Loyola Marymount University

System Analysis Design

EV Charging Station Infrastructure

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Contents

Charging Station Infrastructure for Electric Vehicle

"My motivation for all my companies has been to be involved in something that I thought would have a significant impact on the world."

— Elon Musk

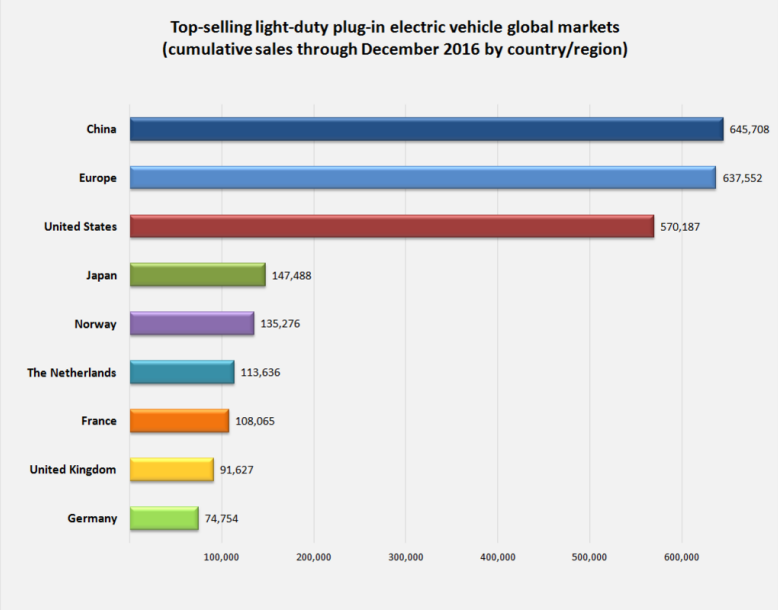
Introduction

1.1 Growing Popularity of Electric Vehicle in the World and U.S.

In recent years, with the development of battery technology, plug-in Electric Vehicle (PEVs) become more and more popular. Global sales of Electric Vehicle have increased more than ten-fold, totaling more than 550,000 units in 2015, and more than two million PEVs have been sold worldwide in the year 2016.

- CHINA 645,708
- EUROPE 637,552
- U.S. 570,187

In 2016, China had the largest stock of all Electric Vehicle with 645,708 vehicles on the roads, representing about 30.5% of the global stock, followed by Europe with 637,553 vehicles and the U.S with 570,187. [1]

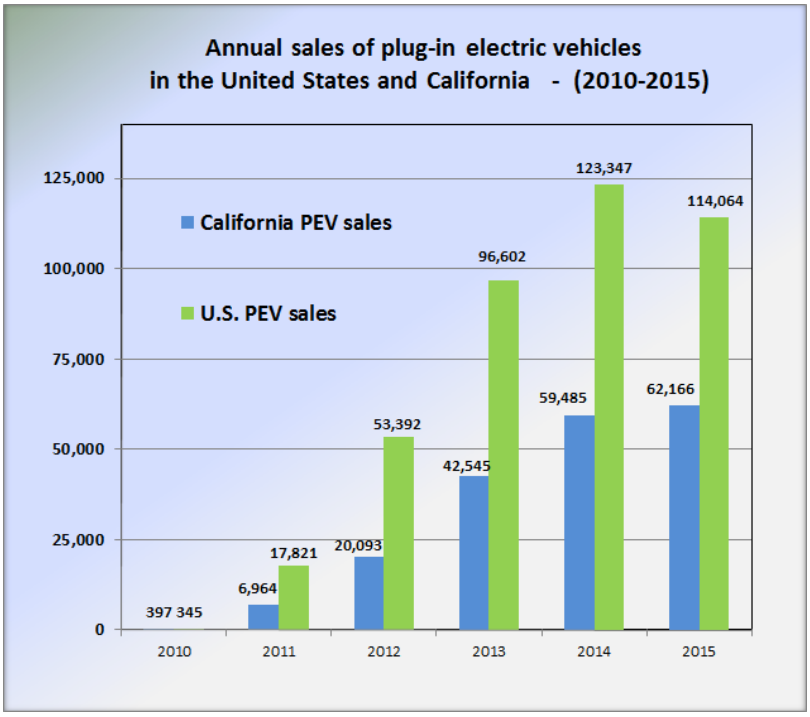


[Fig-1] EV Sold by Country in 2016

In 2015, Electric Vehicle annual sales in the U.S.

- CA YEAR 2012 — 20,093
- CA YEAR 2013 — 42,545
- CA YEAR 2014 — 59,485
- CA YEAR 2015 — 62,166

was 114,064. And in 2016, 157,181 were sold, up 37.6% from 2015. The cumulative sales in the United States totaled 570,187 since the market launch of the Tesla Roadster in 2008. [2]



[Fig-3] EV in the U.S. and CA

Among all the states, California is the largest U.S. car market, which totaled about 270,000 at the end of 2016 and accounts for approximately 48% percent of cumulative Electric Vehicle in the American market from 2011 to 2016.

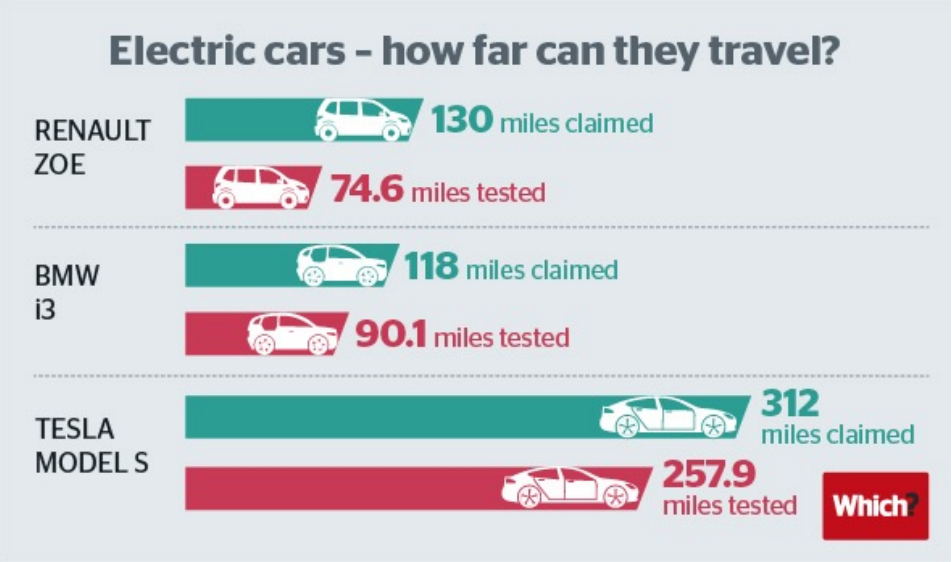
1.2 The Problems Associated with Electric Vehicle

- **Limited Range Miles need Repeat Charging**

With the increasing popularity of Electric Vehicle, most important questions about Electric Vehicle are their battery range. Users expect their electric cars to run as far as possible and be able to compete with a full tank of petrol or diesel cars.

From the [Fig-4], the Tesla Model S has the best range 257.9 miles, which hit 83% of its claimed range 312 miles. The BMW is 90.1miles, hitting with 76% of its claimed range 118 miles. While the Renault Zoe is only 74.6 miles, with a poor 57% of its claimed range 130 miles. [3]

- RENAULT 130 Miles/ 74.6 Miles
- BMW I3 118 Miles/ 90.1Miles
- TESLA 312Miles/ 257.9 Miles

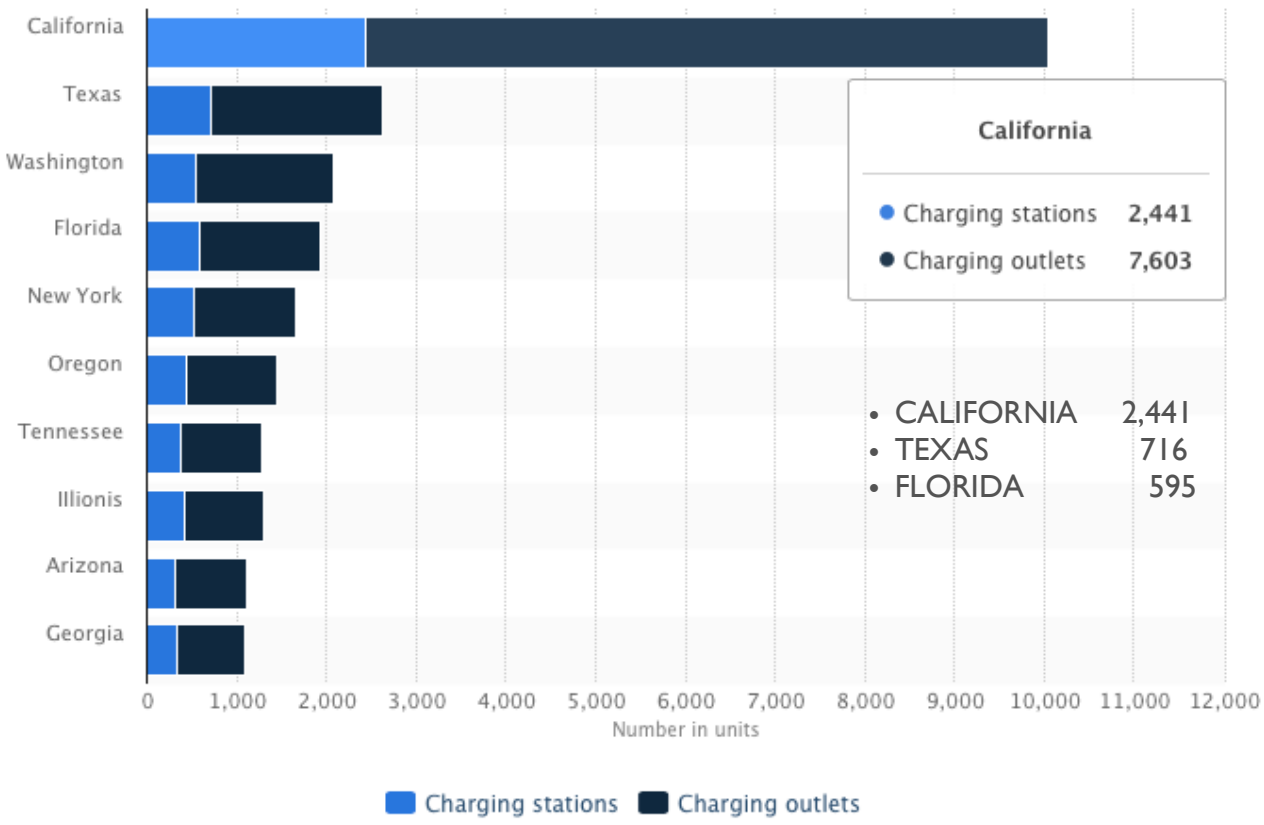


[Fig-4] EV Miles Test

All of them fall short of claimed range! Even though, the Tesla could offer enough real world range for most drivers of over 250 miles. However, BMW and Renault have less than 100 miles, which means the users have to stop for top up charges on longer journeys.

- **Limited Number and Distribution of Charging Stations**

[Fig-5] EV Charging Station in the U.S., represents the leading U.S. states in terms of electric



[Fig-5] EV Charging Stations in the U.S.

vehicle charging stations and charging outlets as of March 27, 2015.

California had 2,441 private and public charging stations.

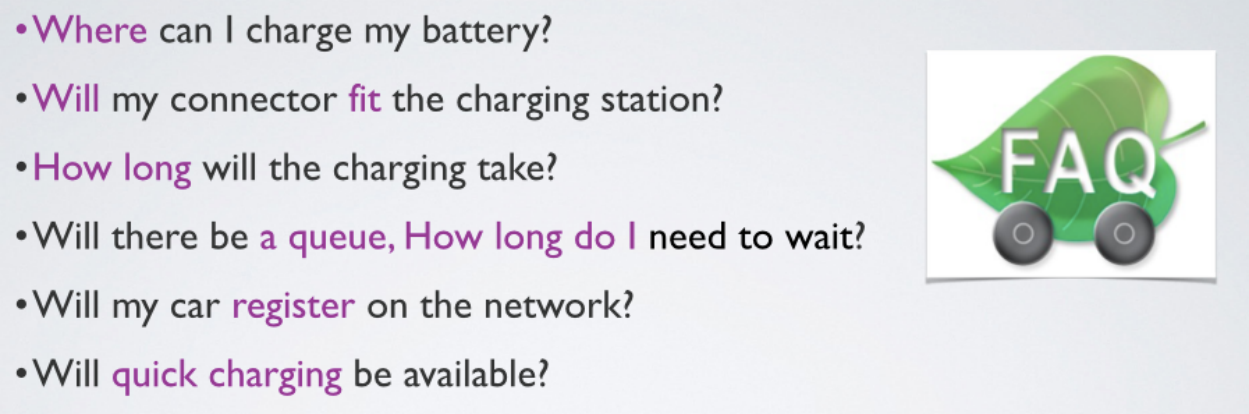
Texas had 716 private and public charging stations.

Florida had only 595 private and public charging stations. [4]

Although the development of Electric Vehicle and EV charging stations is increasing fast and is enormously successful these years, it is far, far from enough!!

1.3 Questions EV Users Posed about EV Charging Stations

In recent years, in spite of the fact that battery performance had largely improved, and electric bills are dramatically lower than fuel cost, the market for Electric Vehicle remains low. The EV users have some concerns about EV charging stations:



Either the user plans to charge at public charging stations, at work, or to purchase a charger of at home. The user will need the answers to these frequently asked questions on EV charging, such as will the connector fit the charging station? How long will the charging take? etc. In this project, we will discuss these problems and find some solutions and build suitable EV charging station network for EV users.

1.4 Types of Plug-in Electric Vehicle (PEV)

A Plug-in Electric Vehicle (PEV) is a general term for any car that runs at least partially on battery power and is recharged from the electricity grid.

There are two different types of PEVs:

1) Battery Electric Vehicle (BEV). Pure BEVs have an electric motor rather than a gasoline en-

BEV and PHEV Characteristics

	Battery Electric Vehicle	Plug-in Hybrid Electric Vehicle
Propulsion	Electric motor / battery only	Electric motor / battery plus gasoline engine
Refueling	Recharge with electricity	Recharge with electricity OR refuel with gasoline
Range	BEVs can travel between 70 – 100 miles (some go even further) on a full charge. Most Californians travel less than 40 miles	PHEVs can travel on battery power alone between 15 – 35 miles, and 300+ in gasoline-electric hybrid mode.
Charging	**Time:** Full size BEVs take about 4-6 hours to fully charge using a 220-volt charger. **Charger Type:** A 220-volt charger can be used for fastest home charging, but all PEVs can also charge from a 120-volt outlet. **Cost:** BEVs typically cost about $1 per gallon equivalent (when charged during off-peak hours at 10□ kWh).	**Time:** PHEVs take about 1 hour to fully charge using a 220-volt charger, and about 3 hours at 120-volts. **Charger Type:** Charging from a 120-volt outlet is usually preferred by PHEV drivers, since there is no cost for charging equipment and the time to charge is minimal. **Cost:** The cost will depend upon the ratio of electric to gasoline miles you drive.
Battery	BEVs on the market today typically have lithium ion batteries that are between 24kWh – 36 kWh in size	PHEVs typically have Lithium Ion batteries, but they are smaller than those found in pure BEVs.
Emissions	BEVs are zero emission vehicles. The only emissions are from utility generation mix.	PHEVs have very low emissions. Actual emissions depend upon the electric to gasoline ratio used.

