

# Electric Vehicle Charging Infrastructure Usage Observed in Large-scale Charging Infrastructure Demonstrations – ARB

John Smart

Idaho National Laboratory

Plug-in Electric Vehicle Infrastructure Information  
Gathering Meeting

May 27, 2014

[www.inl.gov](http://www.inl.gov)



## ***Idaho National Laboratory***

- U.S. Department of Energy (DOE) federal laboratory
- 890 square mile site with 4,000 staff
- Support DOE's strategic goal
  - Increase U.S. energy security and reduce the nation's dependence on foreign oil
- Multi-program DOE laboratory
  - Nuclear Energy
  - Fossil, Biomass, Wind, Geothermal and Hydropower Energy
  - Advanced Vehicles and Battery Testing
  - Homeland Security and Cyber Security



INL is a primary partner in two national electric vehicle (EV) charging infrastructure demonstrations

## The EV Project

- Purpose is to build mature EV charging infrastructure in 17 US regions and study:
- Infrastructure deployment process
- Customer driving and charging behavior
- Impact on electric grid
- 12,000+ AC level 2 charging units, 100+ DC fast chargers
- 8,000+ Electric drive vehicles
- INL data collection Jan 2011 – Dec 2013
- Project partners:



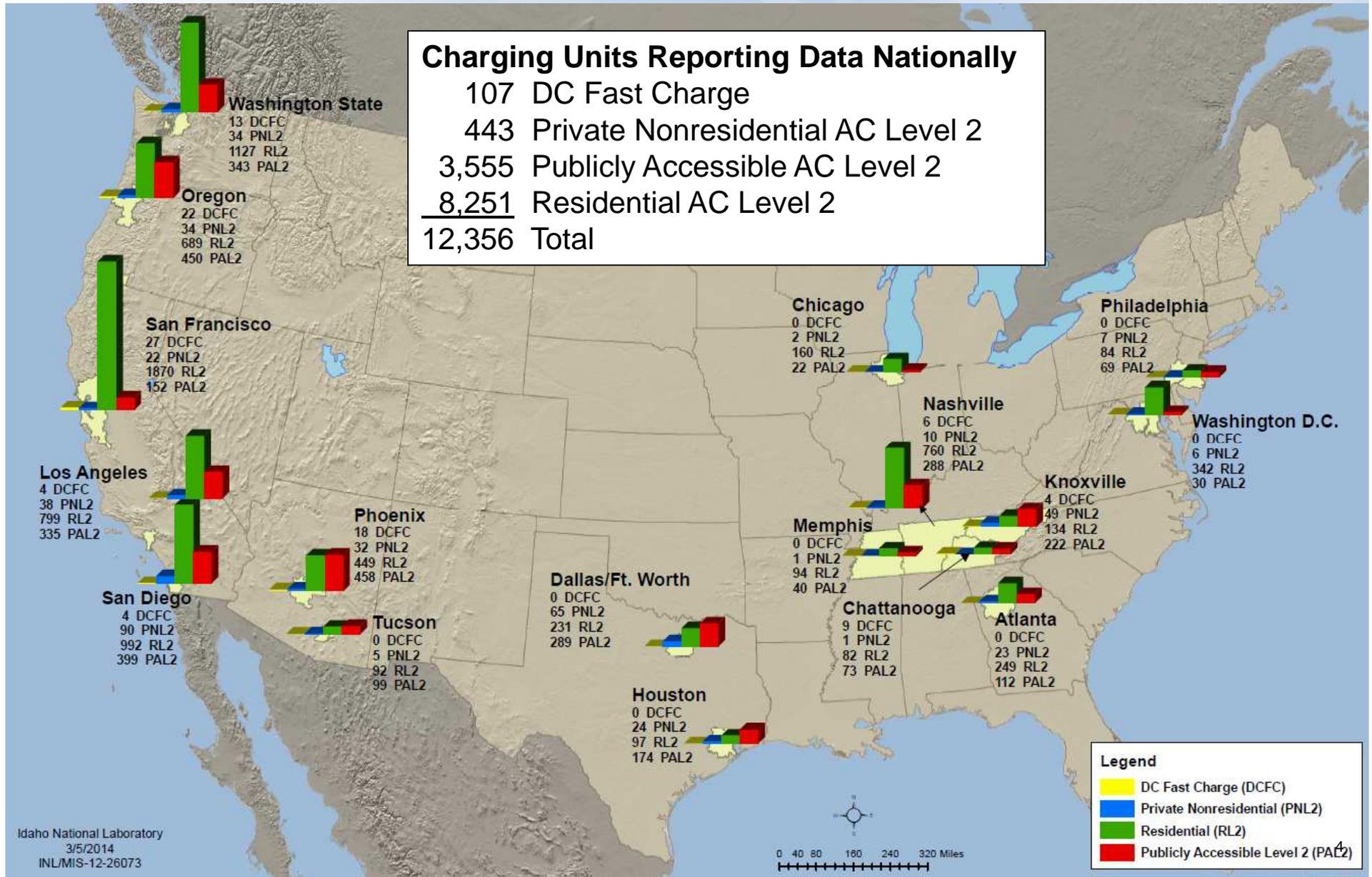
## ChargePoint America

- Deploy 4,700+ residential and public AC level 2 charging units in 11 US regions
- Study customer usage of residential and public infrastructure
- INL data collection May 2011 – Dec 2013

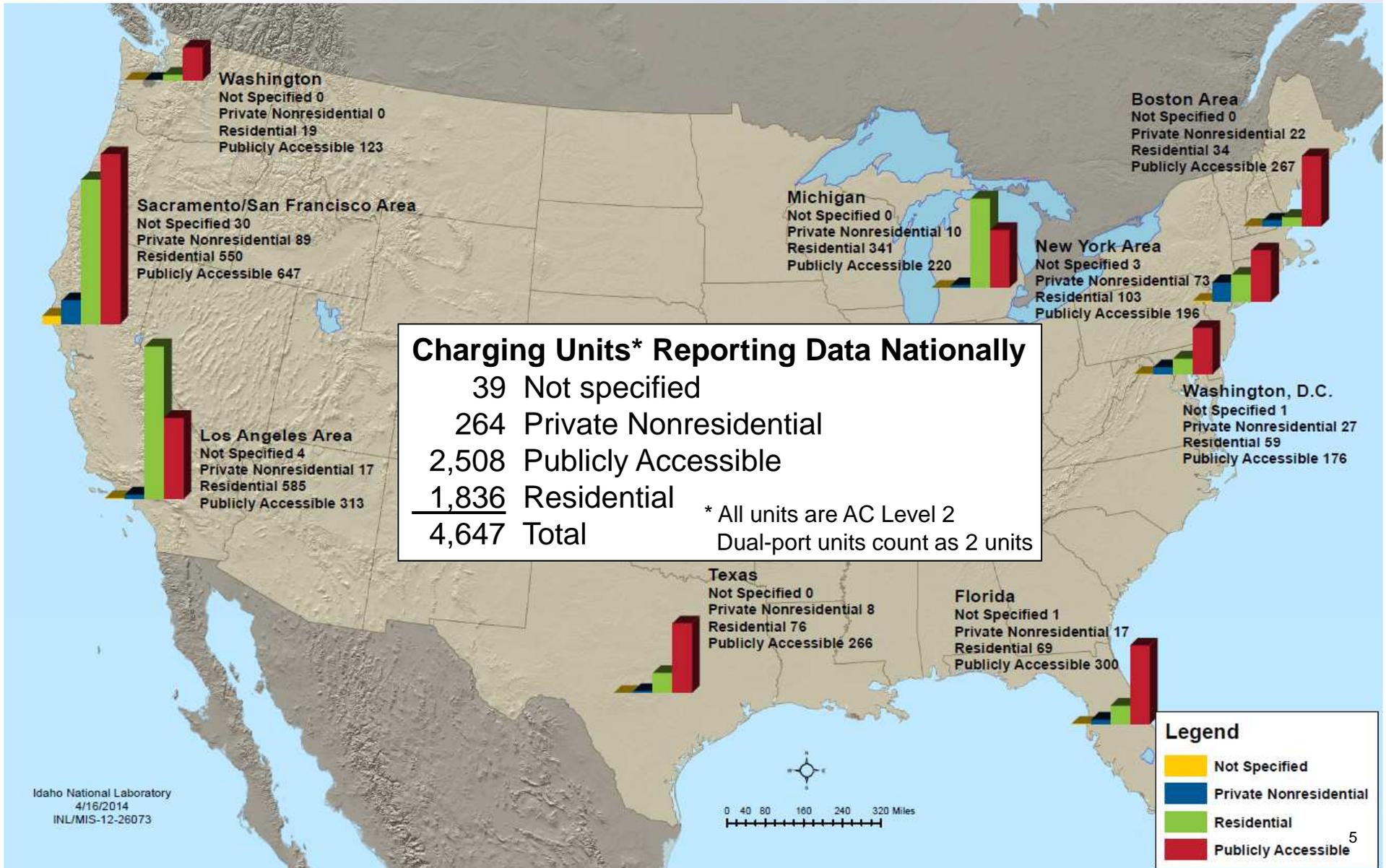
# Infrastructure Deployment in The EV Project through December 2013

## Charging Units Reporting Data Nationally

107 DC Fast Charge  
 443 Private Nonresidential AC Level 2  
 3,555 Publicly Accessible AC Level 2  
8,251 Residential AC Level 2  
 12,356 Total



# Infrastructure Deployment in ChargePoint America through December 2013



## Outline

- How has public AC level 2 EVSE and DC fast charger (DCFC) usage changed over time?
  - What was the impact of implementing payment for use of DCFC
- Did Leaf driving behavior change as public infrastructure usage changed?
  - Electric vehicle miles traveled (eVMT)
  - Time at DCFCs
- Which stations are used most frequently?
  - Free vs. fee by venue
  - Mix of charging at home/workplace/other locations

