of enabling technologies include energy meters/interval meters, thermostat/controls, and communications/network.

Energy Service (Demand Response Service Type) – A type of Demand Response service in which demand resources are compensated based solely on demand reduction performance.

Energy Efficiency – Improvements in equipment or systems that produce the same output while using less energy.

Event – A specified period of time when curtailments are to be undertaken by program participants or when price changes are to be posted.

Firm Power Level – A type of CBL in which the utility establishes for each customer an indicative coincident demand level and the participant elects how much of that indicative demand it will curtail during events. The Firm power level is one of the five categories that EPRI has identified for Demand Response performance measurement.

Impact Evaluation – An evaluation that compares actual performance of demand response programs, based on actual results and data, with expected or planned performance.

Installed Capacity (ICAP) – ICAP market programs are offered to customers who can commit to providing pre-specified load reductions when system contingencies arise. Participants usually receive a day-ahead notice of events and are penalized if they do not respond to calls for load reduction.

Interruptible/Curtailable (I/C) – These programs allow participating customers to receive upfront incentive payments or rate discounts, if they shed their load to a pre-defined level during a specific time. Participants who do not respond can face penalties, depending on the program terms and conditions.

Mandatory (Compliance Type) **–** The Demand Resource faces penalties if it does not comply.

Measurement and Verification (M&V) **–** Electricity consumption data collection, monitoring, and analysis for the purposes of establishing program performance.

Non-spinning reserve **–** An energy generating resource that is currently not running but is capable of being connected to the electric system within 10 minutes of being called, and can continue to operate continuously for a specific amount of time (typically at least 2 hours).

Peak-time Rebates **–** A program that allows customers to earn rebates for reducing their electricity use during days when electricity demand is the highest (critical peak days).

Performance **–** The difference between the baseline and the actual metered usage during the event (also termed as load impact).

Price response **–** Change in electricity consumption or shifting of electricity consumption from some hours of the day to others, in response to price increases or decreases.

Process Evaluation **–** Refers to the overall demand response program implementation procedure or plan including all administrative, marketing and management processes that were followed.

Rate Schedule/Tariff **–** A statement of the electric rates and terms and conditions governing the application, eligibility and contract terms and conditions.

Real-time Pricing (RTP) **–** RTP is a pricing mechanism whereby electricity prices may change as often as hourly (exceptionally more often) to reflect the cost of supply. A price signal is provided to the user on an advanced or forward basis, reflecting the utility's cost of generating and/or purchasing electricity at the wholesale level.

Regulation Service (Demand Response Service Type) **–** A type of Demand Response service in which a demand resource increases and decreases load in response to real-time signals from the system operator. Demand resources providing regulation service are subject to dispatch continuously during a commitment period.

Reliability (Deployment Type) **–** The Demand Resource is dispatched to preserve system reliability at acceptable levels.

Reserve Service (Demand Response Service Type) **–** A type of Demand Response service in which Demand Resources are obligated to be available to provide Demand reduction upon deployment by the System Operator, based on reserve capacity requirements that are established to meet applicable reliability standards.

Resource **-** A generating resource, a dispatchable load, an external resource, or an external transaction.

Retail Demand Response Program **–** A demand response program offered by retailers such as Utilities to end-use customers such as residential, industrial, commercial, agricultural etc.

Retail Electricity Market **–** A system that allows end-use customers to choose their energy service provider from competing retailers.

Smart Metering **–** A concept of metering that constitutes advanced electrical meters to measure consumption and other metering parameters in more detail than conventional meters and provide communications with both a home area network and the utility company.

Spinning Reserve **–** An energy generating resource that is currently running and can be connected to the electric system within 10 minutes of being called and can continue to operate continuously for a specific amount of time (typically at least 2 hours).

Supply **-** Electricity delivered to the system

Time-of-Use (TOU) **–** Electricity prices are set for a specific time period on an advance or forward basis. The electricity prices differ in different blocks of time. Prices paid for energy consumption during different time blocks are pre-established and known to consumers in advance, allowing them to vary their usage in response to such prices and manage their energy costs by shifting usage to a lower cost period or reducing their consumption overall.

Variable-Peak Pricing (VPP) **–** VPP is a three-period rate where the peak period price is directly tied to the day-ahead wholesale market, while the shoulder and off-peak prices are set ahead of time and maintained for a specific period of time (e.g., month, year, etc.). Variable peak pricing provides the customer with an opportunity to purchase energy during the on-peak period at prices that vary according to the energy market.

Voluntary (Compliance Type) **–** The Demand Resource is not penalized if it does not comply.

Wholesale Electricity Market **–** A system that utilizes supply and demand to set electricity prices (termed as clearing price) and allows the purchase and sale of electricity from competing generators to resellers (retailers) at the clearing price.

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