[Table-1] BEVs and PHEVs, data from drive clean.ca.gov

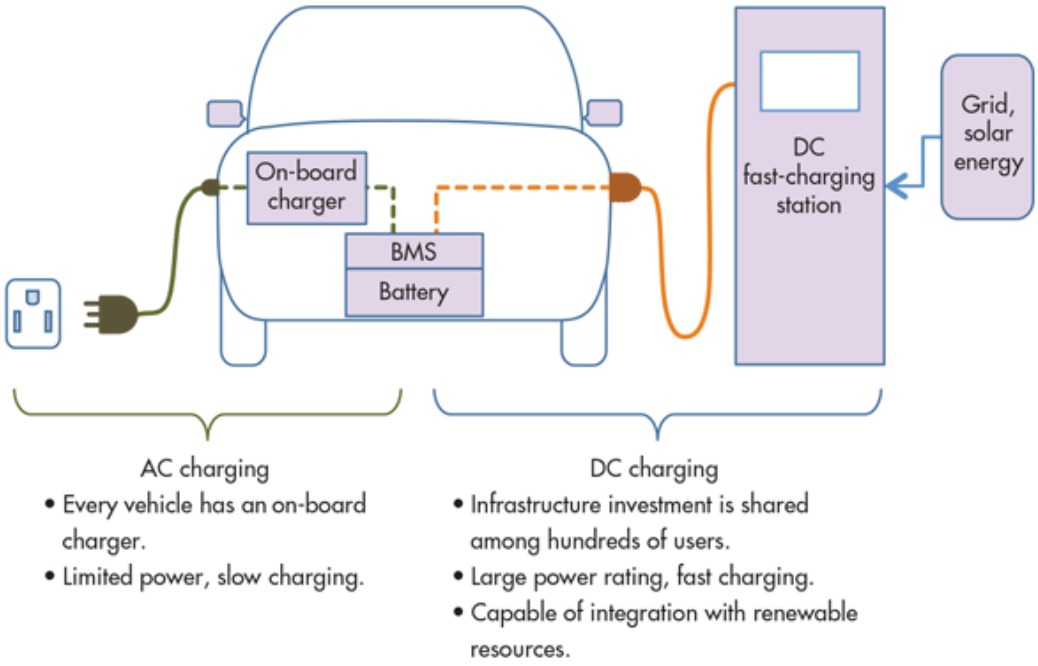
gine. BVE run completely on electricity stored in batteries.

2) Plug-in Hybrid Vehicle (PHEV). PHEVs combine two propulsion modes in one vehicle – an electric motor that is battery powered and can be plugged in and recharged, and a gasoline engine that can be refueled with gasoline. It can recharge with electricity or refuel with gasoline. [5]

- **AC and DC charging at PEVs**

There are two ways to transfer electricity from outside the vehicle to the battery inside:

1) AC charging, also categorized into on-board charger (OBC): It allows an AC power source



[Fig-6] AC Charging VS DC Charging

from the main supply at the consumer's workplace or at home, and converts it to DC to charge the battery. Because of the AC charger's limited power rating—a constraint arising from the limitations of allowable weight, space, and cost, AC charging is slow.

2) DC charging, also categorized as an off-board charging station: It supplies regulated DC power directly to the batteries inside the vehicle. A DC charger's power rating can be as high

as hundreds of kilowatts, because the DC charging equipment is installed at fixed locations with little constraint of size. [6]

1.5 Charging Station Levels

There are three primary types of charging stations: AC Level 1, AC Level 2 and DC fast charging (DCFC). Since the adoption of a standard connector (J1772), every new PEV can be

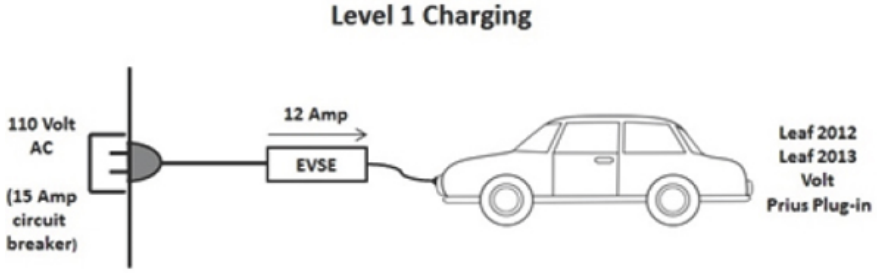
Charging Level	Power Supply	C Amps	Charger Power	Miles/Hour of Charge	Type of PEV	
					Nissan LEAF	Chevrolet Volt
AC/ Level 1	120VAC	16 Amps (Onboard Charger)	1.4 kW	~3–4 miles	~ 12 hours	~ 9 hours
AC/ Level 2	240 VAC	13.7 Amps 27.5 Amps 80.3 Amps (Onboard Charger)	3.3 kW 6.6 kW 20 kW	~17–20 miles	~ 3.5 hours	~ 1.5 hours
DC Charging/ Fast Charging	600 VAC	400 Amps	240 kW	~300–400 miles	~ 25 mins	~ 20 mins

[Table-2] Charging Station Levels, the data based on J1772 standard, North American

charged using any charging equipment with the standard connector. [7]

1.5.1 AC Charging: Level 1

Level 1 refers to Single Phase Alternating Current (AC) using a standard 120-volt plug. In North America it provides 16 Amps at 120 Volts delivering 1.9 kW of power, and about 3-4 miles of



[Fig-7] AC/ Level 1 Charging

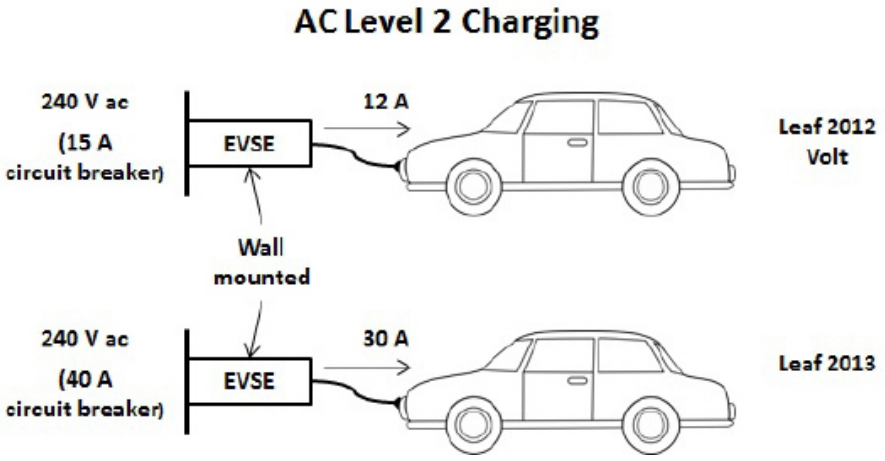
range per hour of charge. A full size battery electric vehicle will take about 12~15 hours to recharge. [8]

[Fig-8] AC/ Level 1 Charging Cable

The vehicle is plugged into the socket through a portable safety de-vice called an electric vehicle supply equipment (EVSE). Every new PEV comes with this portable charging equipment that allows the users to plug in their car to any 120-volt outlet.

1.5.2 AC Charging: Level 2

Level 2 requires charging equipment to be purchased and installed on the wall. In North America, the Society of Automotive Engineers (SAE) used J1772 standard to cover the connector and charging cable used in Level 2 applications. Compared to Level 1, these cables are permanently fixed to the Level 2 charging station.



[Fig-9] AC/ Level 2 Charging Station

[Fig-10] AC/ Level 2, 220 Volt Wall-mounted Charging Station

Level 2 station is either Single or Three Phase Alternating Current (AC) sources of 240V at up to 80Amps delivering 20kW of power. Based on the battery type, charger configuration, and circuit

capacity, it adds about 10 to 20 miles of range to a PEV per hour of charging time. A full size battery electric vehicle will take about 2~4 hours to recharge. [9]

[Fig- 11] DC Fast Charging Station

[Fig- 12] Nissan DC Fast Charging Device Under

1.5.3 DC Charging: Level 3

Level 3 stations refer to Direct Current DC charging, or "fast charging", which provide very high currents of up to 400 Amps, at voltages up to 600Volts, delivering a maximum power of 240kW.

Based on battery type and vehicle, DC fast charging can add about 60-80 miles of range to a PEV in 20 minutes of charging time.

Level 3 DC Fast Charging Is Impractical At Home:

480V input/ up to 50 kW power delivery/ battery up to 80% in as little as 20 minutes

1) DC Fast Chargers suck in more power than an entire average US residential neighborhood. The lights going out every time they charged the car.

2) They can also cost up to $100,000 each.

3) DC fast charging is great for charging at Public Stations because of the high speeds.

Example of DC Fast Charging/ Level 3 Charging Equipment:

Terra 53 multi-standard DC charging station

[Fig- 13] ABB Terra 53 DC Fast Charging Device

The Terra 53 CJ multi-standard DC charger is a configurable dual-connector 50 kW fast charging station. Designed to meet the needs of the "charge and go" driver, the Terra 53 CJ supports all current and next generation Electric Vehicle with the latest CHAdeMO and CCS standards.[10]

Main features:
– Dual outlet, 50kW DC fast charging station
– 30 to 80% in 15 minutes
– CCS and CHAdeMO compliant
– Future proof connection via open industry standards – Flexible interfacing with added value systems
– Remote uptime monitoring and assistance
– Remote updates and upgrades
– 8" daylight readable touch screen display – Graphic visualization of charging progress – RFID authorization
– EMC certified for safe use in industrial and residential areas
– Aesthetic design and rugged all-weather steel housing

Key optional features:
– PIN code authorization
– Credit card payement terminal
– Input power limiting software to avoid expensive grid upgrades
– Web module management software
– Statistics module with data per charger
– Fleet access management module
– Integration with back-offices, payment platforms and smart grid energy systems
– Charger status information for car navigation purposes – Wide temperature range: -35oC to +50oC
– Extended cable length to allow placement flexibility

Advantages of connected charging

Flexible interfacing with customer's added value systems

Optimal insight in charger operation

Maximize charger uptime with fast and reliable service

Optimize user experience

All Terra chargers are connected to ABB's Network Operating Center for monitoring, maintenance, and troubleshooting. ABB offers multiple Connected Services to site owners/operators:

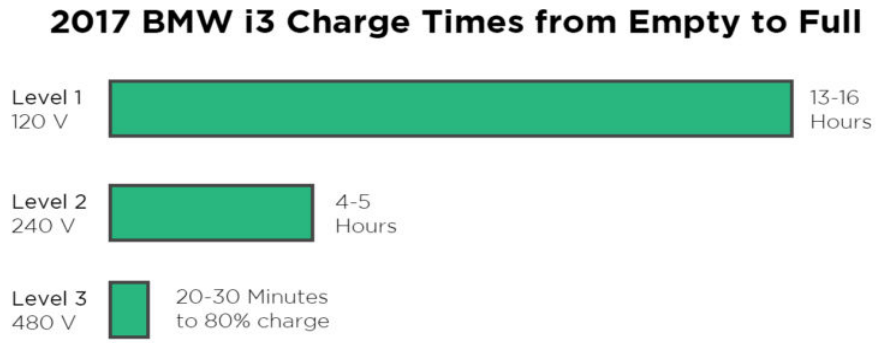
- Web module management software for entry-level operations and analytics.
- Third party OCPP and custom APIs can be developed for more feature rich billing, analytics and diagnostics

Technical specifications

System	Multi-standard DC charging station
Environment	Indoor / outdoor
Operating temperature	-35 °C to +50 °C (de-rating characteristic applies)
Storage temperature	-40 °C to +70 °C
Compliance and safety	c UL us IEC 61000 = Class B certified
Input	
AC power connection	3P + PE
Input voltage range	480 V_{AC} +/-10% (60 Hz)
Max. rated input current & power	75A, 60 kVA Power limiting options available
Power factor (full load)	> 0.95
Efficiency	94% at nominal output power
DC output	
Maximum output power	50 kW
Output voltage range	200 – 500 V_{DC} (Combo-1) 50 – 500 V_{DC} (CHAdeMO)
Maximum output current	125 A_{DC} (Combo-1) 120 A_{DC} (CHAdeMO)
General	
DC connection standard	EN61851-23 / DIN 70121 Combo-1 and CHAdeMO 1.0
DC cable length	12 ft (optional: 20 ft)
DC plug type	Combo-1 / CHAdeMO
RFID system	ISO/IEC14443A/B, ISO/IEC15693, FeliCa™ 1, NFC reader mode
Network connection	GSM modem (2G/3G) 10/100 Base-T Ethernet
Protection	Type 3R
Dimensions (D x W x H)	30" x 21" x 75" 760 mm x 525 mm x 1900 mm
Weight	775 lbs / 350 kg
Shipping dimensions (D x W x H)	48" x 32" x 85" 1200 mm x 800 mm x 2150 mm
Shipping weight	830 lbs / 375 kg

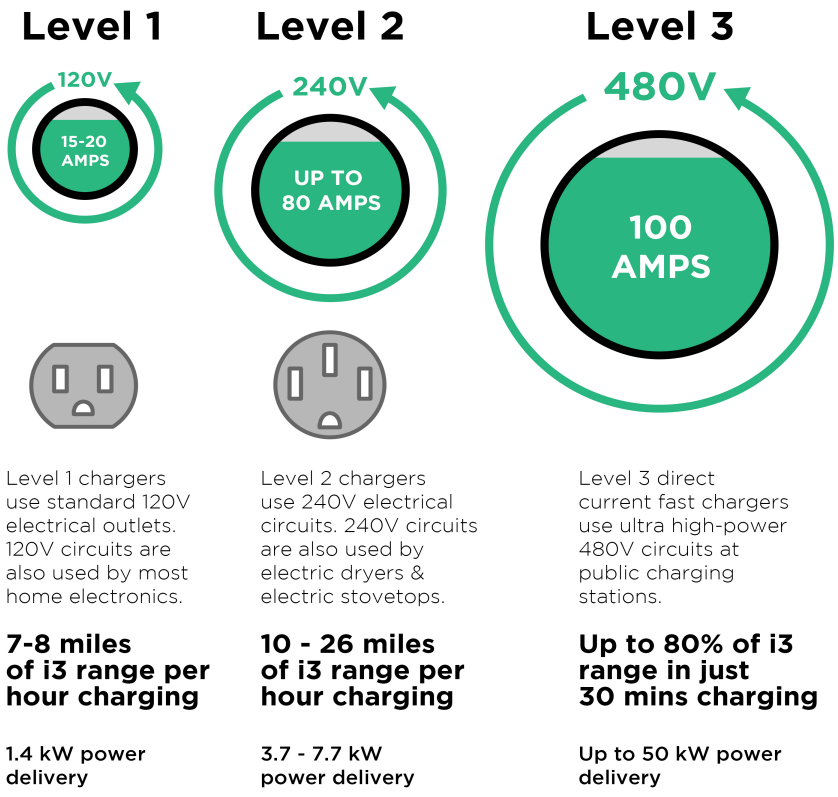
[Fig- 13] ABB Terra 53 DC Fast Charging Device