## ***Public EVSE Usage Fees***

### Blink usage fees

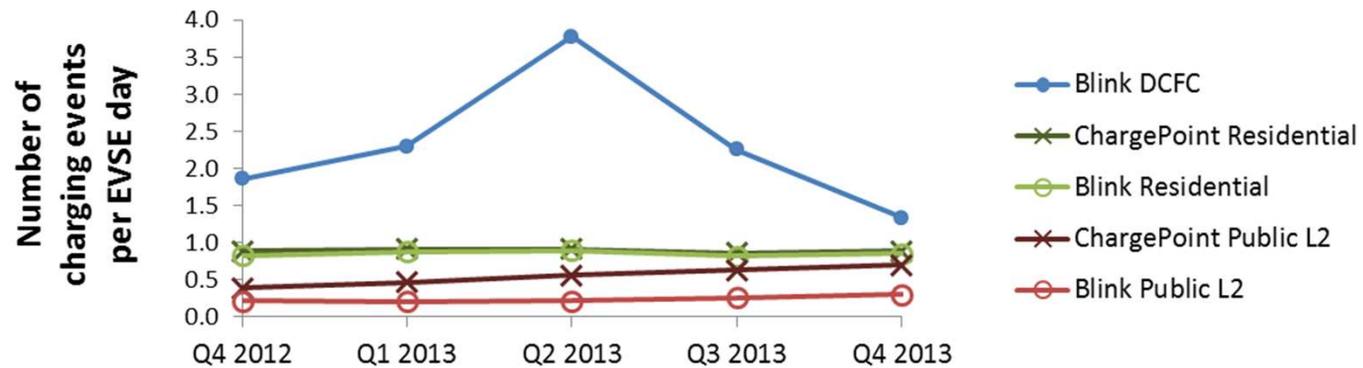
- Public AC Level 2 fees started Jul – Aug 2012
  - Varies from \$1.00 to \$2.00 **per hour connected**
  - 16% of sites were still free as of Dec 31, 2013 (per local site host discretion)
- DC Fast Charger fees started Jul 2013
  - \$5 for Blink member / \$8 for non-member **per session**

### ChargePoint usage fees

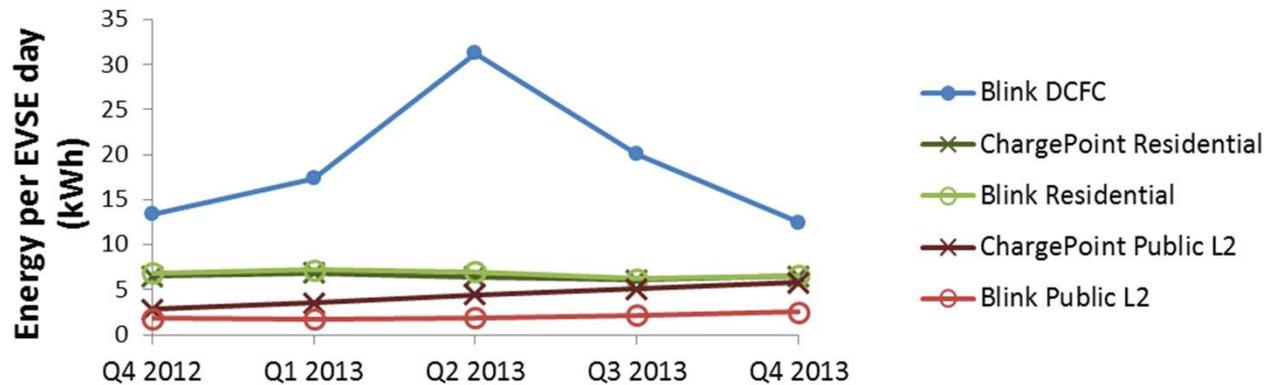
- Vary by site (per local site host discretion)
- Many are free

# Usage Frequency of Public Level 2 EVSE and DC Fast Chargers

### Charging Frequency by EVSE Type

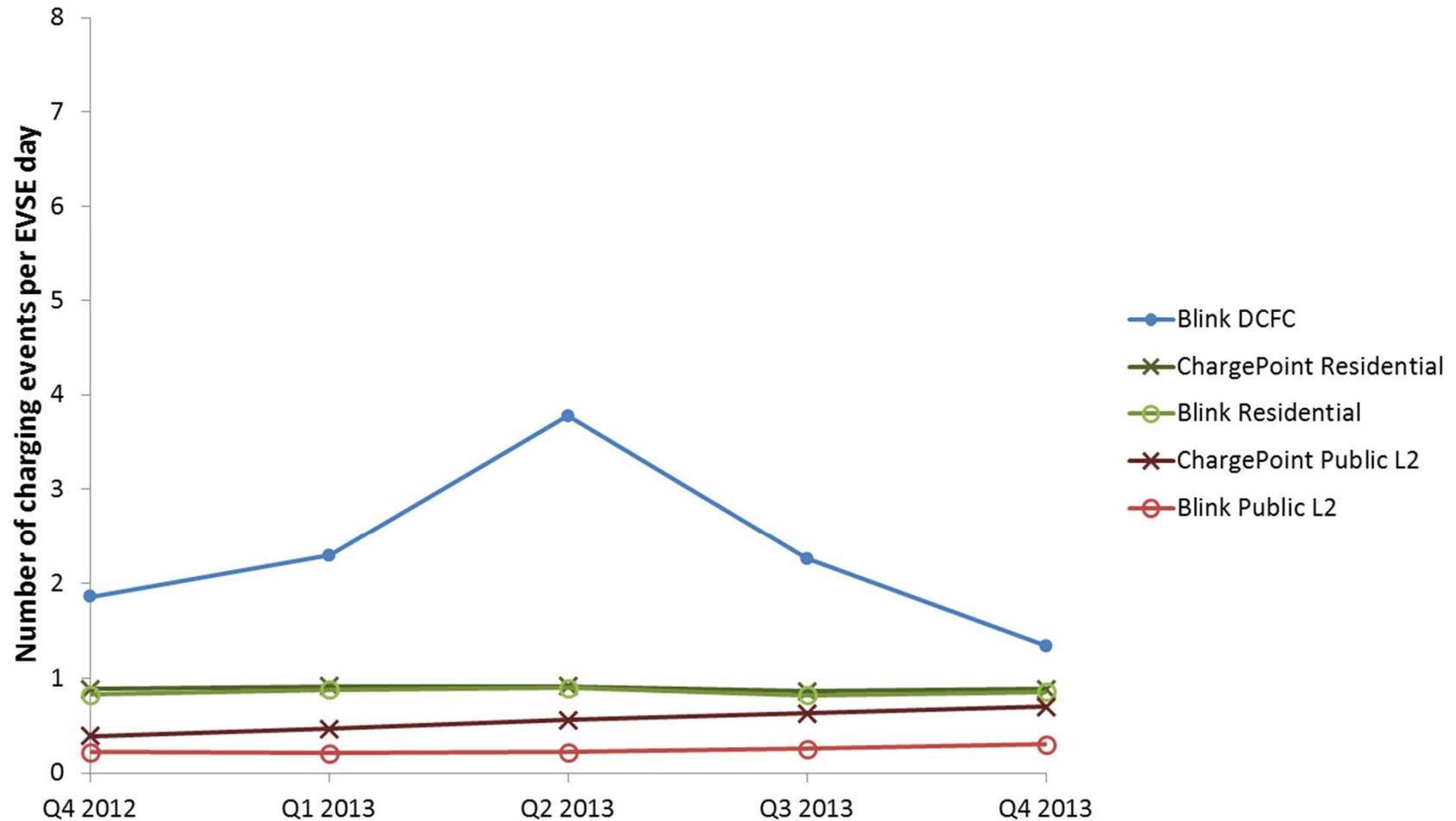


### Charging Energy by EVSE Type



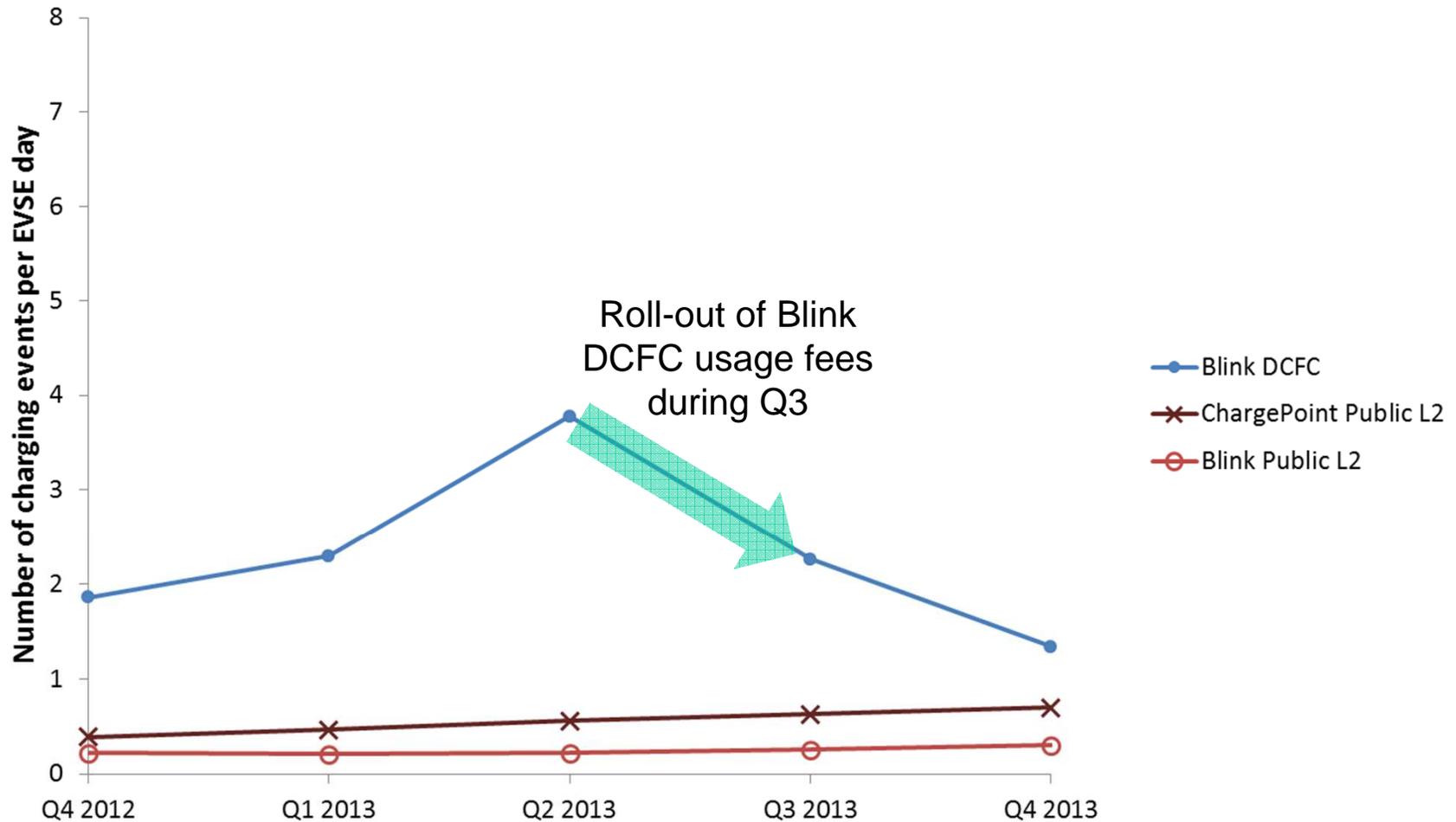
# Usage Frequency of Public Level 2 EVSE and DC Fast Chargers

