CPUC Energy Storage Use Case Analysis

[Renewable energy integration for electrical vehicles]

[Storage with charging station]

Version 0.2

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1. Overview Section

As California supports higher penetration of electrical vehicles (EVs), this may significantly increase load on the grid, and alter power consumption patterns. A typical round-trip work commute of 35 miles per day corresponds to the daily load of an average home (10 kWh). California policies encourage both the reduced tailpipe emissions profile of EVs, and the use of renewable energy sources for EV charging to reduce greenhouse-gas (GHG) emissions and dependency on foreign oil.

There remain many barriers to extensive penetration of EVs, however. On one side, consumers want to save money, to be environmental conscious, and to have a better driving experience. On the other, prospective EV owners exhibit “range anxiety” over how far a vehicle can travel on a single charge; they are concerned that an EV will dramatically impact their electricity bill, and they often read conflicting information about the environmental benefit of EV’s compared to hybrid vehicles.

Developing an infrastructure of charging stations is critical for mass deployment of EVs, in part to cover for range limitation but also to provide charging options to the majority of Californians who live in multi-dwelling units and do not own a home. To that effect, the California Energy Commission (CEC) has an on-going program to invest in alternative infrastructure.

Energy storage is a potentially valuable component for the development of EV charging that optimizes renewable energy inputs. Storage alleviates intermittency from solar generation (e.g., impact of cloud formation), shifts load on the grid to a time when the contribution from wind turbines is higher (e.g., at night), and provides additional comfort to consumers that the energy used to power their vehicles is clean and environmentally preferable.

Storage may also reduce the higher impacts of energy consumption above specified baseline tiers (as in California’s residential retail electric rates), and could provide even greater advantages under time variant pricing structures. This could allow EV charging costs to be more stable than fluctuating gasoline pump prices have been.

2. Use Case Description

This Use Case describes energy storage associated with an EV charging station. First, we consider energy storage deployed with a private charging station within the premises of a consumer home. It is similar to the Use Case where energy storage is deployed with solar PV to offset energy from the grid. Second, we look at the case where the charging station is open to the public, hence increasing significantly the demand requirements as more vehicles will be connected to it during a day. We consider both cases because they cannot be separated from the point of view of the customer who will use both to recharge an EV.

It is assumed that the private station supports a slower level service (SAE level 1 or 2) that can recharge an EV in a few hours at night with Alternative Current (AC). It is assumed that the public station supports a faster charging service that can recharge the EV in 30 minutes with Direct Current (DC) or three-phase AC.

The activities of Tesla illustrate both cases. Working with Solar City, Tesla has applied for rebates for 70 battery home installations under SGIP. They are also planning a new public super charging station between San Francisco and Los Angeles, but it will be limited to Tesla customers. We will also look at other real-world examples from outside California.

2.1 Objectives

Energy storage offers a way to decrease the pollution of an EV by integrating a higher level of renewable energy than the grid. This can be done by (1) integrating a local solar roof or a wind turbine collocated with the station, (2) being connected to a local wind-farm on the same distribution network, or (3) being controlled by the utility to store energy from the grid when there is an overflow of solar energy (mid-day) or solar energy (night).

Cases (2) and (3) involve utilities. They are currently not allowed to operate public charging stations but they could be in charge of Community Energy Storage (CES) function (case 2) or Demand Response (case 3).

2.2 Actors

In this Use Case, the storage facility may be owned by 1) the operator of the station or 2) a third party that has a franchise of stations opened to the public. Although utilities are not allowed to own charging stations for now, but we will discuss this case in comments as this could change in the future.

Name	*Role description*
Auto-makers	Build and deploy EV's including charging interface used at stations
Drivers	Purchaser of EV's and user of station
Station makers	Manufacture charging stations compatible with various services and standards
Station owner	Provide charging service
Utilities	Provide electricity and could manage DR and CES functions
ISO	Regulating the grid and could provide information about best time to recharge via DR

2.3 Regulatory Proceedings and Rules that Govern Procurement Policies and Markets for This Use

Agency	*Description*	*Applies to*
CPUC	Renewable Portfolio Standard Bidding	Utility/Third Party
CPUC	Self Generation Incentive Program	Utility/Station Owner/Drivers
CEC	Investment Plan for the Alternative And Renewable Fuel and Vehicle Technology Program,	Station owners, Third-party Owners, Station Makers
EPA	Fuel Efficiency Standard	Auto Makers/Utilities/ISO