Example of BMW i3:



[Fig-14_1] BMW I3 Charging times

- Level 1 (120 volt) charging: **13 ~ 16 Hrs**
- Level 2 (240 volt) charging: **4 ~ 5 Hrs**
- Level 3 (480 volt) DC fast charging: **20 ~ 30 Mins**

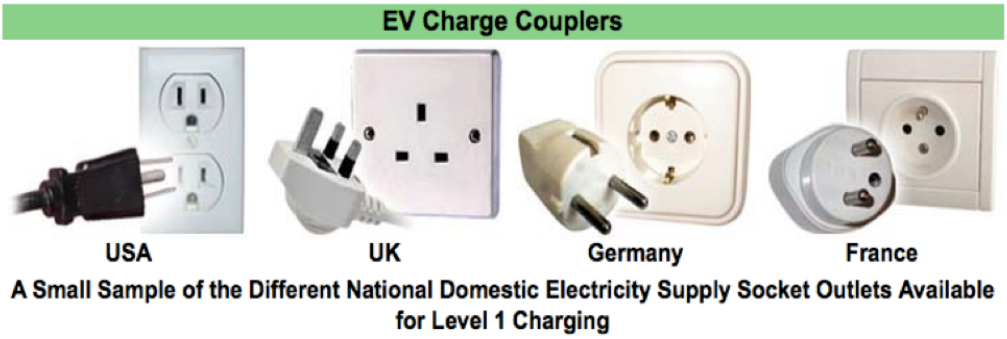


[Fig-14_2] BMW I3 Charging Levels

1.6 EV Charge Couplers

There are many connector standards suitable for Level 1 chargers. In the U.S., the sockets as [Fig-15_1] Level 1 Sockets and Couplers. The situation with Level 2 and Level 3 chargers is much better with fewer variants. However, compatibility between standards is still a problem. Different EV Charge Couplers are displayed as [Fig-15_2] EV Charge Couplers.

There is no single worldwide standard for electrical and mechanical interfaces between chargers and charging stations. For example, level 3 EV charge station standard in Japan is CHAdeMO, and CHINA GB in China. In U.S., the standard is SAE J1772. [11]



[Fig-15_1] Level 1 Sockets and Couplers

[Fig-15_2] EV Charge Couplers

2. Project Goals

2.1 Answers about Charging Stations for EV Users

Where Can I Charge my Car?

Judged by Distance / Convenience:

- at Home : a private garage, a designated parking spot, shared parking facility

- at Work: at your office building's parking facility
- in Public: along the streets, on the highway, and at any public parking facility
- at Retail Business Parking Lot: restaurant, shopping mall, hotels, hospitals etc.
- at Dedicated Charging Center: parking lot, gas stations, charging center

How Long will the Charging Take?

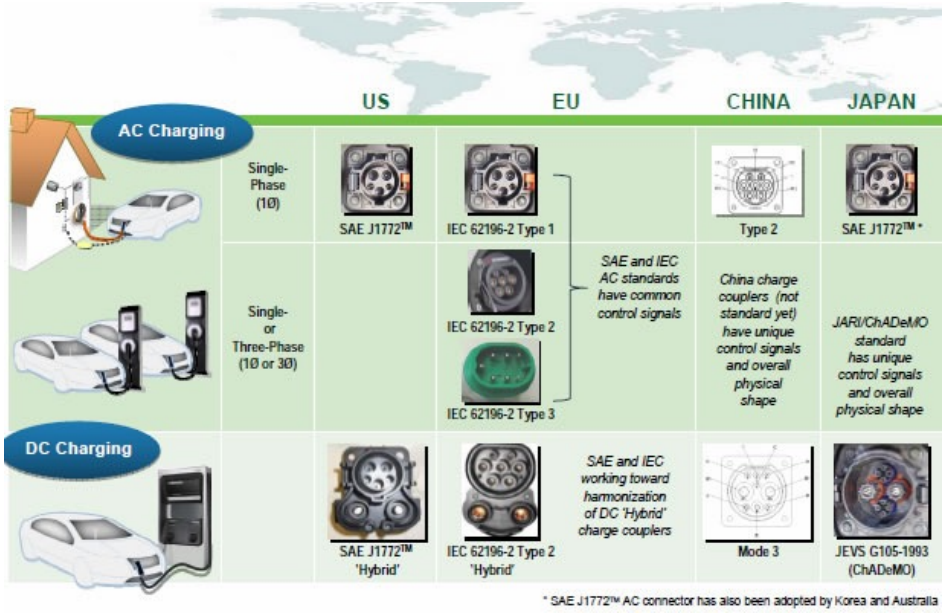
- Regular Socket/ 6~12 Hrs.: This requires a specific charging cable that prevents power outage

and overheating.

- Charging Station/ 1~4 Hrs.: it makes safe and efficient use of the car's and energy source's (e.g. home or office building) capacity.
- Fast Charger/ 20 Mins: 1) Fast Charging stations pop up most often outside cities and along highways. 2) Due to the costly equipment and hardware of fast charging stations, these chargers are usually only purchased and built per request by local governments.

Will my Connector Fit the Charging Station?

The charging station will use U.S. standard SAE J1772



[Fig-16] Charging Station Standards

2.2 Short-term Plan

This project focuses on the Los Angeles and Orange Counties area as the test case. It will design the optimum charging station network first for those two areas.

2.3 Long-term Plan

Create a dense national network of charging stations in CA, then U.S. The Electric Vehicle could charge

- Everywhere — at home; at restaurants, shops and business; at work; street parking; and at commercial charging stations.
- Anytime — EV users could charge their car 24 hrs. anytime they need.
- Fast — the charging is fast without long waiting time.
- Affordable — electricity cost is much cheaper than gasolines.

3. System Identification: LA and Orange County EV Network

3.1 Subsystems

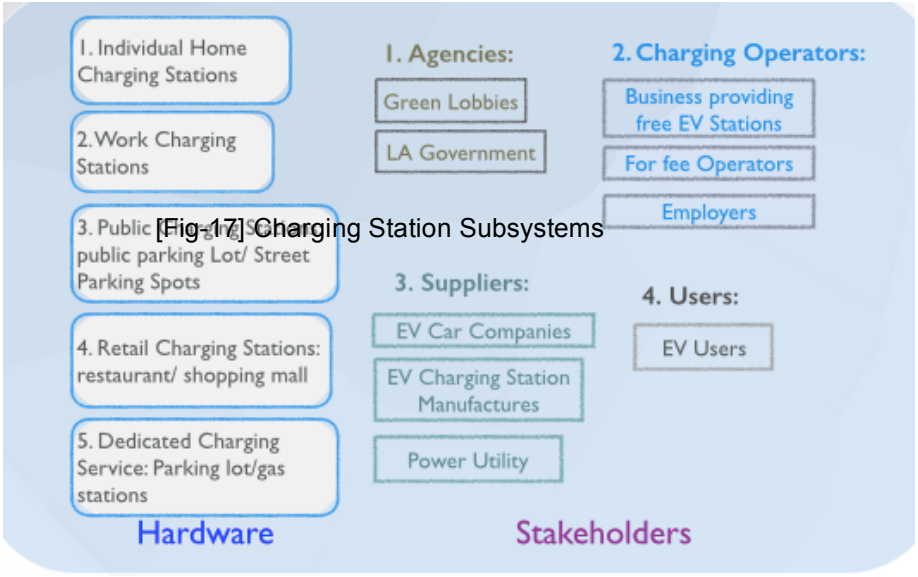
The system includes following subsystems:

Agencies: Green Lobbies, LA Government;

Charging Station Operators: Business Providing free or fee EV Charging Stations, Employers providing charging station for their employees.

Suppliers: EV charging Station Manufactures, EV Car Companies, Power Utility Company.

EV Users: EV consumers.



[Fig-17] Charging Station Subsystems

[Fig-18] Operational Node Connectivity

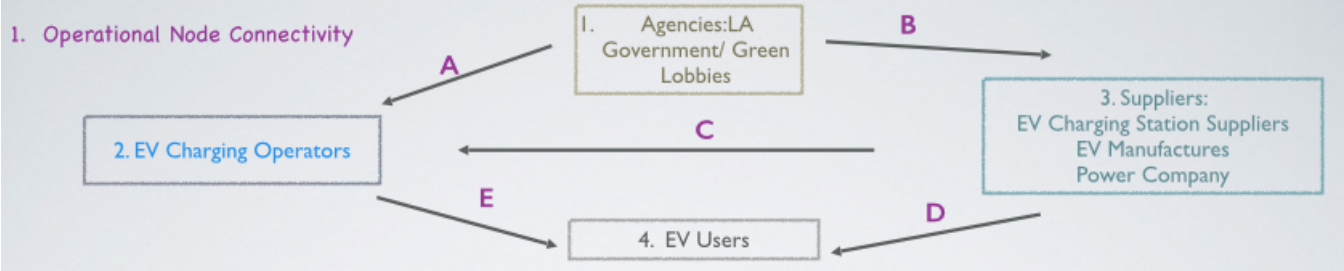
3.2 External Systems

The system refers to following external systems:

- Environment
- Gas/oil Company
- Power Supply Grid
- EV Technology System/ Battery Technology System
- Legislation/ Regulation
- Billing System

4. Stakeholder Needs and Interaction

The following chart, [Fig-18] Operational Node Connectivity, shows charging station stake-holders interaction change:



[Table-3] Information Exchange Matrix illustrates the needlines between stakeholders:

[Table-3] Information Exchange Matrix

Needlines	From Information	To Information	Information Description	Information Attributes	
				Detail	Media
A	Government/ Green Lobbies	EV Charging Operators	Regulations/ Funding	Agencies provide regulations or funds to promote EV changing Operators	Money or Documents
B	Government/ Green Lobbies	EV Supplier	Regulations/ Funding	Agencies provide regulations or funds to promote EV Suppliers	Money or Documents
C	EV Charging Station Suppliers and Power	EV Charging Operators	EV Charging Station Parts and Electric Power	EV suppliers provide charging station parts to operators and Power Company Provide Electric Power to stations	Hardware Parts and Electric Power
D	EV Manufacture	EV Users	Electric Vehicle	EV Manufactures provide all kinds of Electric Vehicle to Users	Electric Vehicle
E	EV Charging Operators	EV Users	Charging Stations	EV Charging Operators provide charging stations for EV Users	EV Charging Stations

5. Requirements

By the year 2025: The Charging Station Network shall meet the overall needs of Electric Vehicle (50% of all cars).

By the year 2030: The Charging Station Network shall meet the overall needs of Electric Vehicle (80% of all cars).

6. Project Projection

6.1 Current Number of Vehicles: Year 2015

From the Appendix-1: Number of Vehicles in CA in 2015, we find the total number of vehicles in CA is 34,346,325, and total of Electric Vehicle at CA is 191,650. It is about 0.558% Electric Vehicle in CA, 2015.

Also, Vehicles Needs in Los Angeles is 7,838,874; in Orange County is 2,831,850. Total Vehicles in LA and Orange County in 2015 is 10,670,724.

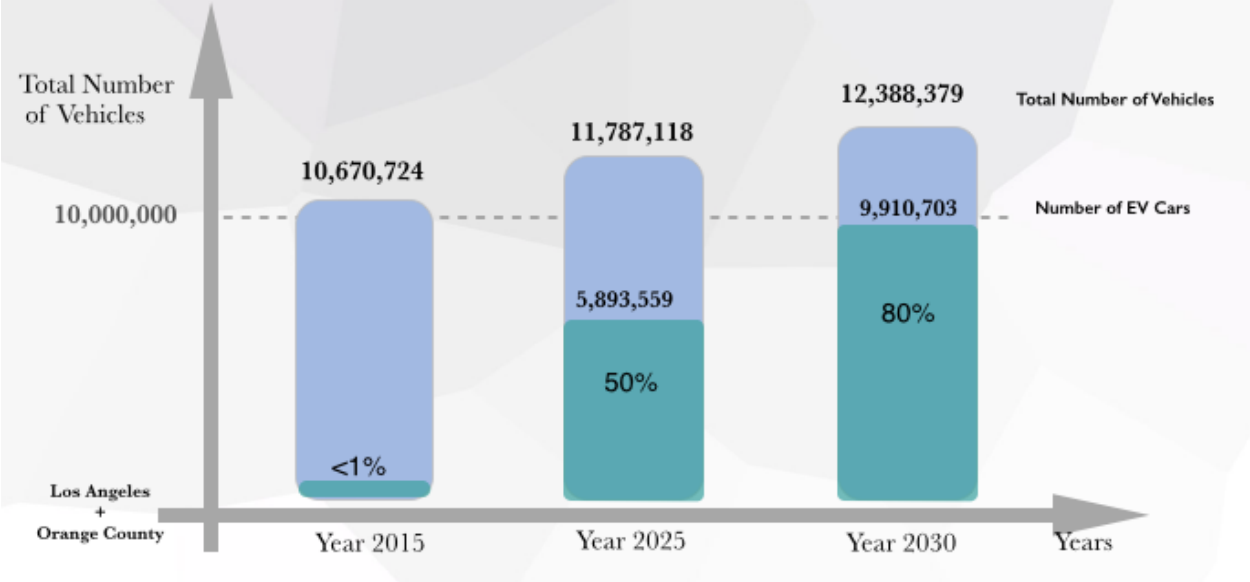
	Counties	Autos	Trucks	TRLRS	M/C	Total
	Los Angles	6,293,639	1,075,340	305,743	164,152	7,838,874
	Orange County	2,248,999	400,421	117,730	64,700	2,831,850
	California	24,696,261	5,931,837	2,705,593	898,909	34,346,325

[Table-4] Vehicles in CA, in 2015

6.2 Projection Number: Year 2025 and Year 2030

The total Vehicle Growth Rate in LA and Orange County is 1% each year, extrapolating from 2015~2016.

According to project requirements, the Charging Station Network in Los Angeles and Orange County shall meet the overall needs of 50% projection of the total 11,787,118 vehicles, which are 5,893,559 Electric Vehicles in the year 2025. By the Year 2030, the Charging Station Network shall meet the overall needs of 80% projection of total 12,388,379 Vehicles, which is 9,910,703 of Electric Vehicles.