Charging Frequency by EVSE Type



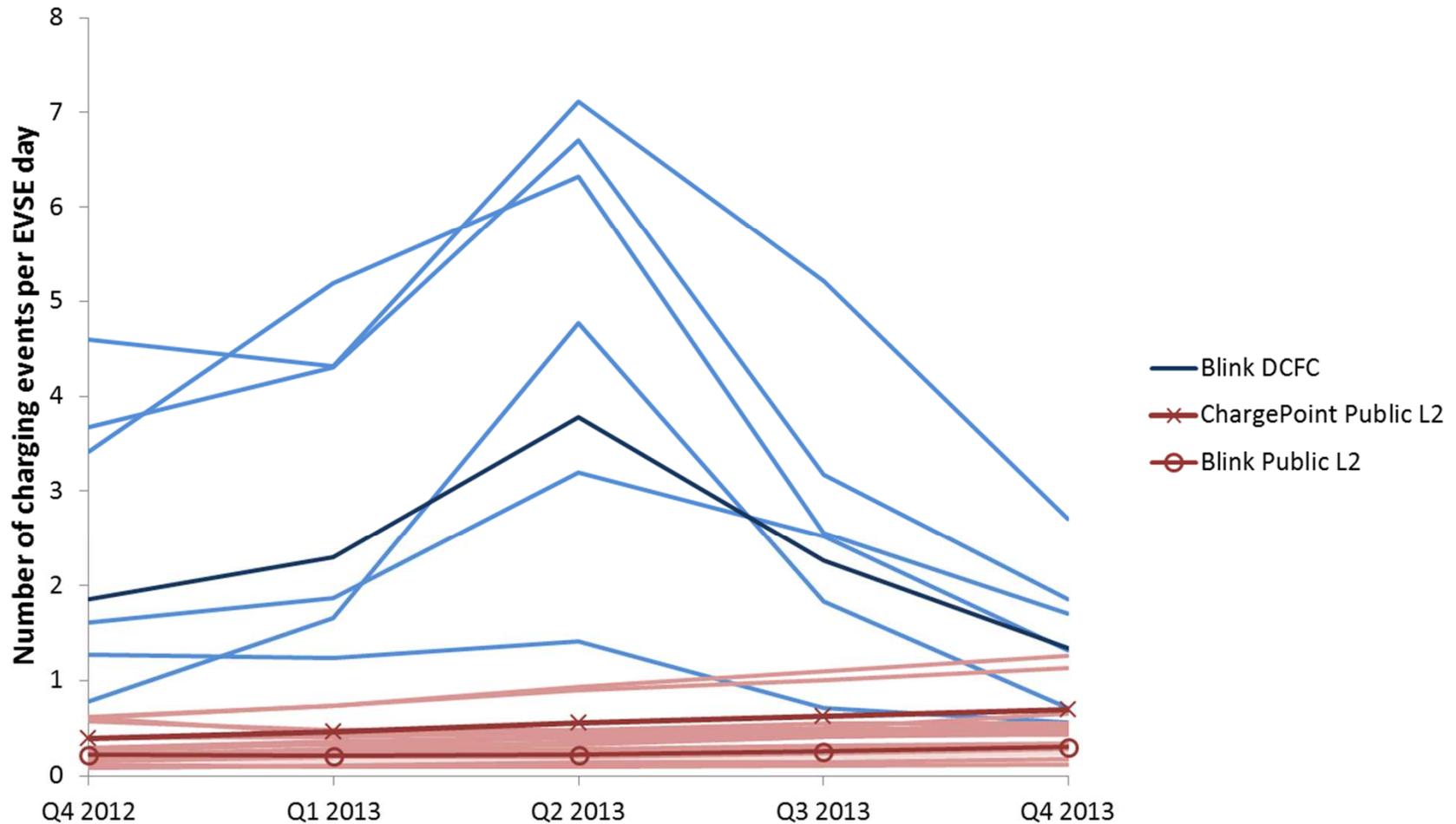
# Usage Frequency of Public Level 2 EVSE and DC Fast Chargers

Charging Frequency by EVSE Type



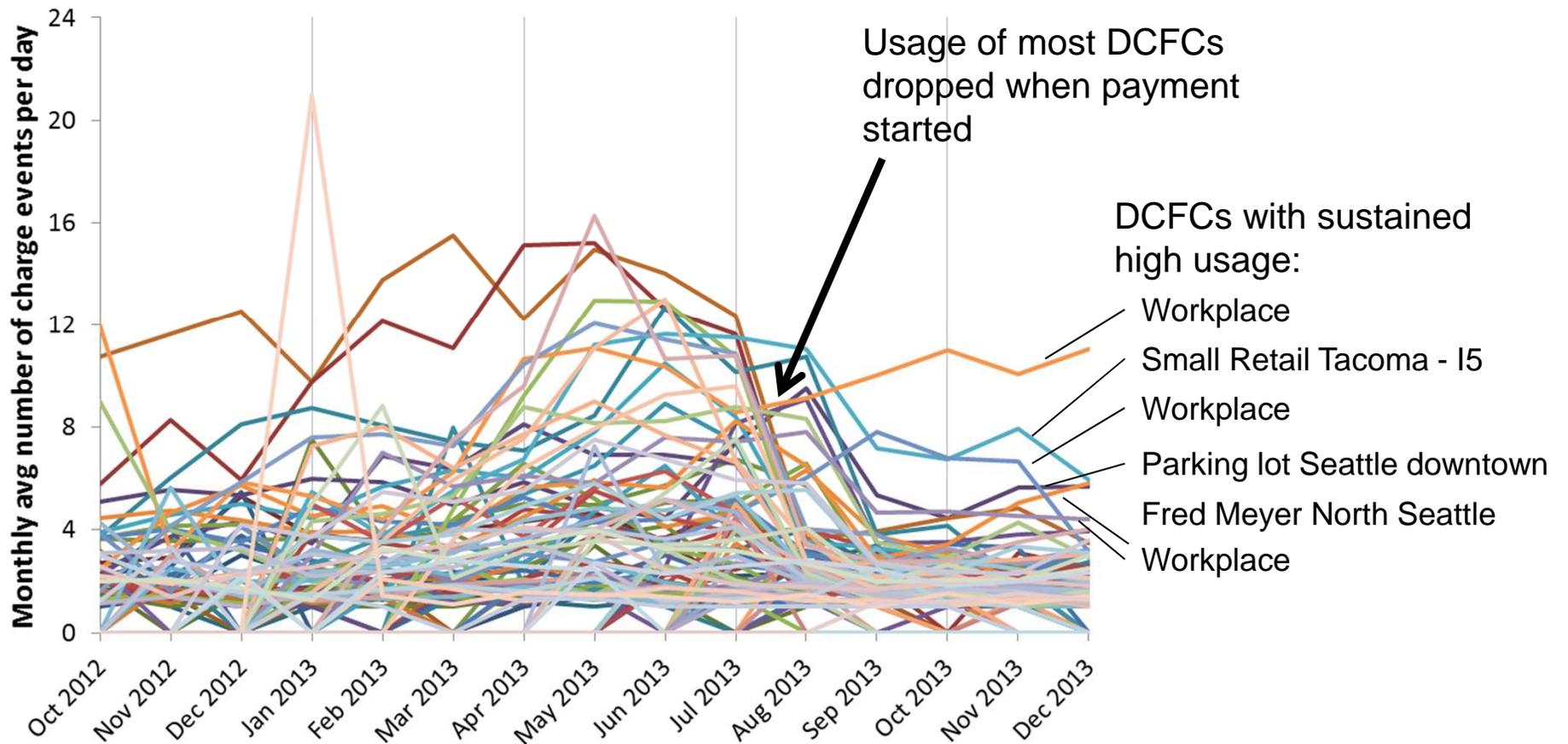
# Usage Frequency of Public Level 2 EVSE and DC Fast Chargers by Region