In addition, On May 23, 2012, Governor Brown issued an Executive Order directing the

Energy Commission, ARB, and the California Public Utilities Commission to work with the Plug

-in Electric Vehicle Collaborative and California Fuel Cell Partnership to develop the

infrastructure that will accommodate zero-emission vehicles from 2015 through 2025. 33 Along

with the Executive Order, the Governor announced a settlement by the California Public Utilities Commission with NRG Energy, Inc., that will support the further construction of at least 200 fast chargers and a minimum of 10,000 other chargers in at least 1,000 locations around the state. The energy storage device is located at the site of the charging station. The station is connected to the distribution network but can be located close to a transformer or sub-station depending on whether it helps integrating a higher level of renewable energy.

2.4 Location

The energy storage device is located at the site of the charging station. For the private station at home, it is typically connected to the distribution panel or directly to the solar roof. For the public station along motorways, the station is connected to the distribution network but can be located close to a transformer or sub-station depending on whether it helps integrating a higher level of renewable energy.

We do not consider the case of the energy storage within the EV although it could be used to capture benefits of providing frequency regulation to a utility or grid operator. This is an approach considered by NRG in collaboration with University of Delaware for the network of charging stations eVgo in Texas and California.

2.5 Operational Requirements

2.5.1 Private station requirements

The private station should be able to recharge an EV that has on average today a battery of 20 kWh. We will take this as the size requirement. The battery should be able to support SAE level 1 and 2 so EV can be recharged during a lunch break or overnight.

Characteristic	*Requirements*
Storage capacity	10kWh or more
Size	Size of small appliance like refrigerator to fit in garage
Service	SAE level 1 or 2

2.5.2 Public station requirements

A public station should support multiple EV's recharging during the day. With 30 minutes interval over 10 hours of day-time, it should support 20 recharges across various EV's

(BEV, PEV, and PHEV). We take an average of 10 kWh, which corresponds to a size of 200 kWh.

This can be supported by a solar installation of about 40 kW (carport), or a couple of few urban wind turbines. However, as the number of EVs increases, multiple stations will be needed (typically eight at gas stations), requiring much larger source of renewable energy (1-2 MWh). It is difficult to see that co-located to the charging station, so the energy storage would need to integrate remote renewable energy sources on the grid in order to scale.

Characteristic	*Requirements*
Storage capacity	200 kWh per station
Size	Size of gas pump
Service	Fast charging service. SAE level 3 is still under work. Available interfaces today: CHAdeMO (Japan), HPC (Tesla), and Combo Charger (SAE)

2.6 Applicable Storage Technologies

The potential storage device that appears most applicable to this Use Case in a home environment is some form of battery that can deliver electricity quickly with a minimal footprint. Commercially viable batteries of this scale include Sodium Sulfur (NAS) and Lithium Ion (Li-Ion).

Batteries are also good candidates for public charging stations. However, other technologies could be deployed to fit in underground spaces (like it is the case for gasoline today). Compressed air storage (CAES) facility could also provide the right combination of response rate and rated power, but is not as widely available as batteries at this scale.

Capacitors do not support the capacity requirements for such large stationery applications.

Storage Type	*Storage capacity*	*Discharge Characteristics*
Batteries (NaS, Li-Ion)	10 kWh to 500kWh	Fast response, medium duration

2.7 Non-Storage Options for Addressing this Objective

Among options available to address renewable energy variability:

- At home--Demand Response programs that control EV's batteries at home. ISO and utilities could coordinate charging events to reduce peak demand and also integrate wind power at night;
- At public station--remote energy storage collocated with solar or wind farm that utilities can connect to the distribution network where the station is located.

It is also important to note the alternative for consumers to use charging stations outside their home or usual workplace. The relative success of the (petroleum hybrid) PHEV gives the flexibility to refuel their vehicle with gas for longer trip, and use electricity for daily commutes.