[Fig-19] Projection the Number of Vehicles in Los Angeles and Orange County

7. Measures of Effectiveness

Four measure of effectiveness to be used in this project:

1. Number of Charging Stations of Level 1, Level 2, and Level 3

Description: Total Number of Charging Stations: Level 1/ Level 2/ Level 3/ DC Fast Charging Stations

Metric: Numbers

Formula:

Total L1 Number = Sum (L1 Number)
Total L2 Number = Sum (L2 Number)
Total L3 Number = Sum (L2 Number)

2. Total Installation Cost

Prescription: Total cost to build all proposed charging stations

Metric: $

Formula: Total Installation Cost = L1 Cost * Total L1 Number + L2 Cost * Total L2 Number + L3 Cost * Total L3 Number

3. Avg. Electricity Cost

Prescription: The cost to customer charge their Electric Vehicle at charging station

Metric: $ per 100 miles of driving

Formula: Avg. Electric Cost = (Level 1 E Cost * Level 1 Number + Level 2 E Cost * Level 2 Number + Level 3 E Cost * Level 3 Number)/ Total Number of Charging Stations

4. Avg. Charging Time

Prescription: Avg. charging time for full charge per EV car

Metric/Hrs

Formula: Avg. Electric Cost = (Level 1 Time * Level 1 Number + Level 2 Time * Level 2 Number + Level 3 Time * Level 3 Number)/ Total Number of Charging Stations

8. Installation and Cost Analysis

8.1 Level 1 Charging Station Cost Analysis

Level 1 Charging Station is regular sockets! Just need authority to plug in charging for free.

- Free - Exists Sockets !
- No charging equipment fee
- Use Standard Wiring /No need High Current Wiring cost

Where to Install the Level 1 Charging Station:

- at Public Parking lots/ at Residential Parking lots
- at Commercial Parking lots/ at Workplace
- at Street/ Roads

8.2 Level 2 Charging Station Cost Analysis

Charging Station Permit

The output power for Level 2 is 240V, thus, Level 2 charging generally requires installation of a dedicated circuit and a charging station. In this case, the homeowner will be required to obtain a permit from local government. [Fig-19] Residential EVSE Permits displayed the documents require a residential EVSE permits.

Supporting Documentation	Description
Plot Plan	Identify the complete layout of existing parking spaces and proposed location of EVSE parking space(s) with respect to existing building and structures
Electrical Load Calculations	Home electrical load calculation that estimates if an existing electrical service will handle the extra load from residential EVSE and wiring methods based on the California Electrical Code (see sample electrical plan)
Electrical Plans	Single-line diagrams showing the system, point of connection to the power supply and the EVSE
EVSE Information	The EVSE manufacturer's installation instructions and charger specifications

[Fig-20_1] Residential EVSE Permits

Installation of EVSE at commercial locations can be more complex than residential installations. And it may require additional permits or submittal documentation. The following are considera-

- ✓ Zoning Requirements
- ✓ Community or Design Guidelines
- ✓ Existing Use Permits
- ✓ Electrical Source/Metering
- ✓ Parking and Signage Requirements
- ✓ Permit and Inspection Fees

[Fig-20_2] Residential EVSE Permits

tions for commercial EVSE.

Level 2 Charging Station Installation Cost

If existing panel is too small or overloaded, need new upgraded Electrical Service Panel and new EV charger circuit breaker.

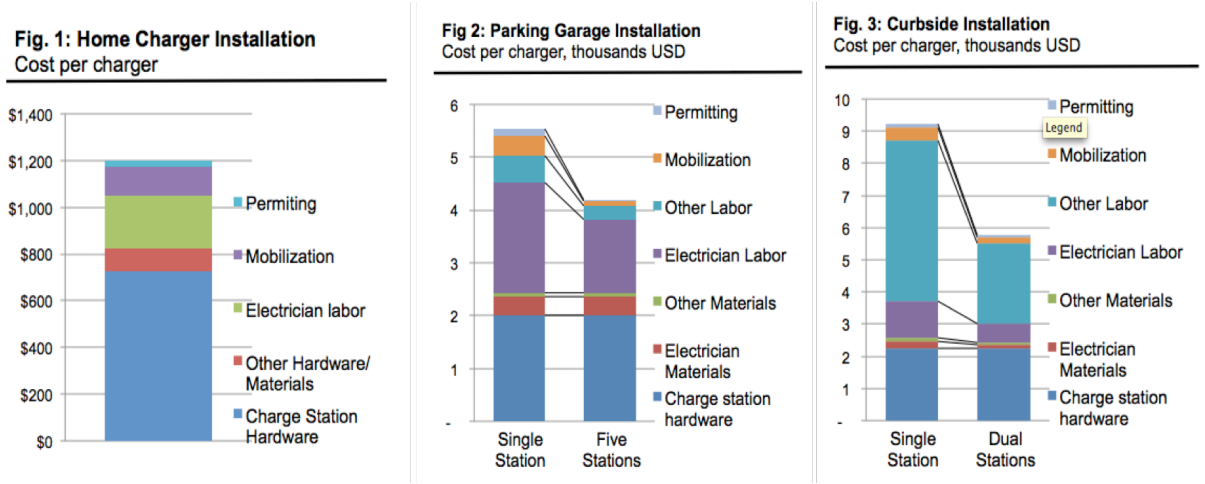
- Standards: SAE J1772, US
- Charging Time: 1 ~ 4 Hours
- Power Supply : 240 V

Thus, installing Level 2 Charging may have happened some issues: Neighborhood Transformer Upgrade, Grid Loading, Peak Demands at Peak Load, etc. Thus Level 2 Charging Cost could

	Level 2 Home	Level 2 Parking lot	Level 2 Curbside	Key Assumptions
Charge Station Hardware	$450~$1000	$1500~$2500	$1500~$3000	
Electrician Materials	$50~$150	$200~$500	$150~$300	$500~$1000, if new breaker is required
Electrician Labor	$100~$350	$1250~$2950	$800~$1500	
Other Materials	NA	$50~$100	$50~$150	$25~$100/ft. for trenching/boring, depends on surface, soil, and underground complexity Mounting, Signage, Protection and Restoration, etc.
Other Labor	NA	$250~$750	$2500~$7500	
Transformer	NA	NA	NA	
Mobilization	$50~$200	$250~$500	$250~$500	Depends on Contractor, $250 ~ $500
Permitting	$0~$100	$50~$200	$250~$500	Varies to City, usually a flat fee
Total	$650 ~ $1800	$3550 ~ $7500	$5500 ~ $13800	

[Table-5] Level 2 Installation Cost

refer to following cost: Charging Equipment Cost, Installation Cost, New high Current Wiring Cost, New larger Circuit Breaker Cost, and Metering(Payment System) Cost. The detail could refer to [Table-5] Level 2 Installation Cost and [Fig-21] Level 2 Installation Cost Chart.



[Fig-21] Level 2 Installation Cost Chart.

Level 2 Charging Station Installation Proposal

From the cost analysis, we could provide the level 2 charging station installation proposal

Where to Install level 2 Charging Station:

- at Home (Optional, depends on home Owners)
- at Parking Lot/ Garage at Street/ Curbside

Who will involve in the Level 2 charging stations:

- Public Parking lot: Government
- Residential Parking lot: Communities/ Neighborhoods
- Commercial Parking lot: Business Owners
- Work Place Parking lot: Employers
- Home: Homeowners

How to Pay:

- Pay together with Parking Fee! — at Street/ Roads ,at Public Parking lots, at Residential Parking lots
- Commercial Parking lot Provide Free Charging for their Customers! — at restaurant, at Shopping Mall, at Supermarkets, etc.
- Employers Provide Free Charging for their Employees!

8.3 Level 3/ DC Charging Station Cost Analysis

DC fast charging Station cost could breakdown following parts:

- DC fast Charging Equipment Cost
- Equipment installation (labor and electric-panel upgrade)
- Utility interconnection
- Host-site identification, analysis, and screening
- Negotiation, legal review, and execution of lease

Details cost refer to following [Table-6] Level 3 Installation Cost:

Component	Cost	Comments
DC fast-charging equipment • 50 kW DC public fast-charging station (480 V ac input) • 3-year warranty and point-of-sale capabilities [1] • Payment of all electricity dispensed (including utility demand charges) • Overhead lighting and required safety equipment	$50,000 per unit	[1]Point-of-sale capabilities might include radio frequency identification authentication and networking to back-office functions (such as account management and customer billing), equipment status signals, and credit card transactions.
Equipment installation (labor and electric-panel upgrade) • Separate power drop or meter for the charging station • Electric panel upgrade (if required) • Construction and environmental and electricity permits • Trenching, backfill, and site restoration • Installation of conduit and power lines to charging station • Installation of concrete pad and electric stub-out • Installation of curb or wheel stop and overhead lighting • Installation and testing of equipment	$20,000 per location	
Utility interconnection • Costs are highly variable and depend on cost-recovery policies of the electric-power provider and condition of existing power distribution components [2] • Generally includes utility costs for preliminary engineering and design,	$10,000 to $20,000 per location	[2] Additional costs could be incurred if addition of multiple chargers increases demand charges or requires additional electricity service upgrades.
Host-site identification, analysis, and screening • Identification of potential sites	$5,000 per location	
Negotiation, legal review, and execution of lease • Making contact with several property owners • Exchanging and negotiating lease documents	$5,000 per location	

[Table-6] Level 3 Installation Cost

Level 3 Charging Station Installation Proposal

Who will involve in Level 3 Charging Station:

- Government
- Commercial fleet Operators
- EV Infrastructure and Service Providers
- Car Dealerships

Where to build:

- Highway Travel Stops and Convenience Stations
- Gas Stations
- Retail Shopping and Commercial Centers

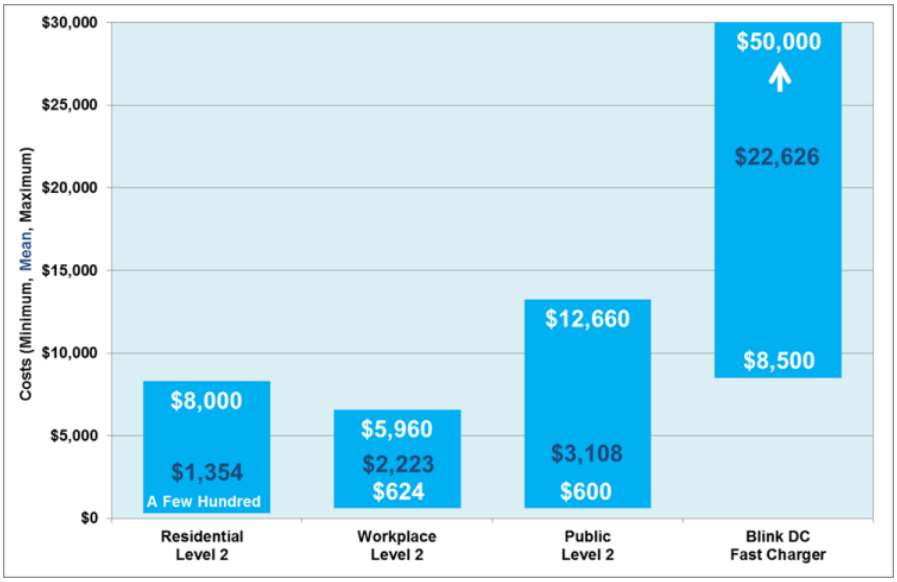
8.4 Cost and Installation Summary

From Part 8.3, different level Charging Station Cost Summary displayed as [Fig- 22] Charging

Level 1: Free
Avg.: 0

Level 2: $600 ~ $12,660
Avg. $1,354 Home
Avg. $1,354 Work Place
Avg. $1,354 Public

DC/ Level 3: $8500 ~ $50,000
Avg.: $2,2626



[Fig- 22] Charging Station Cost Comparison

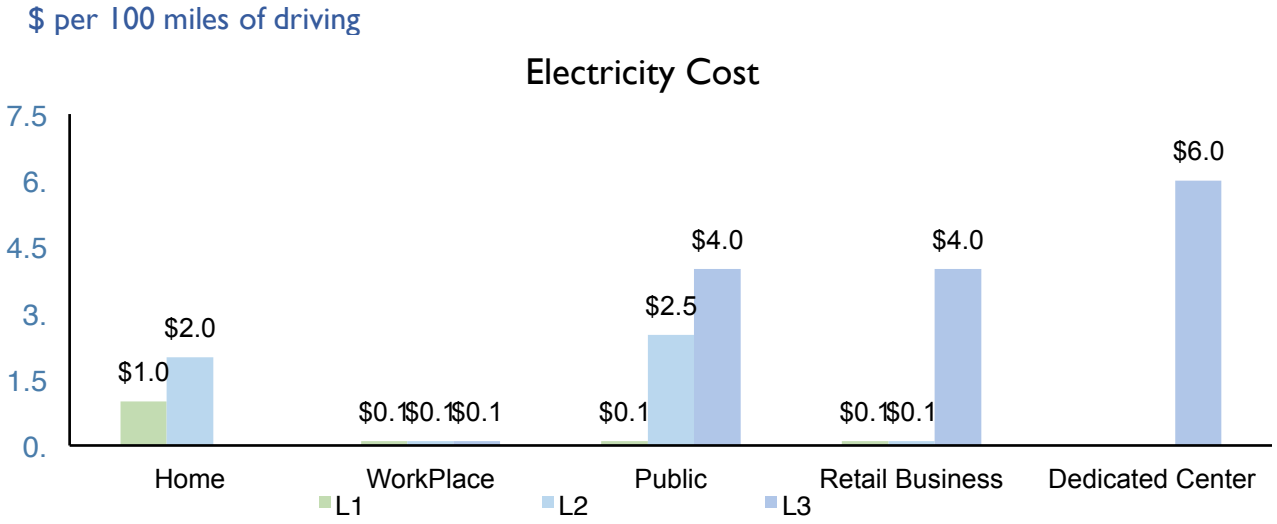
8.5 Cost to Charge the Electric Cars

Estimated Electricity Cost for Users at Different Place, as [Fig- 23] Estimated Electricity Cost for Users at Different Place:

Home:
Level 1: $1
Level 2: $2

Dedicated Center:
DC/Level3: $6

Public: Level 1: Free Level 2: $2.5 DC/Level3: $4.0	Work Place: Level 1: Free Level 2: Free DC/Level3: Free	Retail Business: Level 1: Free Level 2: $2 DC/Level3: $4



[Fig- 23] Estimated Electricity Cost for Users at Different Place

9. Installation Proposal

Charging Stations are installed at different place, as [Fig- 24] Estimated Electricity Cost for Users at Different Place: Level 1 charging stations could be installed at home, workplace, public, and Retail Business. Level 2 charging stations are the same as level 1, which should be installed everywhere except Dedicated Center.

Level 3 DC Fast Charging is impractical at home. They could be installed at retail business, in public, and Dedicated Center. Dedicated Centers are only for DC fast charging, with the same function as Gas Stations.