Charging Frequency by EVSE Type and Region



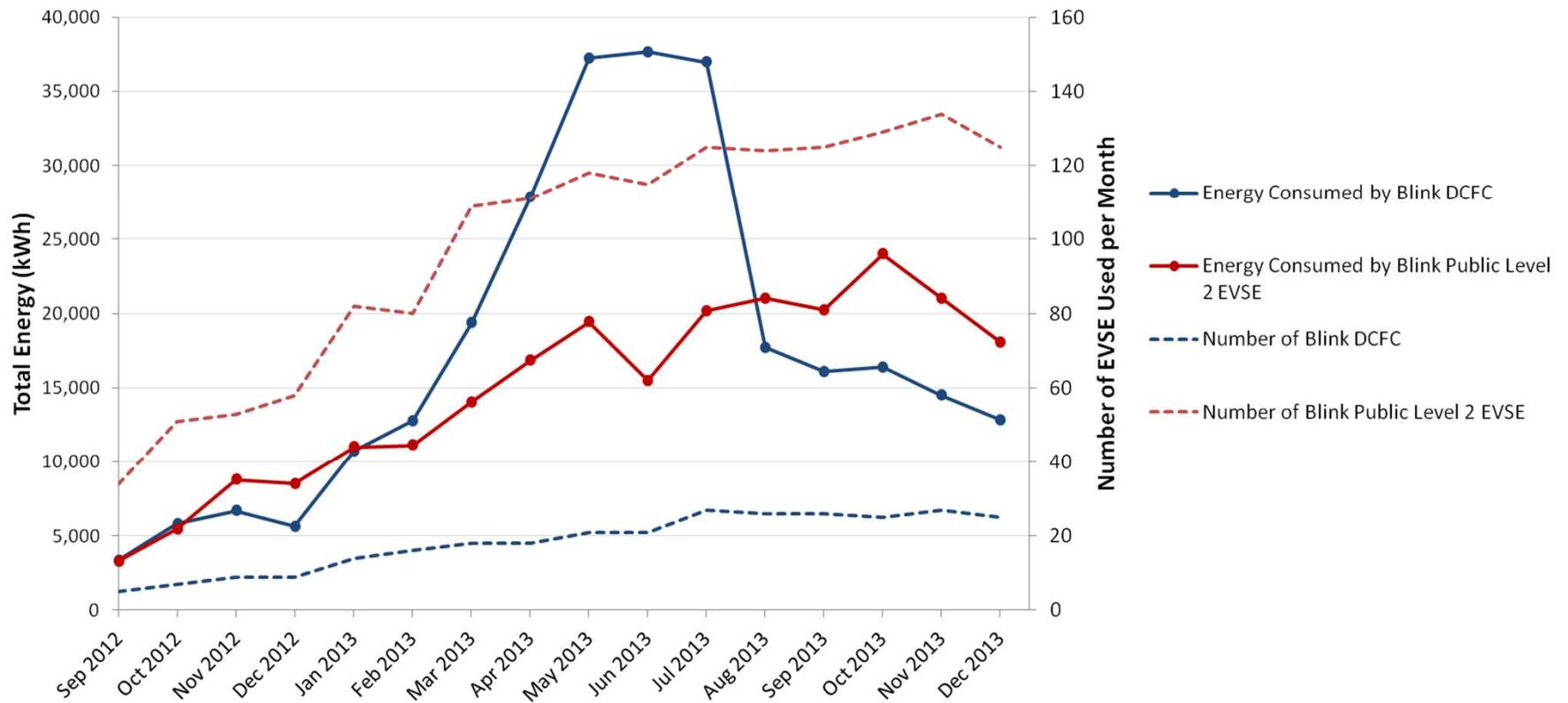
# Usage Frequency of Individual DC Fast Chargers

**Monthly Average Number of Charging Events per Day for Each DCFC**



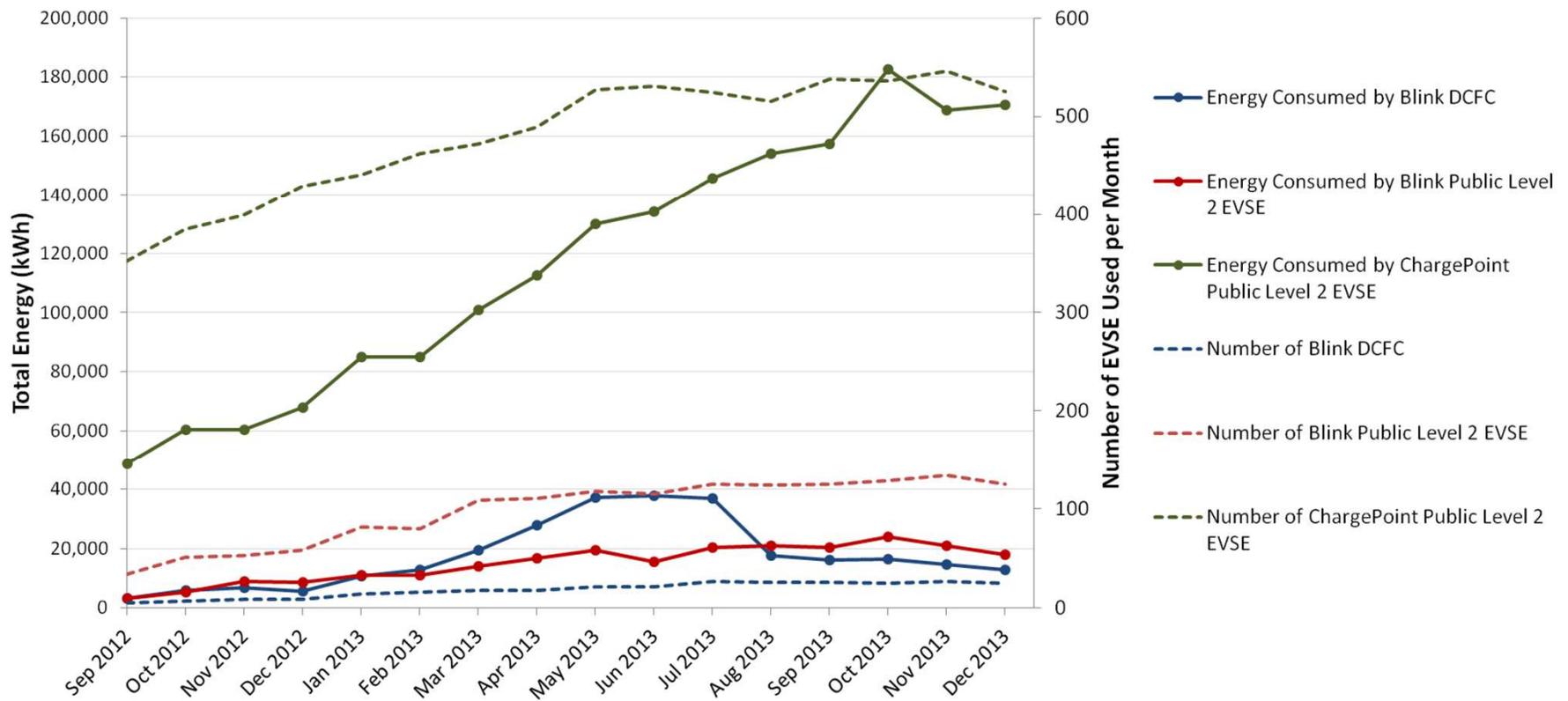
# Total Energy Consumption at Blink Stations in San Francisco

Energy Consumed by Public Level 2 EVSE and DCFC in San Francisco Region by Month



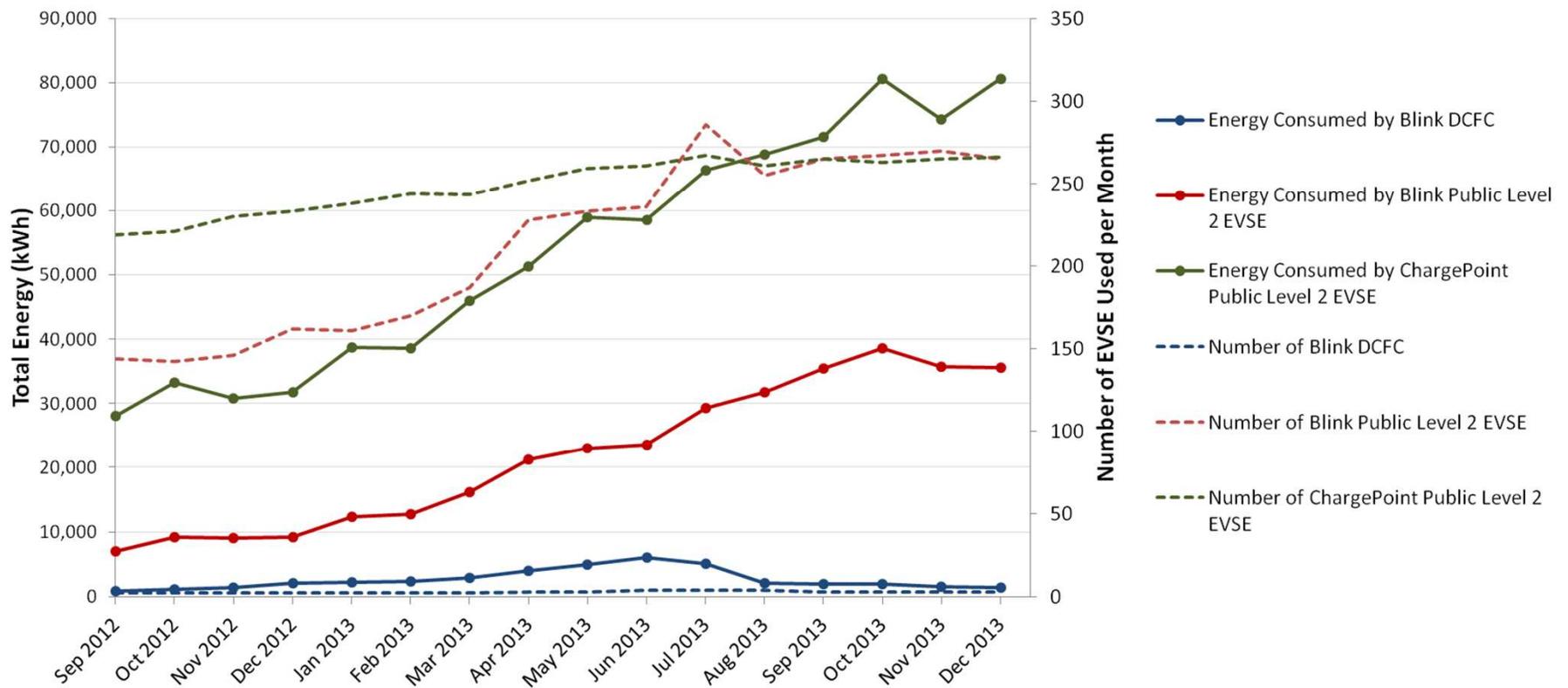
# Total Energy Consumption at Blink and ChargePoint Stations in San Francisco