3. Cost/Benefit Analysis

3.1 Direct Benefits

End Use	*Primary/ Secondary*	*Benefits/Comments*
1. Frequency regulation	S	
2. Spin		
3. Ramp		
4. Black start		
5. Real-time energy balancing	S	
6. Energy arbitrage	S	
7. Resource Adequacy	P	
8. VER[1] / wind ramp/volt support,		
9. VER/ PV shifting, Voltage sag, rapid demand support	P	
10. Supply firming	S	
11. Peak shaving: load shift	P	
12. Transmission peak capacity support (deferral)		
13. Transmission operation (short duration performance, inertia, system reliability)		
14. Transmission congestion relief		
15. Distribution peak capacity support (deferral)	P	
16. Distribution operation (volt/VAR support)		
17. Outage mitigation: microgrid		
18. TOU energy mgt	P	
19. Power quality	S	
20. Back-up power	S	
21. Community Energy Storage	S	

[1] VER = Variable Energy Resource

3.2 Other Beneficial Attributes

Benefit Stream	*Y/N*	*Assumptions*
Flexibility (Dynamic Operations)	Y	
Reduced Fossil Fuel Use	Y	
Reduced Emissions	Y	
Increased T&D Utilization		
Reduced T&D Investment Risk		
Power Factor Correction		
Optionality		
Other		

3.3 Analysis of Costs

Cost Type	*Description*
Energy storage element	Cost is approximately $500/kWh but can vary significantly on technology used
Installation	Cost to get permit to install station is significant for home installations (about $2,000) . For public installations, infrastructure work requires significant planning with local authorities and utilities
O&M	The addition of an energy storage gives the ability to control the stations remotely (smart systems) and should minimize O&M costs as a result compared to gas stations that require to continuously refill the tanks with truck rolls

3.4 Cost-effectiveness Considerations

Prices of batteries are coming down significantly now with the deployment of EVs, and other technologies like CAES could make energy storage installations even more attractive. In particular, home owners and managers of multi-dwelling units are sensitive to the pay-back period of their investment. It is not clear whether the addition of an energy storage unit of 10 kWh at a home today makes a solar deployment more cost-effective. The move from Net Metering to Time-of-Use could make it more cost effective. In Japan, where consumers have been marked by the black-out after the Tsunami, Nissan is offering a 6 kWh battery with its charging station to provide back-up power.

The price of energy storage in public infrastructure is much less consequential. However, the size of the installation (200 kWh per pump) makes it significant in size, and it is not clear whether it makes more sense for the utilities to deploy it with solar or wind farms connected to the distribution network, or for the operators of public station to invest in energy storage to guarantee a better level of service. Clean energy at public stations could be marketed by different levels like "50% green" or "100% green" compared to what the grid provides. This would be similar to the 87/89/91 scheme at gas stations today and end-consumers could easily manage that offer. Regulators would have the ability to subsidize various offers to give incentive to use less fossil fuel.

4. Barriers Analysis and Policy Options

4.1 Barrier Resolution

Barriers Identified	*Y/N*	*Venue for Resolution*
System Need	Y	TBD
Cohesive Regulatory Framework	N	Not for public station (SGIP for private station)
Evolving Markets	Y	TBD
Resource Adequacy Value	Y	TBD
Cost Effectiveness Analysis	N	TBD
Cost Recovery Policies	Y	TBD
Cost Transparency & Price Signals	Y	TBD
Commercial Operating Experience	N	TBD
Interconnection Processes	N	TBD

4.2 Other Considerations

It is important to note that consumers purchase cars for aesthetic reasons as well, and over investments in renewable integration would not necessarily lead to further penetration of EV's. Rather, energy storage can be used as a flexible tool to provide a consistent EV offering to end-consumers: the ability to recharge an EV with significantly less emission than internal combustion engines (ICE) or hybrids, and at a price that is predictable and smaller than the price of gasoline in miles equivalent. Finally, the technology used for energy storage should reduce and not increase the time of recharge so it is a comparable or better experience than refueling an ICE. In particular, safety considerations for fast-charging stations at 400-500V must be taken into account.