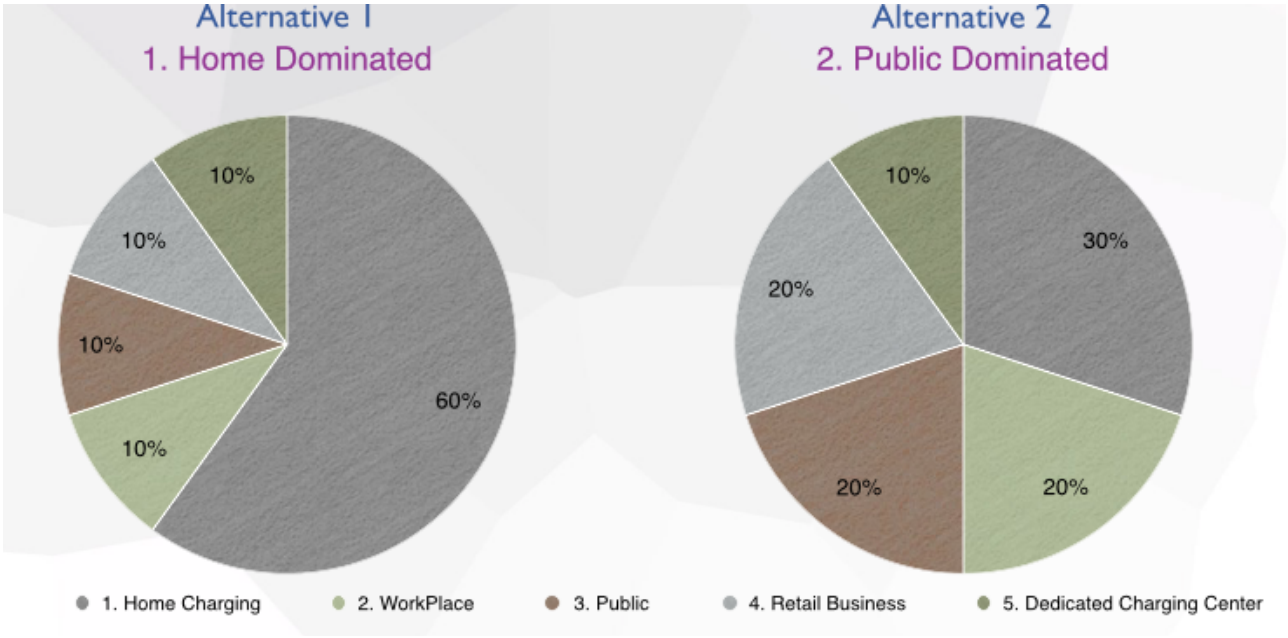
10. Alternatives

This project selected two alternatives:

Alternative 1: Home Dominated, most of EV charging stations will be built at home.

Home charging stations will be the main charging source for all Electric Vehicle: meeting the needs of 50% of total Electric Vehicle. As [Fig- 25] Selected Alternatives: Home Dominated and Public Dominated displayed: the distribution of charging stations is Home Charging Station 60%, the rest of 10%.

Alternative 2: Public Dominated, most of EV charging stations will be built at Public.



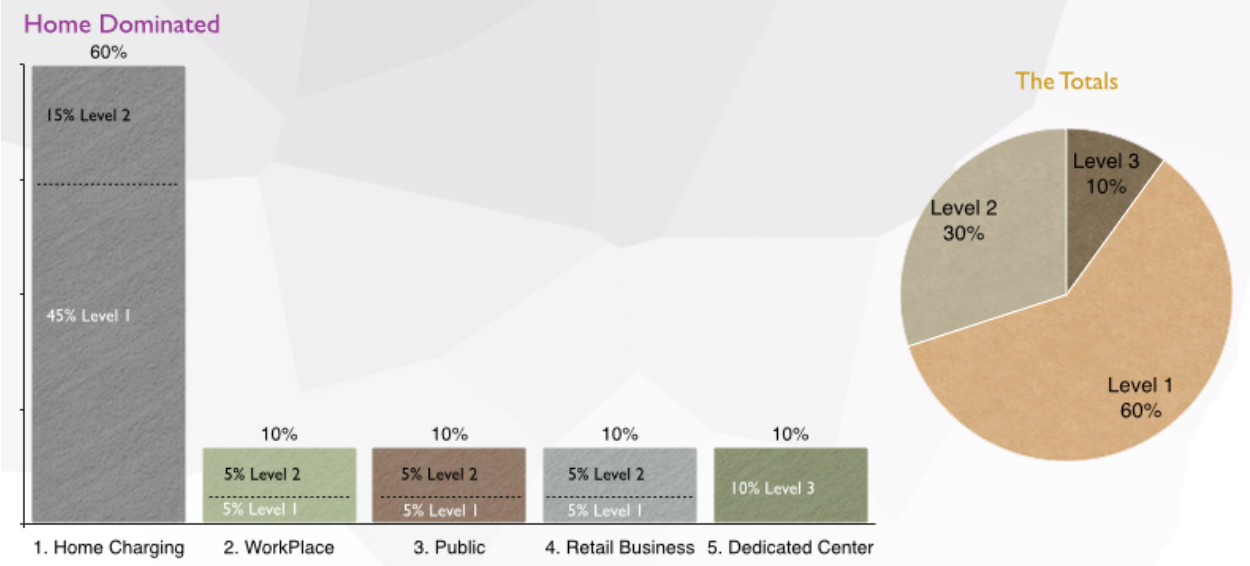
[Fig- 25] Selected Alternatives: Home Dominated and Public Dominated

Public charging stations will be the main charging source for all Electric Vehicle: meeting the needs of 50% of total Electric Vehicle. As [Fig- 25] Selected Alternatives: Home Dominated and Public Dominated displayed: the distribution of charging stations is Home Charging Station 30%; workplace, public place, and retail business place are 20%; Dedicated Center is 10%.

10.1 Home Dominated Alternative

Breakdown Home Dominated alternative to mix level of charging stations. As [Fig-26] Home Dominated Mix Levels displayed:

For Home Charging Station is 45% Level 1 + 15% Level 2; Workplace, Public, and Retail Business Charging Station are 5% Level 1 + 5% Level 2; Dedicated Charging Center is 10% Level 3.



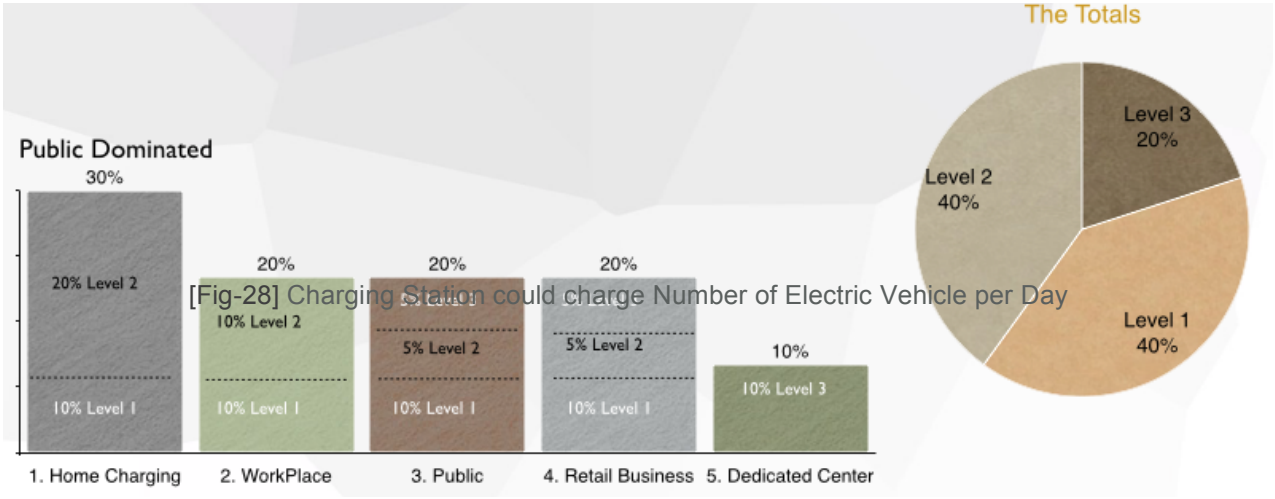
[Fig-26] Home Dominated Mix Levels

The totals: 60% Level 1 Charging Station, 30% Level 2 Charging Station, and 10% Level 3 Charging Station.

10.2 Public Dominated Alternative

Breakdown Home Dominated alternative to mix level of charging stations. As [Fig-26] Home Dominated Mix Levels displayed:

For Home Charging Station is 10% Level 1 + 20% Level 2; Workplace is 10% Level 1 + 10% Level 2; Public, and Retail Business Charging Station are 10% Level 1 + 5% Level 2 + 5% Level 3; Dedicated Charging Center is 10% Level 3.



[Fig-28] Charging Station could charge Number of Electric Vehicle per Day

[Fig-27] Public Dominated Mix Levels

The totals: 40% Level 1 Charging Station, 40% Level 2 Charging Station, and 20% Level 3 Charging Station

10.3 Alternative and MOEs

- **Calculate Number of Charging Station**

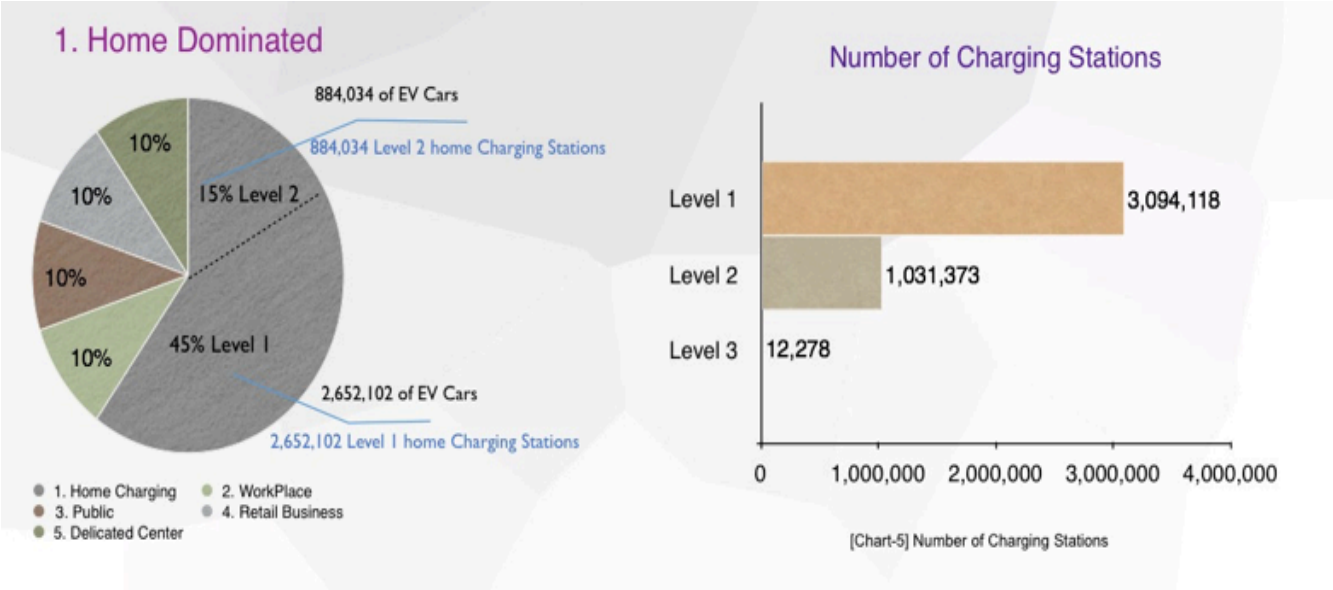
For the Level 1 Charging Station, assuming a full charge need 12 Hrs. A charging station could charge 2 Electric Vehicle a Day. At home, the charging station is private, will only charge one car per day. For the Level 2 Charging Station, assuming a full charge need 4 Hrs. A charging station could charge 6 Electric Vehicle a Day. At home, the charging station is private, will only charge one car per day.

For the Level 3 Charging Station, assuming a full charge need 0.5 Hrs. A charging station could charge 48 Electric Vehicle a Day.

		AC/ Level 1 (Number of Cars Per day)	AC/ Level 2 (Number of Cars Per day)	DC/ Level 3 (Number of Cars Per day)
1	Home	1	1	
2	Work Place	2	6	
3	Public	2	6	48
4	Retail Business	2	6	48
5	Dedicated Center			48

Take 2025 as example: meet the needs of 5,893,559 Electric Vehicle in 2025.

Home Dominated Alternative: 45% Level 1 home charging stations meet 2,652,106 of Electric Vehicle, which need 2,652,106 of charging stations. 15% Level 1 home charging stations meet 884,034 of Electric Vehicle, which need 884,034 of charging stations. The total number of charging stations of Home Dominated Alternative: Level 1 is 3,094,118; Level 2 is 1,031,373, and Level 3 is 12,278.



[Fig-29] Number of Different Level Charging Station, 2025

MOEs Results

From [Fig- 22] Charging Station Cost Comparison, we could get the installation cost details for each level charging station. From [Fig- 24] Estimated Electricity Cost for Users at Different Place, we could get the electricity cost for each level charging station.

The MOEs of Home Dominated Alternative calculate results could refer to following [Table 7] Alternative1, Home Dominant Scenario, 50% Projection,

a) Number of Charging Stations of Level 1, 2 and 3 is L1 = 3,094,118; L2 = 1,031373; L3 = 12,278;

b) Total Installation Cost is $1,889,254,007;

c) Avg. Electricity Cost is $1.55 per 100 miles of driving;

d) Avg. Charging Time is 8.45 Hrs.