Energy Consumed by Public Level 2 EVSE and DCFC in San Francisco Region by Month



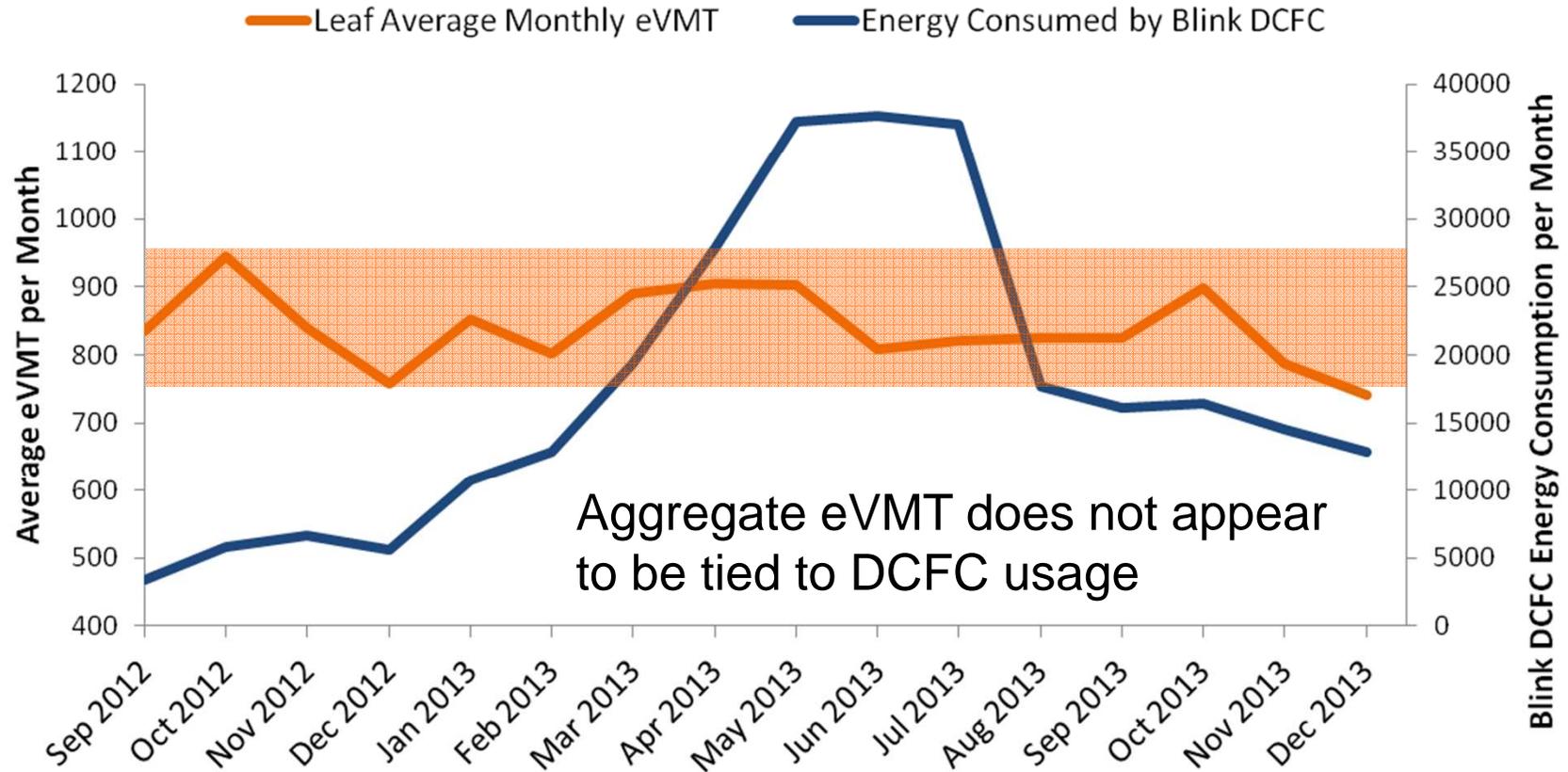
# Total Energy Consumption at Blink and ChargePoint Stations in Los Angeles

Energy Consumed by Public Level 2 EVSE and DCFC in Los Angeles Region by Month



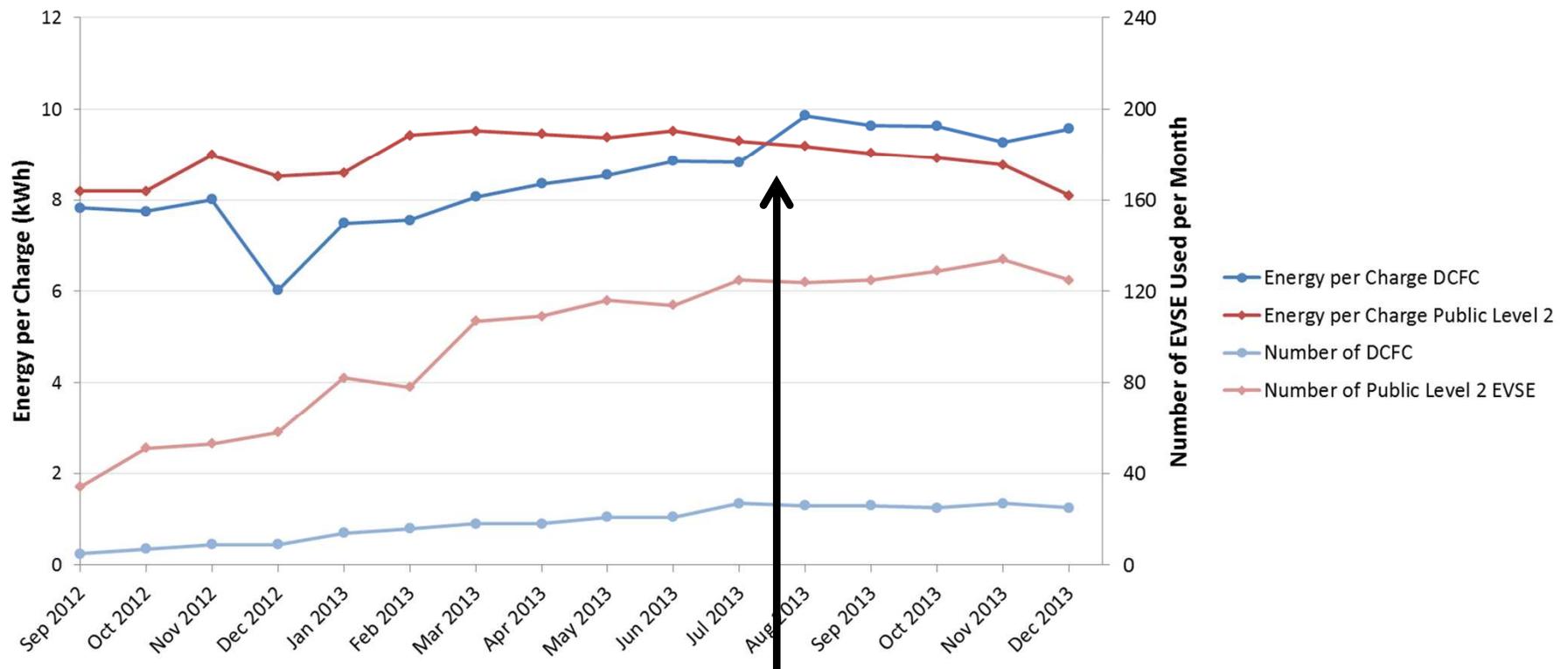
# Leaf eVMT in San Francisco

San Francisco EV Project Leaf eVMT vs. Blink DCFC Usage in San Francisco



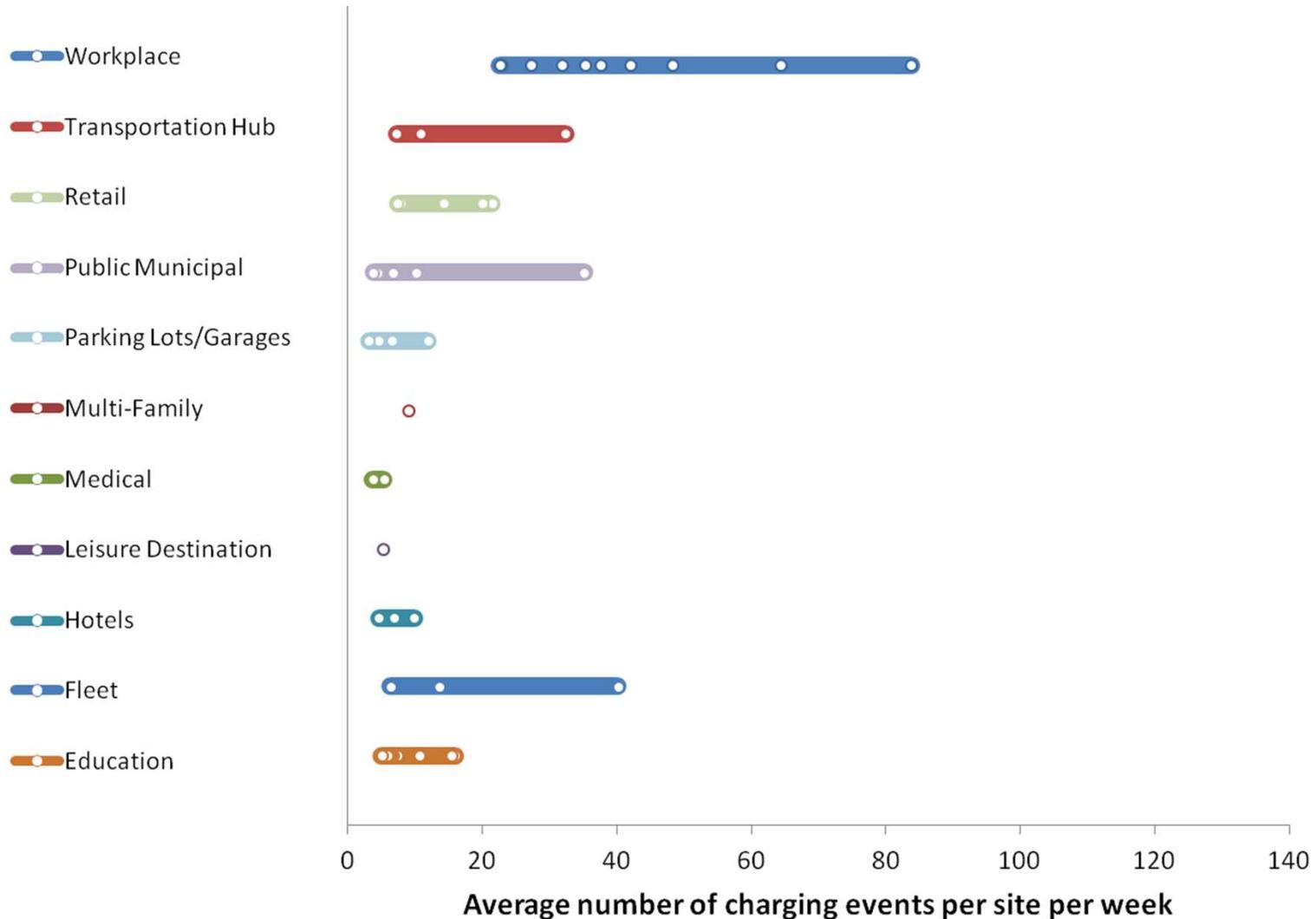
# Energy per Charging Event Over Time

Average Energy Consumed per Charge by Public Level 2 EVSE and DCFC in San Francisco Region by Month