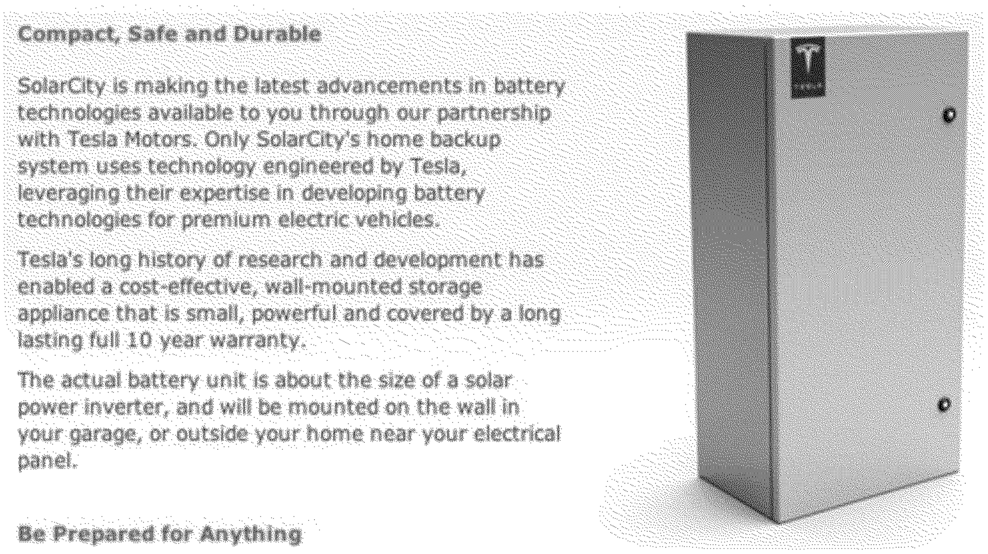
5. Real World Examples

We look at four real-world examples: two at consumer premises (private charging stations) and two along motorways (public charging stations).

5.1 Example 1: Solar City and Tesla (California)

5.1.1 Project Description

Solar City is installing batteries at the home of 70 owners on Tesla EV's. Solar City uses the Li-ion technology packaged by Tesla. Solar City applied to PG&E for rebates under the SGIP program. Starting in 2009, SGIP started offering credits of $2 per watt for energy storage systems that can store power from an eligible on-site generation system and discharge it at rated capacity for a four-hour period. Most installations are rated for 5kW with a four hour discharge. The total amount that SolarCity filed for is 500kW (2MWh) corresponding to a 28-kWh average.



Picture – courtesy of Solar City

Location	California
Operational Status	Deployment in 2012
Ownership	Solar City
Primary Benefit Streams	Reduce Emissions and Load
Secondary Benefits	Back-up Power and Integration of solar roof
Available Cost Information	

5.1.2 Outstanding Issues

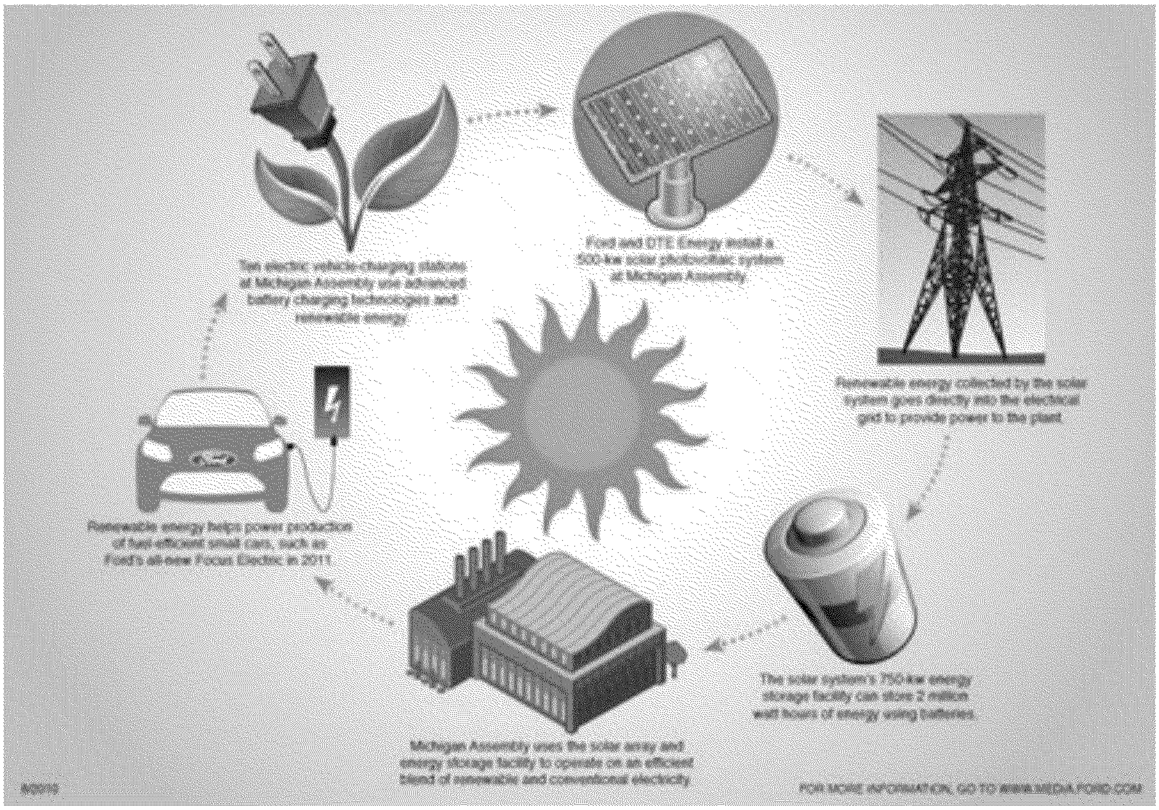
Description	*Source*
Can SGIP scale to support the procurement of batteries, or it should be done under a different program	Olivier Jerphagnon, The Green Frog
	Ask Tesla/SolarCity and owners of vehicles