Total Vehicles		10,670,724	11,787,118			50%		5,893,559			
			Cars Number of	Number of Stations[1]	Average Installation Cost($)[2]	Total Installation Cost($)	Distribution	Efficiency Time(Hrs)[3]	Conector Cost	Bills Electric /Per 100 mille[4]	Notes:
10%Dedic	Level 3/	1	589,356	12,278	$22	$277,907.63	5	0.5	$2.00	$6.00	[1][3]refer to Table-5 Charging Station could charge Number of Electric Vehicle per Day [2]refer to [Fig- 26] Charging Station Cost Comparison [4]refer to [Fig- 27] Estimated Electricity Cost for Users at Different Place
10% Retail	Level 1	5%	294,678	147,339	$0	$0	2	12	$0	$0.00	
	Level 2	5%	294,678	49,113	$3.1	$152,643.17	2	4	$800	$2.00	
10% Public	Level 1	5%	294,678	147,339	$0	$0	2	12	$0	$0.00	
	Level 2	5%	294,678	49,113	$3.1	$152,643.17	2	4	$800	$2.00	
10% Work	Level 1	5%	294,678	147,339	$0	$0	2	12	$0	$0.00	
	Level 2	5%	294,678	49,113	$2.2	$109,178.18	2	4	$800	$0.00	
60% Home	Level 1	45%	2,652,102	2,652,102	$0	$0	22	12	$0	$1.00	
	Level 2	15%	884,034	884,034	$1.3	$1,196,981	7	4	$800	$2.00	
Total Level 1	Total Level 2	Total Level 3	Total Number	Total Number	w Mean	Total Cost	Total	w Mean(Hrs)	w Mean($)	w Mean$/per 100	4. w Mean = Weighted Mean
3,094,118	1,031,37	12,278	5,893,559	4,137,770	$288	$1,889,254	50	8.45	$440	$1.55	

[Table 7] Alternative1, Home Dominant Scenario, 50% Projection,

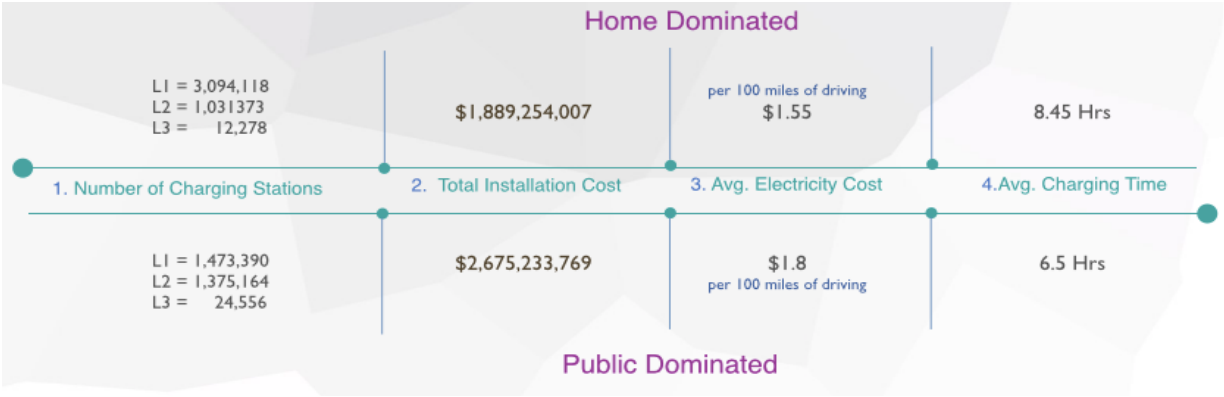
Using the same methods, we could calculate Public Dominated Alternative. The MOEs result can refer to Appendix-7: [Table 7] Alternative 2, Public Dominated Scenario, 50% Projection,

Year 2025, [Table 8] Alternative1, Home Dominated Scenario, 80% Projection, 2030, and [Table 9] Alternative 2, Public Dominated Scenario, 80% Projection, Year 2030

10.4 Alternatives and MOEs Summary

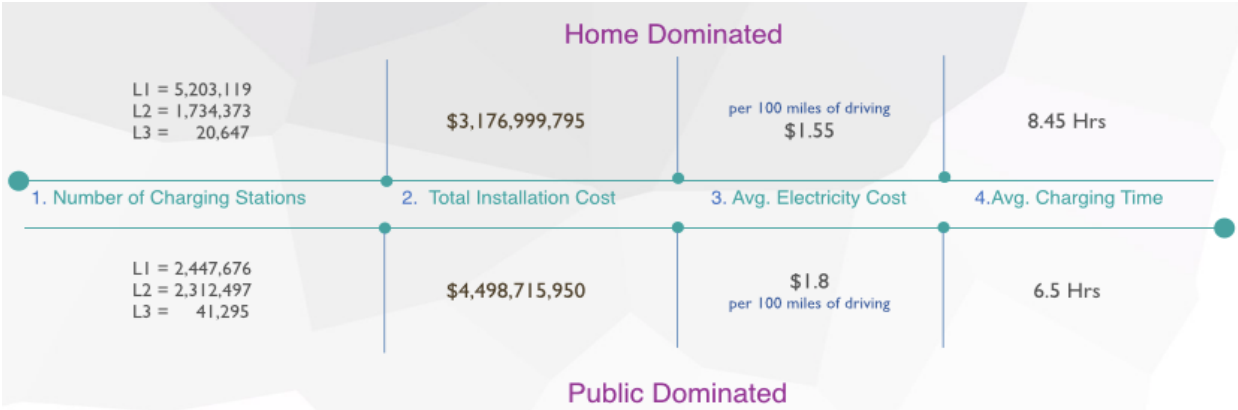
Here is the summary of two alternatives and MOEs result.

The size of the Charging Station Network shall meet the overall needs of 5,893,559 Electric Vehicle in 2025. The MOEs results for two alternatives as following: *[Fig-30] Alternatives and MOEs Result Summary, Year2025.*



[Fig-30] Alternatives and MOEs Result Summary, Year2025

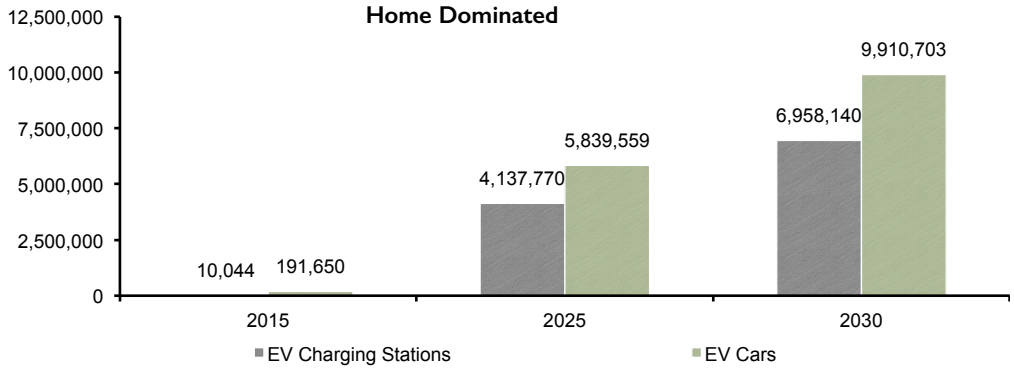
The size of the Charging Station Network shall meet the overall needs of 12,388,379 Electric Vehicle in 2030. The MOEs results for two alternatives as following: *[Fig-31] Alternatives and MOEs Result Summary, Year2030.*



Here are the results of EV Charging Station Comparison in the year 2015, 2025, and 2030.

In the year 2015, the total number of Electric Vehicle is 191,650, and total number of EV charging stations is 10,004.

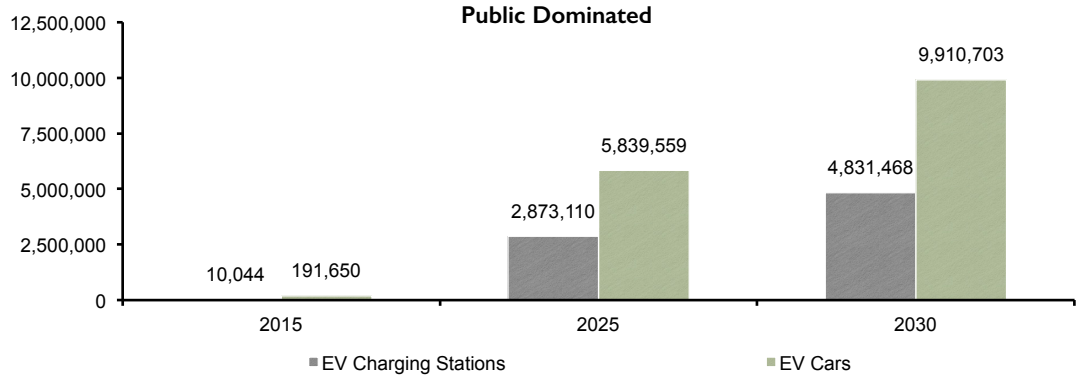
As the project proposed, for the Home Dominated Alternative, the total number of EV charging stations will increase to 4,137,770 to meet the needs of 5,839,559 Electric Vehicles in the year 2025, and increase to 6,958,140 to meet the needs of 9,910,703 Electric Vehicles in the year



[Fig-32] Home Dominated, Total Number of Charging Stations and Electric Vehicle

2030.

For the Public Dominated Alternative, the total number of EV charging stations will increase to



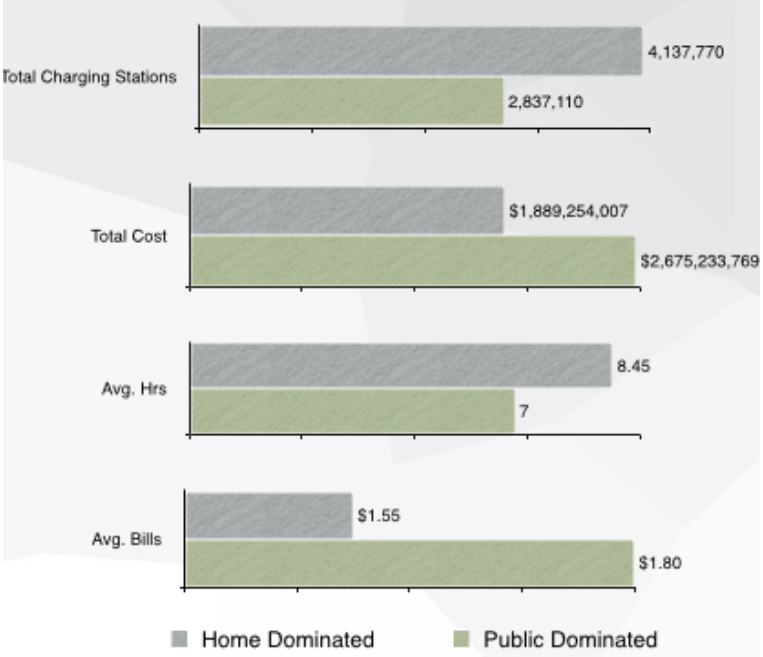
[Fig-33] Public Dominated, Total Number of Charging Stations and Electric Vehicle

2,873,110 to meet the needs of 5,839,559 Electric Vehicle in the year 2025, and increase to 4,8 31,468 to meet the needs of 9,910,703 Electric Vehicle in the year 2030

10.5 Selected Solution

Which alternative is better? Home Dominated VS Public Dominated

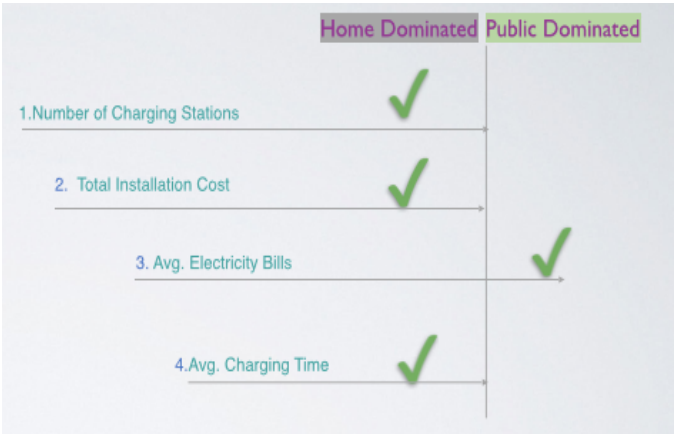
Let's compare the MOEs result of Year 2025, as [Chart-8] Home Dominated vs Public Dominated, 2025 displayed



[Fig-34] Home Dominated MOEs VS Public Dominated MOEs, 2025

- Total Number of Charging Stations: Home Dominated is 4,137,770; Public Dominated is 2,837,110.
- Total installation cost for Home Dominated Alternative is $1,889,254,007, which is less than the cost of Public Dominated Alternative $2,675,233,769.
- The Avg. Charging Hours of Home Dominated Alternative is 8.45 hrs., which is a bit longer than 7 hrs., the Avg. Charging Hrs of Public Dominated.

[Chart-8]



[Fig-35] Home Dominated VS Public Dominated

- The Avg. Electricity Cost of Home Dominated Alternative is $1.55 Hrs, which is cheaper than $1.8, the Avg. Electricity Cost of Public Dominated.

Hence, selected solution will be Home Dominated Alternative.

11. System Risk Analysis

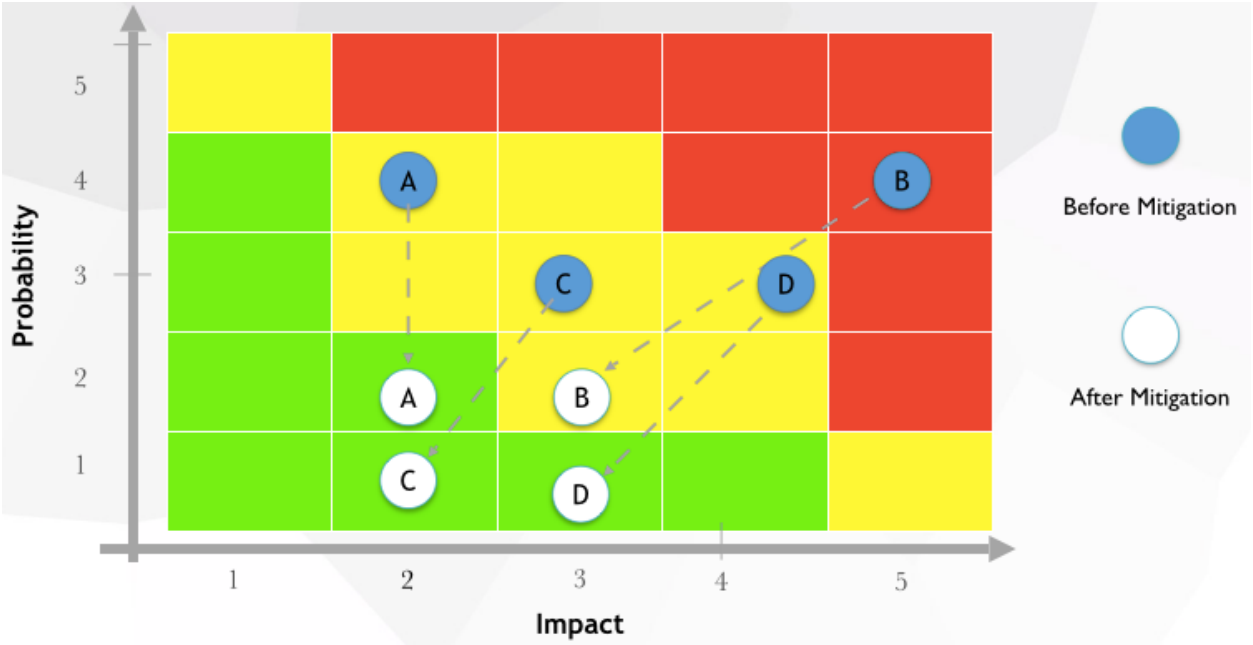
Table 8 described four types of system risks, which includes Legal Risk, Financial Risk, Political

ID	Type	Title	Description	Mitigation	Impact	Probability	Status	Impact	Probability [0~5]
A	Level 1 Legal	Authority Failure	Business owner refuses to authorize the EV drivers to use the sockets	Government to give the tax incentives to business	2	4	Open	2	2
B	DC Financial Risk	Cost	Building a DC charging station could cost from $100,000 to $122,000. Not able to build enough DC charging	Government could partner with car dealers and makers to fund the	5	4	Open	3	2
C	Political	Anti-EV	Political environment and cost of gasoline. Yields anti-EV pressures	Re-visit the projections every year during 2015-	3	3	Open	2	1
D	Vehicle Users	Gasoline car preferen	Vehicle Users prefer to gasoline cars because of personal driving habit	Massive public campaign	4	3	Open	3	1

[Table-8] Risk Management

Risk, and Vehicle Users Risk. The details can refer to [Table-8] Risk Management.