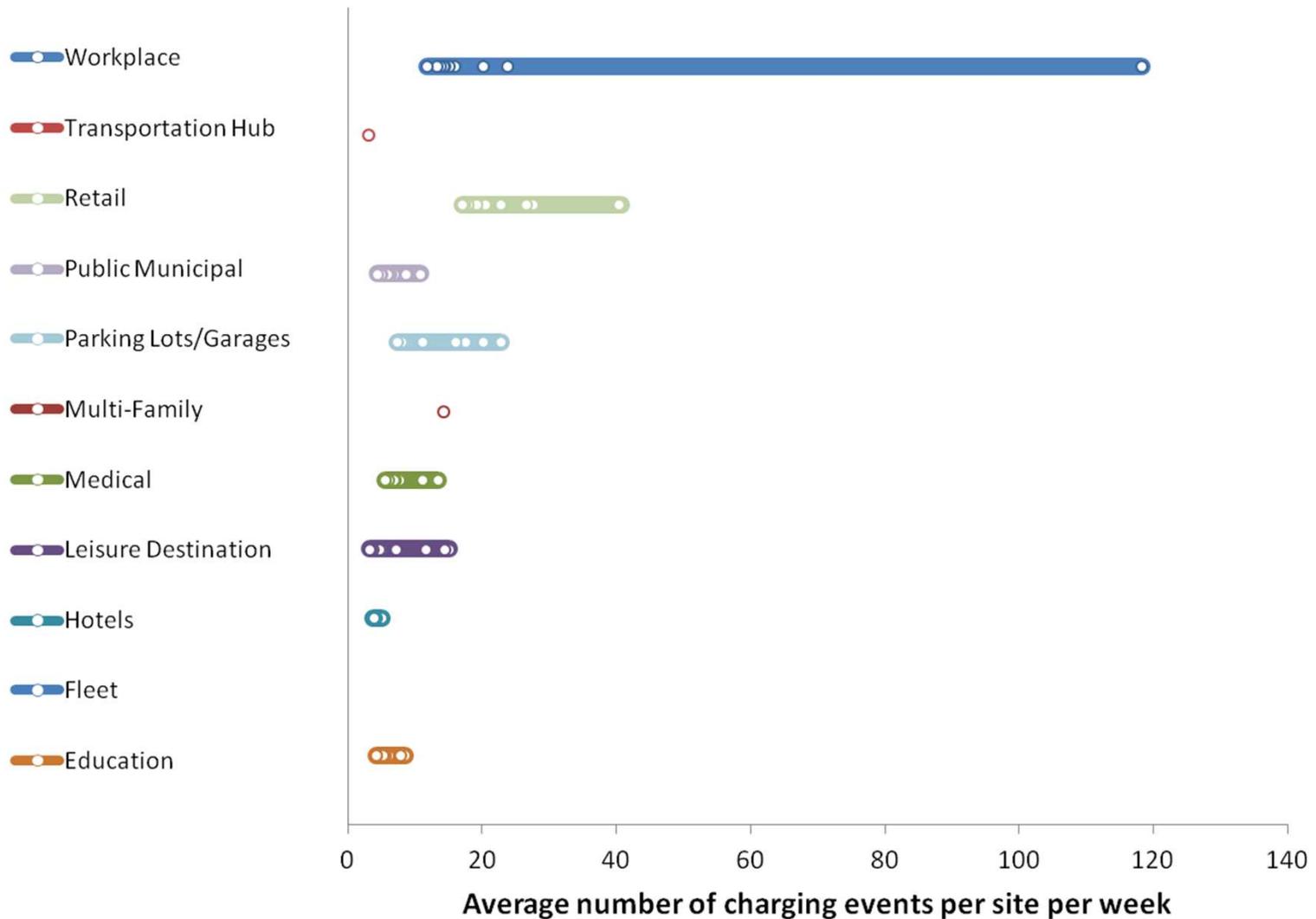


- DCFC events were longer after the introduction of payment
- Flat fee per session may prompt an “all-you-can eat” mentality

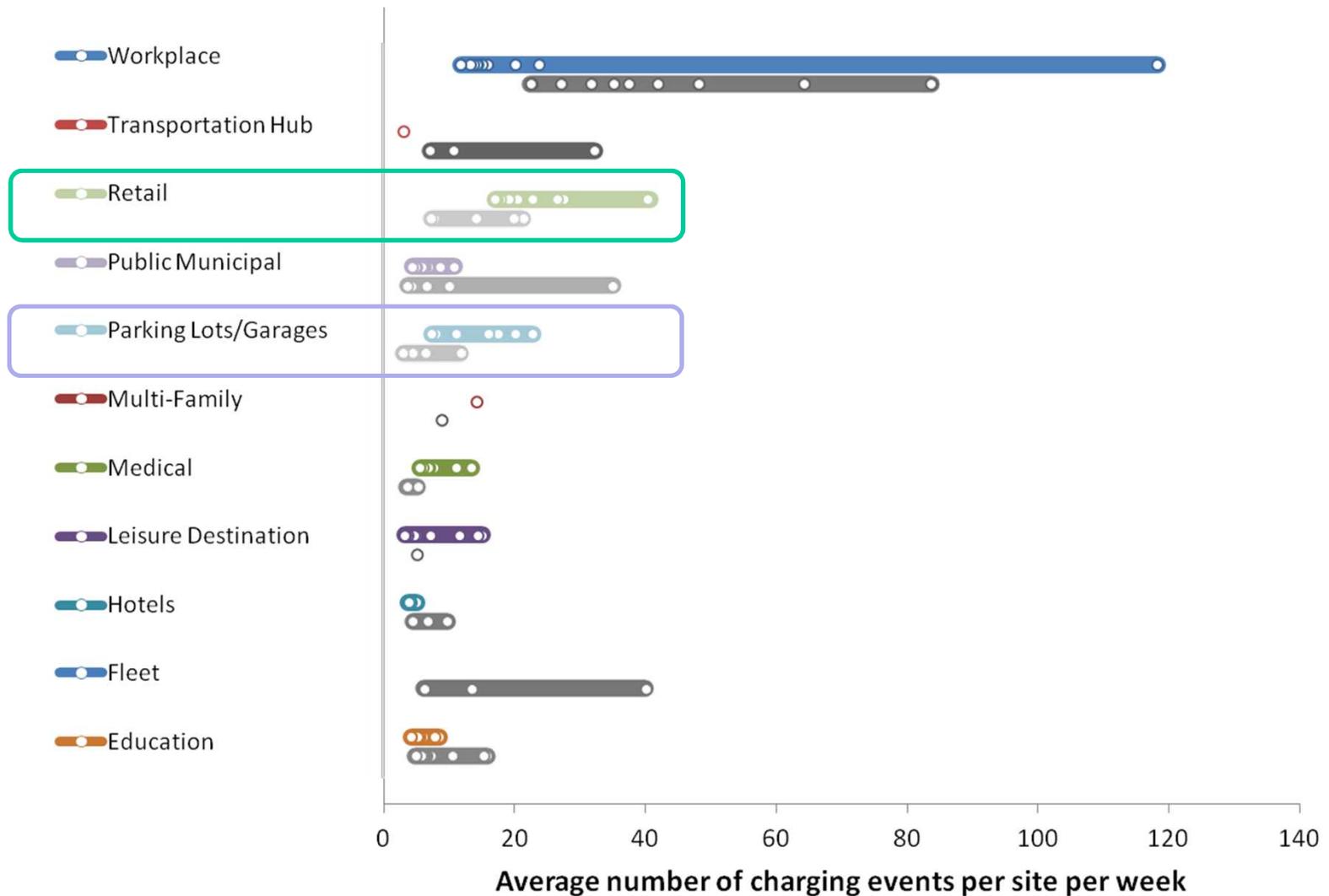
## Top 10 Most Highly Used **Free** Public Level 2 Blink EVSE Sites by Venue