5.1.3 Contact/Reference Materials

5.2 Example 3: Ford (Michigan)

5.2.1 Project Description

Ford has teamed up with DTE Energy, Xtreme Power and the state of Michigan to establish one of the largest solar power generation systems in Michigan at Ford's Assembly plant. The energy storage component consists of 750 kWh from Xtreme Power (lead acid battery) and 50kWH of re-used EV batteries (Lithium-Ion). This will be used to power the plant with a mix renewable and conventional energy, but more interesting to the Use Case, it will power 10 EV charging stations with 100% renewable energy as the plant.



Picture – courtesy of Ford

The size of energy storage per station is 80 kWh. This shows the storage requirement in a high throughput environment at the factory (corresponding to high penetration rate of EV's on the road) is much higher than a stand-alone installation at home or in a parking lot. This gives good insights on the scope of public charging installation to interoperate with the grid. There is an order of magnitude difference (100 kWh compared to 10 kWh). Most public charging stations today at parking structure and airports use lower level of service (SAE level 2) and do not see a high throughput of vehicles during a day compared to a gas station.

It is worth to note that depending on the success of the pilot with re-used EV batteries, Ford will decide what type of technology it will deploy at its factories to produce EVs.

Location	Ford Motor Company, Michigan
Operational Status	Project launched in 2010 and completed in 2011
Ownership	Ford
Primary Benefit Streams	Reduce Emissions
Secondary Benefits	Integration of solar roof
Available Cost Information	

5.2.2 Outstanding Issues

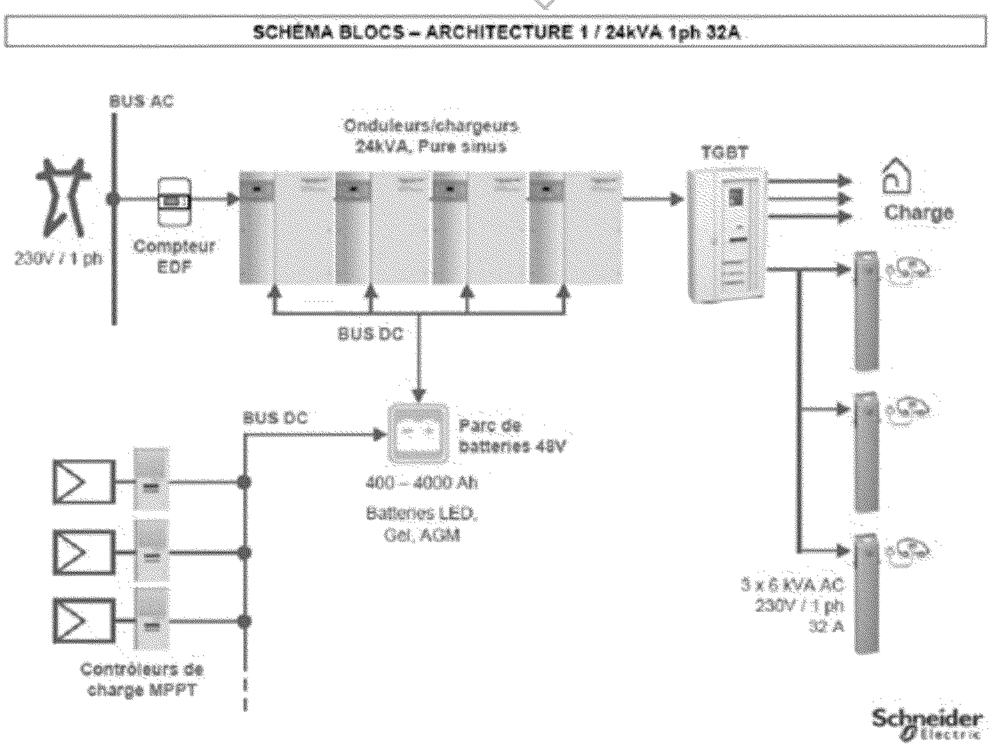
Description	*Source*
What is best type of batteries?	Ford
Maintenance of batteries given frequent charge/discharge cycles?	Olivier Jerphagnon, The Green Frog