After mitigation, all the risks were fell into green zone, as [Fig-31] Risk Mitigation displayed

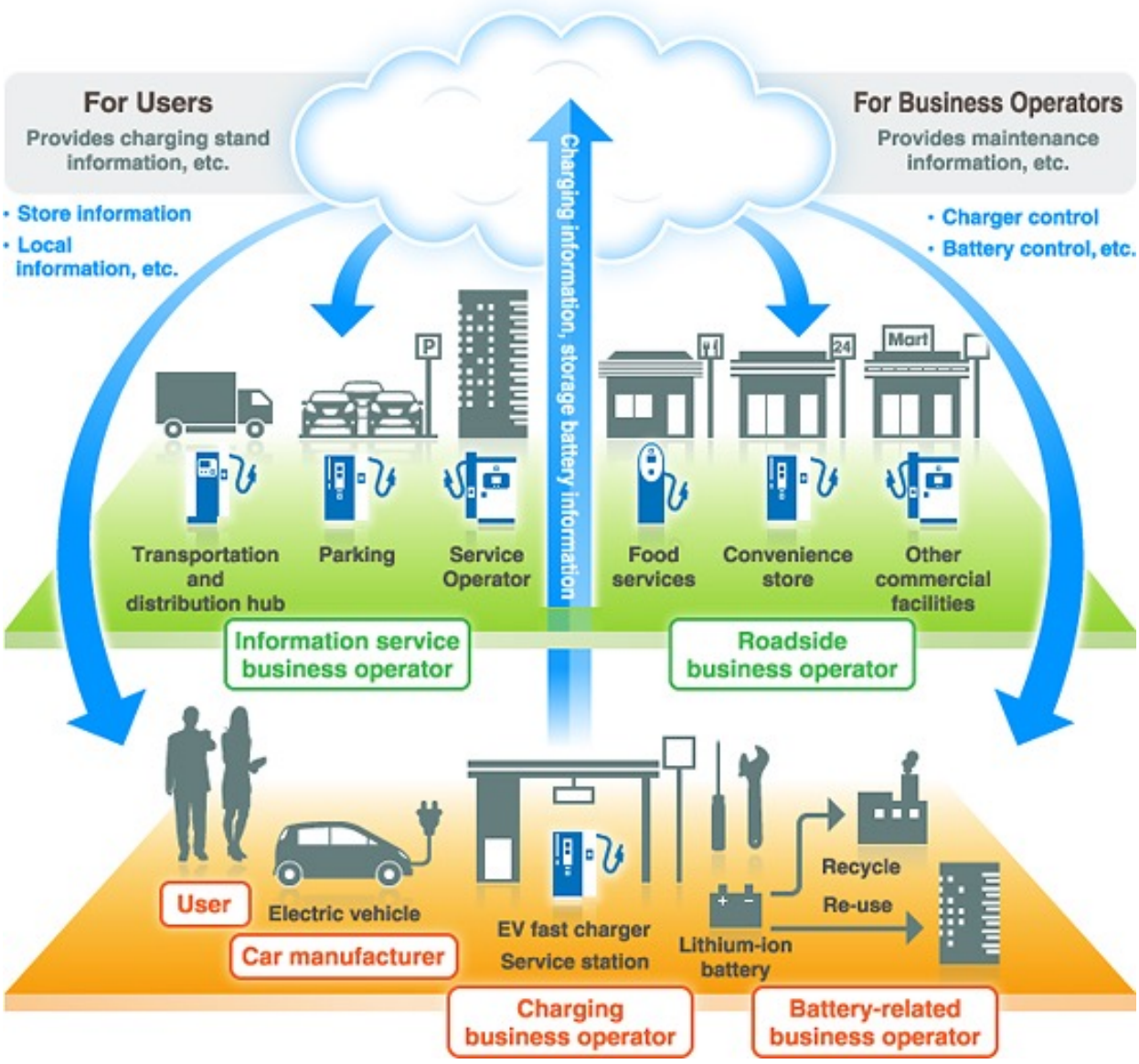


[Fig-36] Risk Mitigation

12. System Architecting View

DC fast charging station concept model, which is very similar to a gas station. The Fast Charging Center includes distribution hub, parking, service operator, food services, convenience stores, and other commercial facilities.

The users could charge at service center, which would take about 20 mins. During the time, the users could shop at convenience store or wash the car.



[Fig-37] EV Charging Conceptual Model

13. System Thinking

13.1 Common Good

- **EV Technical Innovation:** The demand of electronic cars will stimulate EV industry and drive related EV technical innovation, which will develop more energy clean and efficient cars.
- **Energy and Cost Saving:** Electricity is more affordable than gasoline, which is energy and cost saving for whole nation.
- **Environmental Pollution Reducing:** Less gasoline cars will **r**educe environmental pollution, and promote the development of sustainable eco-system
- **Energy Crisis Relief:** The gas and oil reserves are limited, the development of EV will relive the energy crisis and the conflicts over oil.

13.2 Charging Station Promotion

- **Government:** Building Public Access Charging Stations. Tax Reduction to encourage business operators to develop Charging Stations.
- **Car Dealers:** Building or providing free Charging Station for their Customers. For example: BMW's ChargeNow partnership with the EvGo network provides 2 years of free 30-minute DC fast charging sessions.
- **Mobile Apps:** Developing Mobile Apps that Users could find nearby Charging Stations.

14. Ethics

- **EV Spots for EVs:** An internal combustion car should not park in a spot designated for a plug-in car. That's a firm rule, no matter how crowded a parking lot is, and no matter how infrequently the charging location is used.
- **Charge Up and Move On:** As soon as the charging session is completed, it is better to un-plug and move your car as soon as possible, making way for a fellow plug-in driver.
- **Home Charging Sharing and Authority:** It is generous to share individual charging stations with others. Also, make it easier for others to find the charge station. aware not to use personal charging station without authority.
- **Abuse of Free Charging:** Avoid using free charging station as main charging source, either in public or workplace. Free charging stations were original designed for the convince or emergency use

15. Future: Wireless Charging

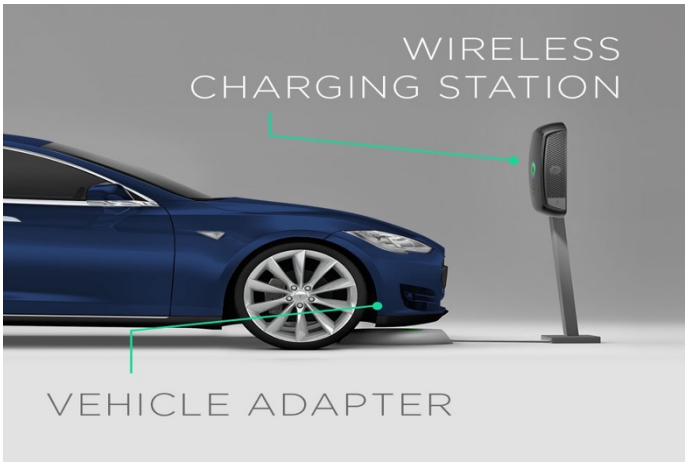
Plugless has two parts, as [Fig- 39] Wireless Charging Station Parts displayed:

1) Charging Station:

Control Panel and Parking Pad

2) Vehicle Adapter

When the users pull up to park, the Wireless Charging Station's Control Panel wakes up and guides user over the pad



[Fig- 38] Wireless Charging Station

1. Charging Station

Control Panel

Parking Pad

2. Vehicle Adapter

[Fig- 39] Wireless Charging Station Parts

with real-time guidance arrows for easy alignment.

After the Vehicle Adapter on the EV and the Wireless Charging Station’s Parking Pad are aligned, power is sent to EV over an air gap and the EV begins charging.

Wireless Charging is convenient and safe！

1) Wireless Charging Installation:

Electrical Requirements:

- Voltage: 208-240V Single Phase AC
- Amperage: 30 A for Volt and LEAF systems/ 50 A for Tesla Model S and BMW i3
- Service Panel: Dedicated 2-pole breaker rated for continuous use

[Fig- 40] Wireless Charging Model Gen 1

- Control Panel Wiring Inputs: Line 1, Line 2, and Ground Receptacle: (For indoor use ONLY)

[Fig- 41] Wireless Charging Model Gen 2

2) **Disadvantages:**

- Cost about $1500 each
- Limited to Indoor
- Limited to Level 2 Charging Station (charging time about 2 ~ 4 Hrs)
- Less Efficient: about 12% less than Wired Charging Station

There are several electric cars that support wireless charging, such as LEAF, Tesla Model S, and BMW I3.

16. Conclusions

- **Purpose:** This project addresses the issues associated with providing suitable chargers and the charging infrastructure for Electric Vehicle.
- **Solutions:** Through analyzing EV Charging Station technology, the project proposed two alternatives EV Charging Station infrastructure to support the growing population of EVs future Electric Vehicle' needs.
- **SE Methods:** In this project, I used following SE principles and methods: Use basic SE process, System Thinking, System Architecting View, Project Management Cost Analysis, Risk Management, etc.

17. Lesson Learned

- **Knowledge on Charging Stations:** Different Type of Electric Vehicles, Different Type of Level Charging Station, Charging Station's Installation and Cost, etc.
- **Apply SE to Real Life project:** Applying System Engineering principles and methods, such as Risk Management and MOEs, to the real project.
- **System Engineer View vs Engineer View:** As system engineers, we shall not only consider on technical view, but also need the skills on operational view and architecting view.
- **Ability to Deal With Complicated Project:** The project covered a lot of the text and image fields data, Make a simple and accurate reporting.

Appendix

Appendix-1:

Number of Vehicles in CA, 2015

DEPARTMENT OF MOTOR VEHICLES
ESTIMATED VEHICLES REGISTERED BY COUNTY
FOR THE PERIOD OF JANUARY 1 THROUGH DECEMBER 31, 2015

COUNTIES	AUTOS	TRUCKS	TRLRS	M/C	TOTAL
ALAMEDA	1,082,464	178,753	60,858	34,267	1,356,342
ALPINE	2,801	1,121	403	79	4,404
AMADOR	28,445	15,123	10,688	2,134	56,390
BUTTE	125,799	53,422	45,407	7,530	232,158
CALAVERAS	36,866	19,681	15,579	2,950	75,076
COLUSA	12,418	7,970	8,364	480	29,232
CONTRA COSTA	765,068	144,712	62,380	27,573	999,733
DEL NORTE	14,166	6,870	5,354	854	27,244
EL DORADO	130,988	45,947	37,656	8,517	223,108
FRESNO	492,048	173,784	95,440	19,200	780,472
GLENN	15,988	10,012	9,376	867	36,243
HUMBOLDT	79,531	41,336	27,566	4,999	153,432
IMPERIAL	113,104	41,485	23,151	2,932	180,672
INYO	13,507	7,645	5,592	986	27,730
KERN	424,033	187,694	106,417	19,420	737,564
KINGS	65,916	26,655	15,044	2,854	110,469
LAKE	46,287	21,835	16,644	3,139	87,905
LASSEN	15,579	10,052	9,733	1,091	36,455
LOS ANGELES	6,293,639	1,075,340	305,743	164,152	7,838,874
MADERA	75,560	32,984	25,012	3,815	137,371
MARIN	195,604	31,318	11,478	7,449	245,849
MARIPOSA	13,735	7,737	5,991	1,048	28,511
MENDOCINO	58,746	32,240	20,752	3,890	115,628
MERCED	133,566	52,433	29,267	4,699	219,965
MODOC	4,998	4,153	4,001	232	13,384
MONO	8,845	4,210	3,358	660	17,073
MONTEREY	257,225	77,720	35,057	8,571	378,573
NAPA	94,609	30,259	16,768	4,248	145,884
NEVADA	70,873	28,881	25,028	5,650	130,432
ORANGE	2,248,999	400,421	117,730	64,700	2,831,850
PLACER	272,870	74,722	49,995	13,371	410,958
PLUMAS	14,617	8,776	8,136	1,003	32,532
RIVERSIDE	1,329,526	359,997	162,256	50,420	1,902,199
SACRAMENTO	918,131	217,897	105,423	33,242	1,274,693
SAN BENITO	36,592	14,859	8,231	2,362	62,044
SAN BERNARDINO	1,216,312	340,884	173,064	46,096	1,776,356
SAN DIEGO	2,152,356	460,115	179,674	89,111	2,881,256
SAN FRANCISCO	407,656	54,768	8,337	23,342	494,103
SAN JOAQUIN	406,551	125,288	84,580	15,193	631,612
SAN LUIS OBISPO	182,483	64,815	45,249	11,560	304,107
SAN MATEO	604,122	88,291	21,572	17,681	731,666
SANTA BARBARA	269,520	78,114	32,908	13,384	393,926
SANTA CLARA	1,349,898	193,802	65,839	41,219	1,650,758
SANTA CRUZ	175,930	50,554	20,323	10,556	257,363
SHASTA	107,808	50,206	49,169	8,088	215,271
SIERRA	2,525	1,604	1,229	171	5,529
SISKIYOU	29,976	18,014	15,395	2,004	65,389
SOLANO	281,622	69,828	36,918	13,267	401,635
STANISLAUS	293,844	106,685	65,260	12,214	478,003
SUTTER	54,488	23,671	19,334	2,333	99,826
TEHAMA	33,837	19,037	18,758	2,019	73,651
TRINITY	8,683	6,006	5,266	741	20,696
TULARE	219,359	96,585	52,185	8,985	377,114
TUOLUMNE	39,572	20,054	14,183	3,135	76,944
VENTURA	576,281	135,388	52,990	25,253	789,912
YOLO	115,357	35,607	25,403	4,355	180,722
YUBA	38,767	15,697	12,976	2,390	69,830
OUT OF STATE	89,846	35,616	87,165	4,077	216,704
* MISC. VEHICLES					113,725
2015 FEE PAID VEHICLE REGISTRATIONS	**24,487,807**	**5,648,187**	**2,633,983**	**884,665**	**33,768,367**
FEE EXEMPT VEHICLE REGISTRATIONS	208,454	283,650	71,610	14,244	577,958
2015 GRAND TOTAL	**24,696,261**	**5,931,837**	**2,705,593**	**898,909**	**34,346,325**
2014 COMPARISON	24,010,642	5,871,811	2,636,702	877,207	33,550,486
% CHANGE FROM PRIOR YEAR	2.9%	1.0%	2.6%	2.5%	2.4%

FOREIGN-BASED IRP VEHICLES (Vehicles based in other states which pay fees to operate in California) 1,549,000

[Fig-4] DEPARTMENT OF MOTOR VEHICLES ESTIMATED VEHICLES REGISTERED BY COUNTY FOR THE PERIOD OF JANUARY 1 THROUGH DECEMBER 31, 2015
https://www.dmv.ca.gov

Appendix-2:

Estimated Number of Vehicles in LA and Orange County, 2025 and 2030

Counties	2015	2025	2030	
Los Angles	7,838,874	8,658,994	9,100,689	
Orange County	2,831,850	3,128,124	3,287,690	
Total	**10,670,724**	**11,787,118**	**12,388,379**	

[Table-2_2] Estimate Number of Vehicles in LA and Orange County, 2025 AND 2030

Notes: DEPARTMENT OF MOTOR VEHICLES ESTIMATED VEHICLES REGISTERED BY COUNTY FOR THE PERIOD OF JANUARY 1 THROUGH DECEMBER 31, 2015
https://www.dmv.ca.gov

Appendix-3:

Total Number of EV Charging Stations in CA, 2017

Notes: Data including both Public and Private Charging Stations

Total Public and Private Alternative Fueling Station Counts								
STATE	Biodiesel	CNG	E85	Electric* (stations/charging outlets)	HY	LNG	LPG	Totals** by State
California	42	320	120	4,280 / 14,888	38	45	324	15,777
Florida	14	56	77	977 / 2,174	0	3	153	2,477
Texas	17	125	211	973 / 2,496	1	20	487	3,357
New York	35	114	77	834 / 1,644	1	0	75	1,946
Washington	41	27	21	747 / 1,866	0	2	90	2,047
Georgia	24	48	55	643 / 1,775	0	4	100	2,006
Oregon	70	17	10	543 / 1,288	0	2	57	1,444
Michigan	10	24	254	535 / 1,107	2	0	108	1,505
Illinois	12	48	264	518 / 1,136	1	2	119	1,582
Maryland	12	16	36	512 /1,233	0	1	34	1,332
Massachusetts	12	16	7	507 / 1,292	2	1	35	1,365
Colorado	16	45	88	459 / 1,077	1	1	59	1,287
North Carolina	122	40	58	459 / 1,052	0	1	106	1,379
Virginia	10	18	30	442 / 1,024	0	2	91	1,175
Tennessee	31	20	78	437 / 1,013	0	5	88	1,235
Arizona	76	35	27	429 / 1,035	0	8	93	1,274
Pennsylvania	6	68	41	360 / 715	1	3	115	949
Ohio	14	60	154	343 / 653	2	6	89	978

[Table-3] Charging Stations at U.S. by States. Data last updated: 03/13/2017

*Includes legacy chargers, but does not include residential electric charging infrastructure.
**Totals by States indicate the total number of stations for all fuel types combined. Individual stations are counted multiple times if the station offers multiple types of fuel. For Electric, the total number of charging outlets was used in the calculation.

Appendix-4:

Level 2 Charging Cost Table

	Level 2 Home	Level 2 Parking lot	Level 2 Curbside	Key Assumptions
Charge Station Hardware	$450~$1000	$1500~$2500	$1500~$3000	
Electrician Materials	$50~$150	$200~$500	$150~$300	$500~$1000, if new breaker is required
Electrician Labor	$100~$350	$1250~$2950	$800~$1500	
Other Materials	NA	$50~$100	$50~$150	$25~$100/ft for trenching/boring, depends on surface, soil, and underground complexity Mounting, Signage, Protection and Restoration, etc
Other Labor	NA	$250~$750	$2500~$7500	
Transformer	NA	NA	NA	
Mobilization	$50~$200	$250~$500	$250~$500	Depends on Contractor, $250 ~ $500
Permitting	$0~$100	$50~$200	$250~$500	Varies to City, usually a flat fee
Total	$650 ~ $1800	$3550 ~ $7500	$5500 ~ $13800	

[Table-4] Level 2 Charging Cost

Maintenance costs not included in the analysis

Appendix-5:

DC Charging Cost Table

Component	Cost	Comments
DC fast-charging equipment • 50 kW DC public fast-charging station (480 V AC) • 3-year warranty and point-of-sale capabilities [1] • Payment for all electricity dispensed (including utility demand charges) • Overhead lighting and required safety equipment	$50,000 per unit	[1]Point-of-sale capabilities might include radio frequency identification authentication and networking to back-office functions (such as account management and customer billing), equipment status signals, and credit card transactions.
Equipment installation (labor and electric-panel upgrade) • Separate power drop or meter for charging station • Electric panel upgrade (if required) • Construction, environment and electricity permits • Trenching, backfill, and site restoration • Installation of conduit and power lines to station • Installation of concrete pad and electric stub-out • Installation of curb or wheel stop and overhead lighting • Installation and testing of equipment	$20,000 per location	

Component	Cost	Comments
Utility interconnection • Costs are highly variable and depend on cost-recovery policies of the electric-power provider and condition of existing power distribution components [2] • Generally includes utility costs for preliminary engineering and design, transformer upgrades, and labor for connection to the grid	$10,000 to $20,000 per location	[2]Additional costs could be incurred if addition of multiple chargers increases demand charges or requires additional electricity service upgrades.
Host-site identification, analysis, and screening • Identification of potential sites • Consultation with electric-power providers	$5,000 per location	
Negotiation, legal review, and execution of lease • Making contact with several property owners • Exchanging and negotiating lease documents • Executing and recording documents	$5,000 per location	

[Table-5 DC Fast Charging Cost

Appendix-6:

Table 6. Home Dominated Scenario, 50% Projection, in 2025

Total Vehicles in 2025: 11,787,118

2015	2025	Projection	Number of EV Cars:
Total Vehicles 10,670,724	11,787,118	50%	5,893,559

Home Dominant Scenario			Number of Cars	Number of Stations[1]	Average Installation Cost($)[2]	Total Installation Cost($)	Distribution	Efficiency Time(hrs)[3]	Connector Cost	Electric Bills /Per 100 mile[4]	Notes:
10%Dedicated	Level 3/ DC	10%	589,356	12,278	$22,626	$277,807,637	5.00%	0.5	$2,000	$6.00	[1][3]refer to Table-5 Charging Station could charge Number of EV cars per Day [2]refer to [Fig- 26] Charging Station Cost Comparison [4]refer to [Fig- 27] Estimated Electricity Cost for Users at Different Place
10% Retail	Level 1	5%	294,678	147,339	$0	$0	2.50%	12	$0	$0.00	
	Level 2	5%	294,678	49,113	$3,108	$152,643,178	2.50%	4	$800	$2.00	
10% Public	Level 1	5%	294,678	147,339	$0	$0	2.50%	12	$0	$0.00	
	Level 2	5%	294,678	49,113	$3,108	$152,643,178	2.50%	4	$800	$2.00	
10% Work	Level 1	5%	294,678	147,339	$0	$0	2.50%	12	$0	$0.00	
	Level 2	5%	294,678	49,113	$2,223	$109,178,180	2.50%	4	$800	$0.00	
60% Home	Level 1	45%	2,652,102	2,652,102	$0	$0	22.50%	12	$0	$1.00	
	Level 2	15%	884,034	884,034	$1,354	$1,196,981,833	7.50%	4	$800	$2.00	
Total Level 1	Total Level 2	Total Level 3	Total Number	Total Number	w Mean	Total Cost	Total	w Mean(Hrs)	w Mean($)	w Mean$/per 100 Miles	4. w Mean = Weighted Mean
3,094,118	1,031,373	12,278	5,893,559	4,137,770	$2888	$1,889,254,007	50.00%	8.45	$440	$1.55	

[Table 6] Alternative1, Home Dominated Scenario, 50% Projection, Year 2025

Notes:
In 2015, the Electric Vehicle not up to 1% of total number of cars, very small percentage! This project will base on the number of expected converted number!
In 2015, the DC EV charging station not up to 2,000 in LA and Orange County, very small amount! This project will not proposal the EV charging station for exist Electric Vehicle, but proposal larger amount of EV charging stations to meet future needs!

Appendix-7:

Table 7. Public Dominated Scenario, 50% Projection, in 2025

Total Vehicles in 2025: 11,787,118

2015	2025	Projection	Number of EV Cars:
Total Vehicles 10,670,724	11,787,118	50%	5,893,559

Public Dominant Scenario			Number of Cars	Number of Stations[1]	Average Installation Cost($)[2]	Total Installation Cost($)	Distribution	Efficiency Time(hrs)[3]	Connector Cost	Electric Bills /Per 100 mile[4]	Notes:
10%Dedicated	Level 3	10%	589,356	12,278	$22,626	$277,807,637	5.00%	0.5	$2,000	$6.00	[1][3]refer to Table-5 Charging Station could charge Number of EV cars per Day [2]refer to [Fig. 26] Charging Station Cost Comparison [4]refer to [Fig. 27] Estimated Electricity Cost for Users at Different Place
20% Retail	Level 1	10%	589,356	294,678	$0	$0	5.00%	12.0	$0	$0.00	
	Level 2	5%	294,678	49,113	$3,108	$152,643,178	2.50%	4.0	$800	$2.00	
	Level 3	5%	294,678	6,139	$22,626	$138,903,819	2.50%	0.5	$2,000	$4.00	
20% Public	Level 1	10%	589,356	294,678	$0	$0	5.00%	12.0	$0	$1.00	
	Level 2	5%	294,678	49,113	$3,108	$152,643,178	2.50%	4.0	$800	$2.00	
	Level 3	5%	294,678	6,139	$22,626	$138,903,819	2.50%	0.5	$2,000	$4.00	
20% Work	Level 1	10%	589,356	294,678	$0	$0	5.00%	12.0	$0	$0.00	
	Level 2	10%	589,356	98,226	$2,223	$218,356,361	5.00%	4.0	$800	$0.00	
30% Home	Level 1	10%	589,356	589,356	$0	$0	5.00%	12.0	$0	$1.00	
	Level 2	20%	1,178,712	1,178,712	$1,354	$1,595,975,777	10.00%	4.0	$800	$2.00	

Total Level 1	Total Level 2	Total Level 3	Total Number of EV Cars	Total Number of Charging Stations	w Mean Installation Cost	Total Installation Cost	Total	w Mean(hrs)	w Mean($)	w Mean$/per 100 Miles	4. w Mean = Weighted Mean
1,473,390	1,375,164	24,556	5,893,559	2,873,110	$5,329.10	$2,675,233,769	50.00%	6.50	$720	$1.80	

[Table 7] Alt ernative2, Public Dominated Scenario, 50% Projection, Year 2025

Appendix-8:

Table 8. Home Dominated Scenario, 80% Projection, in 2030

Total Vehicles in 2030: 12,388,379

	2015	2030				Projection		Number of EV Cars:		
Total Vehicles	10,670,724	12,388,379				80%		9,910,703		
Home Dominant Scenario			Number of Cars	Number of Stations[1]	Average Installation Cost($)[2]	Total Installation Cost($)	Distribution	Efficiency Time(Hrs)[3]	Connector Cost	Electric Bills /Per 100 mile[4]	Notes:
10%Dedicated	Level 3/ DC	10%	991,070	20,647	$22,626	$467,165,772	8.00%	0.5	$2,000	$6.00	[1][3]refer to Table-5 Charging Station could charge Number of EV cars per Day [2]refer to [Fig- 26] Charging Station Cost Comparison [4]refer to [Fig- 27] Estimated Electricity Cost for Users at Different PlaceLevel 2
10% Retail	Level 1	5%	495,535	247,768	$0	$0	4.00%	12	$0	$0.00	
	Level 2	5%	495,535	82,589	$3,108	$256,687,213	4.00%	4	$800	$2.00	
10% Public	Level 1	5%	495,535	247,768	$0	$0	4.00%	12	$0	$0.00	
	Level 2	5%	495,535	82,589	$3,108	$256,687,213	4.00%	4	$800	$2.00	
10% Work	Level 1	5%	495,535	247,768	$0	$0	4.00%	12	$0	$0.00	
	Level 2	5%	495,535	82,589	$2,223	$183,595,777	4.00%	4	$800	$0.00	
60% Home	Level 1	45%	4,459,816	4,459,816	$0	$0	36.00%	12	$0	$1.00	
	Level 2	15%	1,486,605	1,486,605	$1,354	$2,012,863,820	12.00%	4	$800	$2.00	
Total Level 1	Total Level 2	Total Level 3	Total Number	Total Number	w Mean	Total Cost	Total	w Mean(Hrs)	w Mean($)	w Mean$/per 100 Miles	4. w Mean = Weighted Mean
5,203,119	1,734,373	20,647	9,910,703	6,958,140	$2888	$3,176,999,795	80.00%	8.45	$440	$1.55	

[Table 8] Alternative1, Home Dominated Scenario, 80% Projection, Year 2030

Appendix-9:

Table 9. Public Dominated Scenario, 80% Projection, in 2030

Total Vehicles in 2030: 12,388,379

2015			2030				Projection		Number of EV Cars:		
Total Vehicles			10,670,724			12,388,379			80%		9,910,703.2
Public Dominant Scenario			Number of Cars	Number of Stations[1]	Average Installation Cost($)[2]	Total Installation Cost($)	Distribution	Efficiency Time(Hrs)[3]	Connector Cost	Electric Bills /Per 100 mile[4]	Notes:
10%Dedicated	Level 3	10%	991,070	20,647	$22,626	$467,165,772	8.00%	0.5	$2,000	$6.00	[1][3]refer to Table-5 Charging Station could charge Number of EV cars per Day [2]refer to [Fig- 26] Charging Station Cost Comparison [4]refer to [Fig- 27] Estimated Electricity Cost for Users at Different Place
20% Retail	Level 1	10%	991,070	495,535	$0	$0	8.00%	12.0	$0	$0.00	
	Level 2	5%	495,535	82,589	$3,108	$256,687,213	4.00%	4.0	$800	$2.00	
	Level 3	5%	495,535	10,324	$22,626	$233,582,886	4.00%	0.5	$2,000	$4.00	
20% Public	Level 1	10%	991,070	495,535	$0	$0	8.00%	12.0	$0	$1.00	
	Level 2	5%	495,535	82,589	$3,108	$256,687,213	4.00%	4.0	$800	$2.00	
	Level 3	5%	495,535	10,324	$22,626	$233,582,886	4.00%	0.5	$2,000	$4.00	
20% Work	Level 1	10%	991,070	495,535	$0	$0	8.00%	12.0	$0	$0.00	
	Level 2	10%	991,070	165,178	$2,223	$367,191,554	8.00%	4.0	$800	$0.00	
30% Home	Level 1	10%	991,070	991,070	$0	$0	8.00%	12.0	$0	$1.00	
	Level 2	20%	1,982,141	1,982,141	$1,354	$2,683,818,427	16.00%	4.0	$800	$2.00	
Total Level 1	Total Level 2	Total Level 3	Total Number of EV Cars	Total Number of Charging Stations	w Mean Installation Cost	Total Installation Cost	Total	w Mean(Hrs)	w Mean($)	w Mean$/per 100 Miles	4. w Mean = Weighted Mean
2,477,676	2,312,497	41,295	9,910,703	4,831,468	$5,329.10	$4,498,715,950	80.00%	6.50	$720	$1.80	

[Table 9] Alt ernative2, Public Dominated Scenario, 80% Projection, Year 2030

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