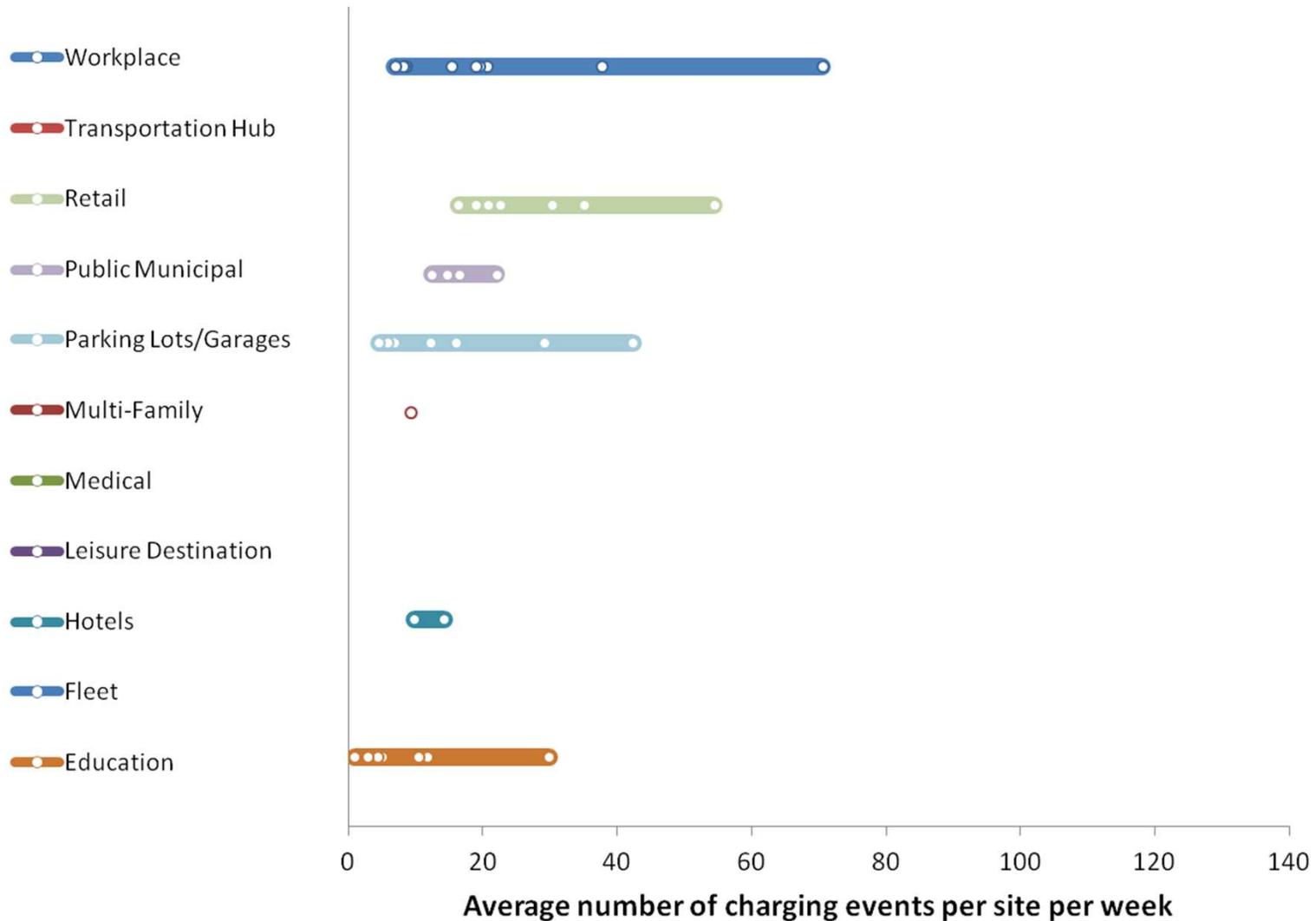
## Top 10 Most Highly Used **For-Cost** Public Level 2 Blink EVSE Sites by Venue



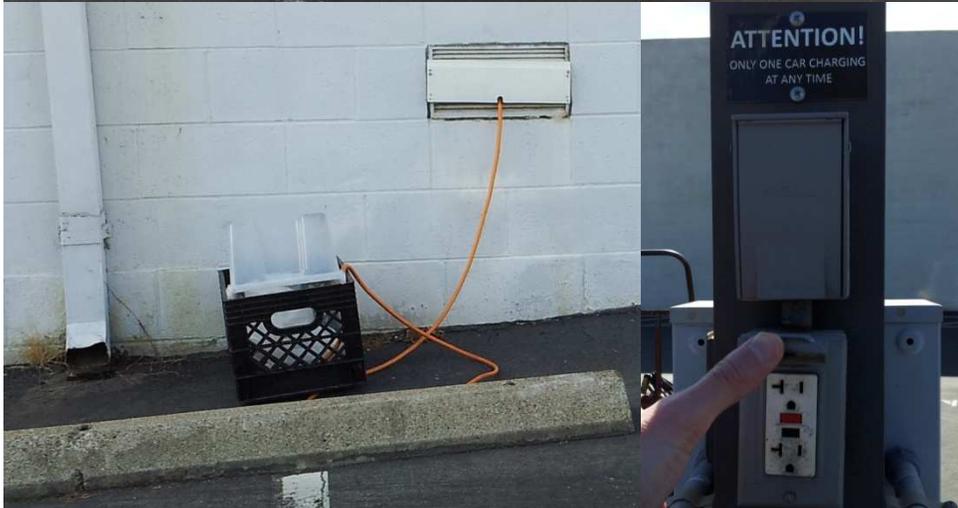
# Top 10 Most Highly Used **For-Cost** / Free Public Level 2 Blink EVSE Sites by Venue



# Top 10 Most Highly Used **For-Cost** Blink DCFC Sites by Venue



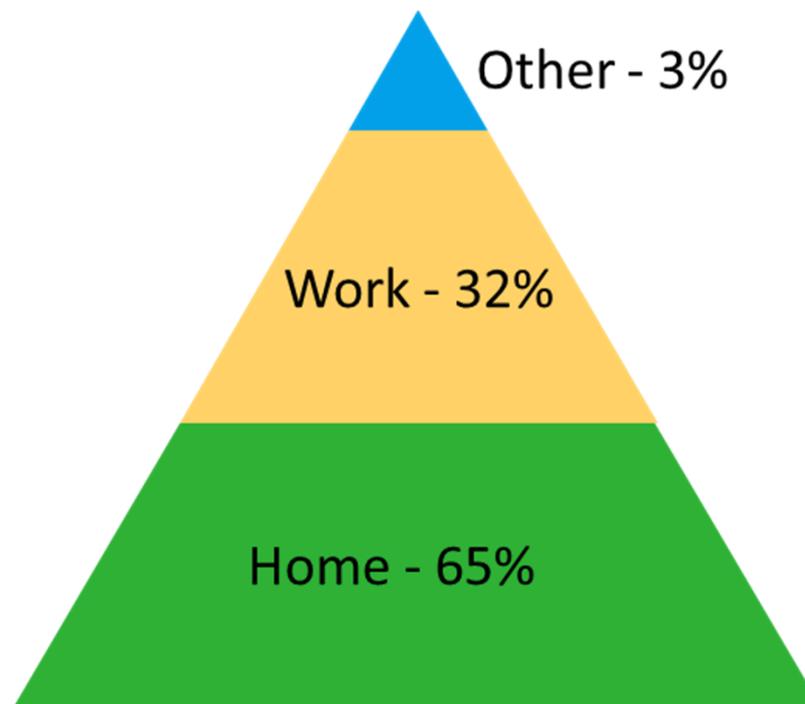
# Workplace Charging



## ***Charging Location Preference – Nissan Leaf***

707 Nissan Leafs with Access to Workplace Charging, 2012 – 2013

### **Overall Charging Frequency by Location (to scale)**



#### **Careful!**

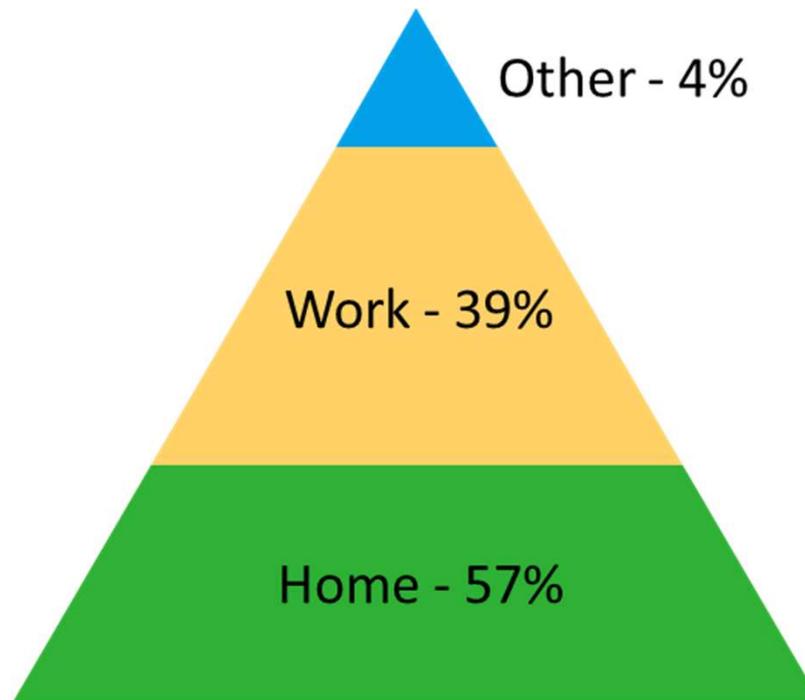
How important is this 3% to individual drivers' mobility needs?

How does cost to use workplace charging influence this behavior?

## ***Charging Location Preference – Chevy Volt***

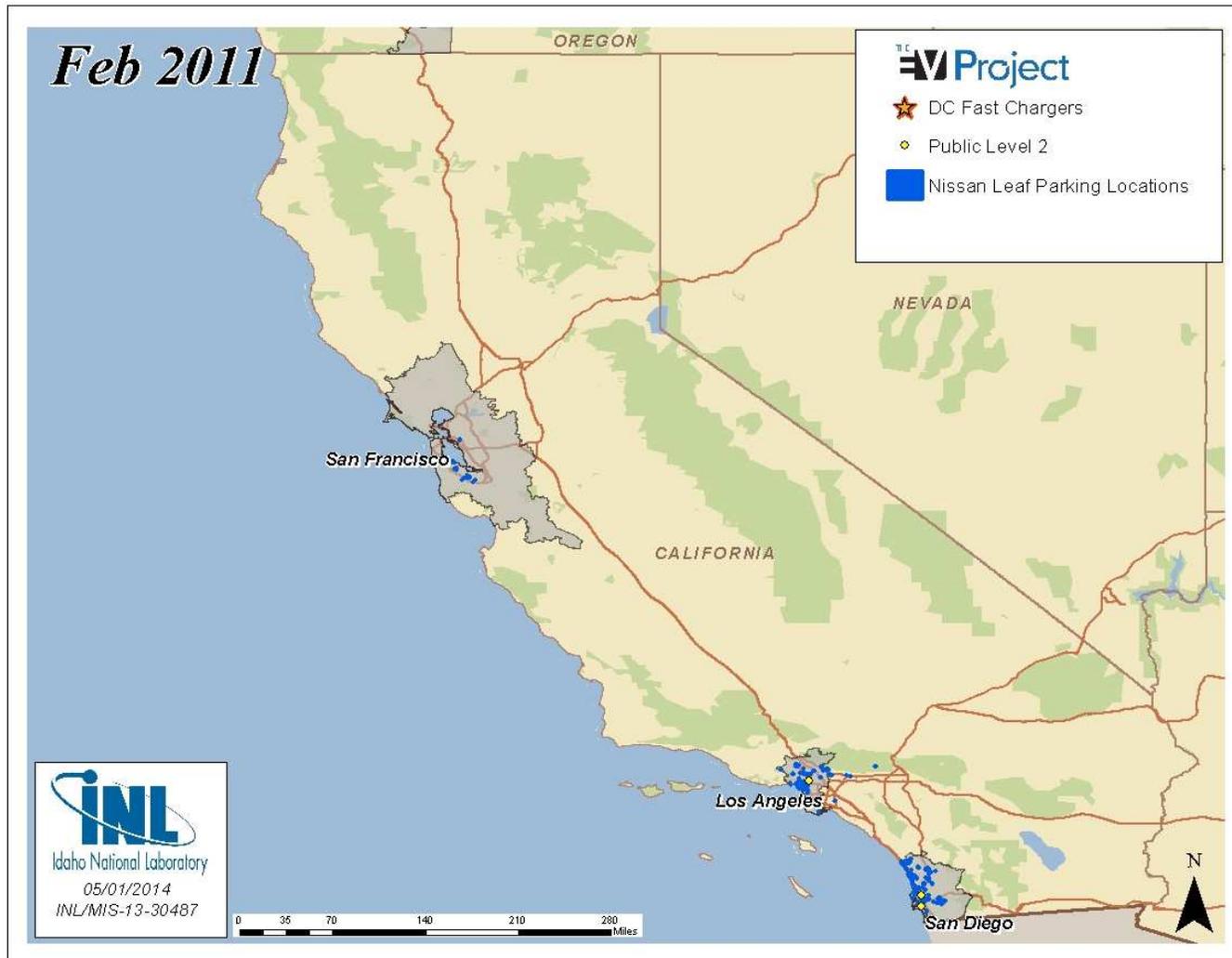
96 Chevrolet Volts with Access to Workplace Charging, 2013