5.2.3 Contact/Reference Materials

5.3 Example 4: Project Green on Island of La Reunion (France)

5.3.1 Project Description

The French island of La Reunion has the highest level of solar in its energy mix (30% at peak, 5% on average). The recent decrease in feed-in-tariffs and the emergence of EV's has led the local actors (solar integrators, car dealership, energy operator, etc.) to look at deploying a network of 50 charging stations power by solar.



Picture – courtesy of Schneider Electric

SB_GT&S_0185787

The charging station functions at 32 Amps and 230V – single phase. The 48V batteries are connected to the grid via an AC-to-DC converter and solar installations. Each battery module supports 19.2 kWh (400Ah at 48V) and one station can host up to 10 modules for a total capacity of 192 kWh per station.

The team deploying the 50-station pilot consists of : Renault (EV maker), EDF (utility), le Groupe Bernard Hayot (car dealership), Total (energy giant), Tenesol/Sunzil (solar integrator), Schneider Electric (equipment manufacturers), GE and ADAMELEC. The main goal is to reduce emissions in a region where the energy mix comes from fossil fuels at 67%.

The project will also study the demand profile and optimize the dimensioning of the different parts of the architecture to deliver the best service to consumers. In particular, the project will aim to demonstrate a mobile charging offering on the island across 50 stations.

Location	Island of La Reunion, France
Operational Status	Pilot on 50 stations
Ownership	EDF
Primary Benefit Streams	Reduce Emissions
Secondary Benefits	Mobility of offering across multiple stations
Available Cost Information	Ask contact at Tenesol

5.3.2 Outstanding Issues

Description	*Source*
Cost of batteries	Sunzil (Tenesol)

5.3.3 Contact/Reference Materials

Contact at Sunzil (formerly Tenesol)
Yannick MELLE
Director for Indian Ocean installations
16 rue Gustave Eiffel
ZA Ravine à Marquet
97419 La Possession
Standard : 0262 444 444
Mobile : 0692 82 82 11

6. Conclusion and Recommendations

We looked at both private and public charging stations. Energy storage can play a significant role to reduce carbon emissions and provide several benefits to the grid.

The deployment of smaller energy storage elements (10-20 kWh) at the customer premise makes particular sense in conjunction with solar installations. As the cost of energy storage will continue to decrease, utilities will receive more SGIP applications. Like for solar in the past, it is pertinent to discuss whether SGIP can scale to support the deployment of EVs. The Energy Storage (AB 2514) could facilitate the procurement of energy storage by end-consumers so the amount of distributed storage increases as solar increases to relax the pressure on the grid that has difficulty to integrate solar and wind due to intermittency.

The deployment of larger energy storage elements (100-200 kWh) at public charging stations is more complicated but can offer additional benefits to overall eco-system. The role of the utility becomes more important and more discussions are needed to see how this could be integrated with AB 2514. In particular, as noted in the Governor's executive order earlier this year to encourage distributed generation, it would make sense to deploy those stations close to transformers or sub-stations to facilitate the integration of wind and solar into the network. If transformers or sub-stations are installed along motorways, the Use Case could become a viable model to aggregate a large number of EV charges. It remains to be discussed how the operators of the public stations would interact with the grid, either via the local utility or directly with the California ISO.