**Overall Charging Frequency by Location  
(to scale)**



How does cost to use workplace charging influence this behavior?

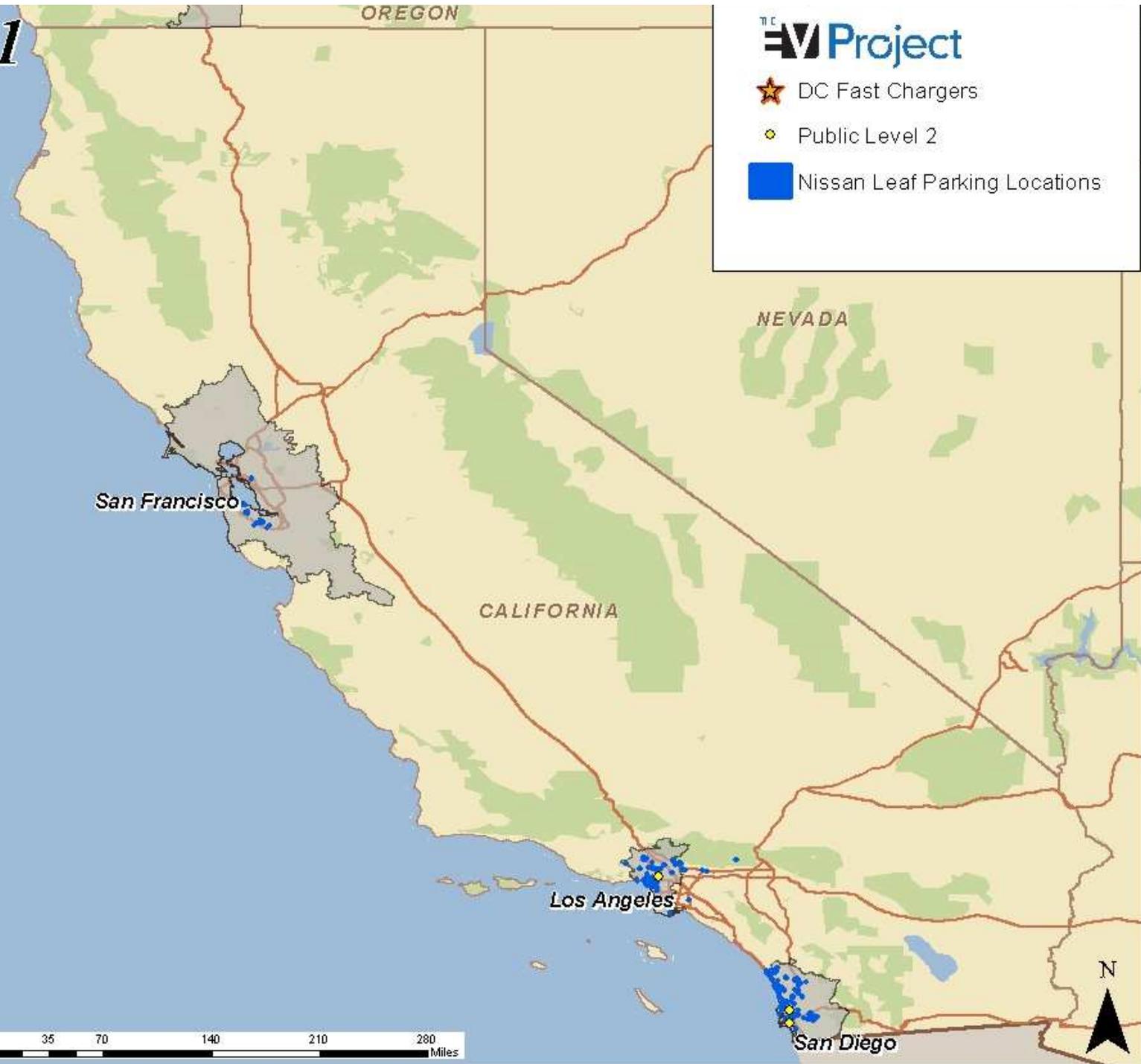
# Travel Extents of EV Project Leafs Based in CA



*Feb 2011*

**TC Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



**INL**  
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487

*Mar 2011*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

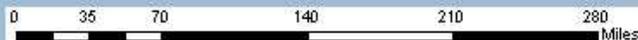
San Diego



Idaho National Laboratory

05/01/2014

INL/MIS-13-30487



*Apr 2011*

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

San Diego



Idaho National Laboratory

05/01/2014

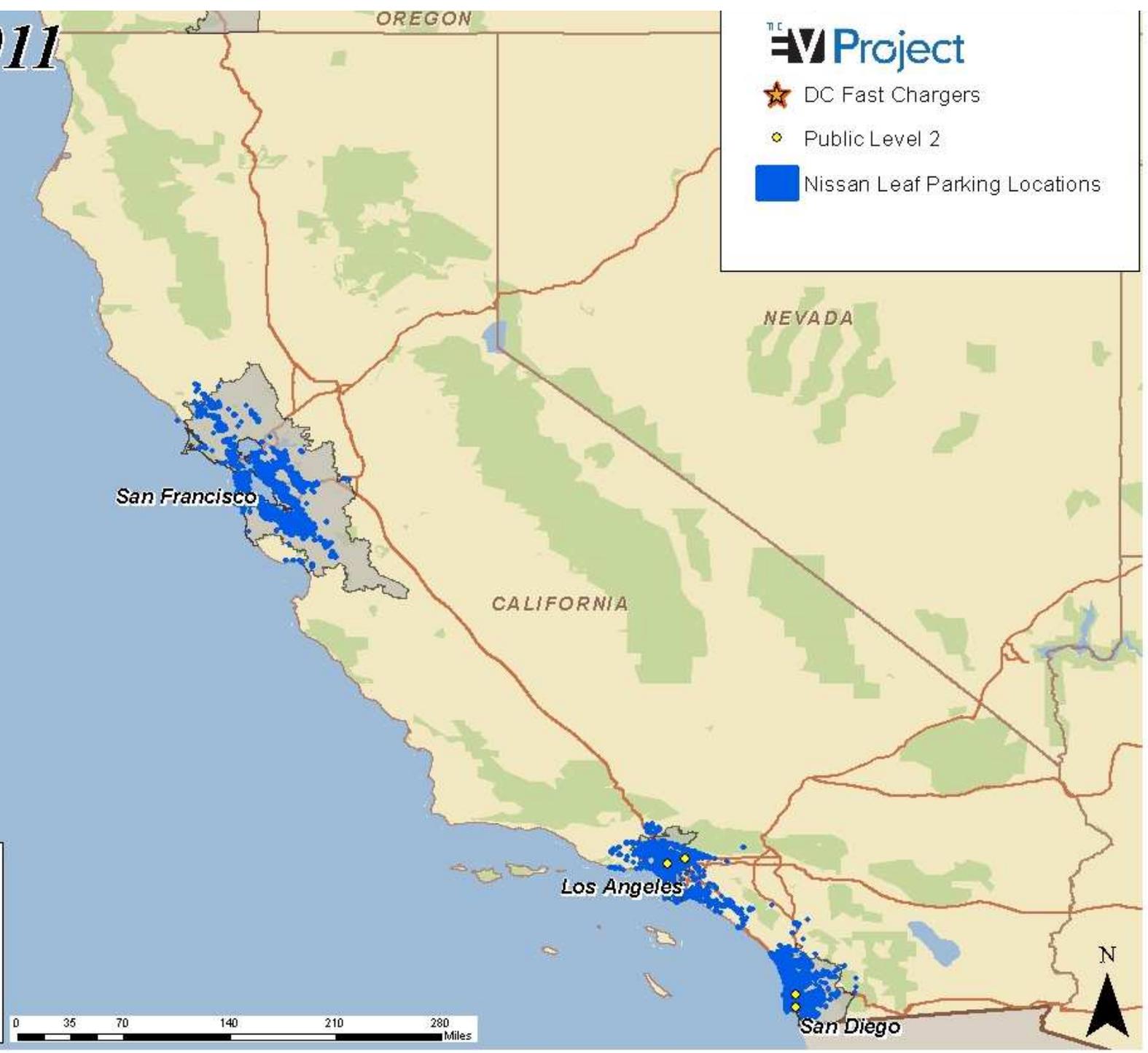
INL/MIS-13-30487



*May 2011*

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



Idaho National Laboratory

05/01/2014

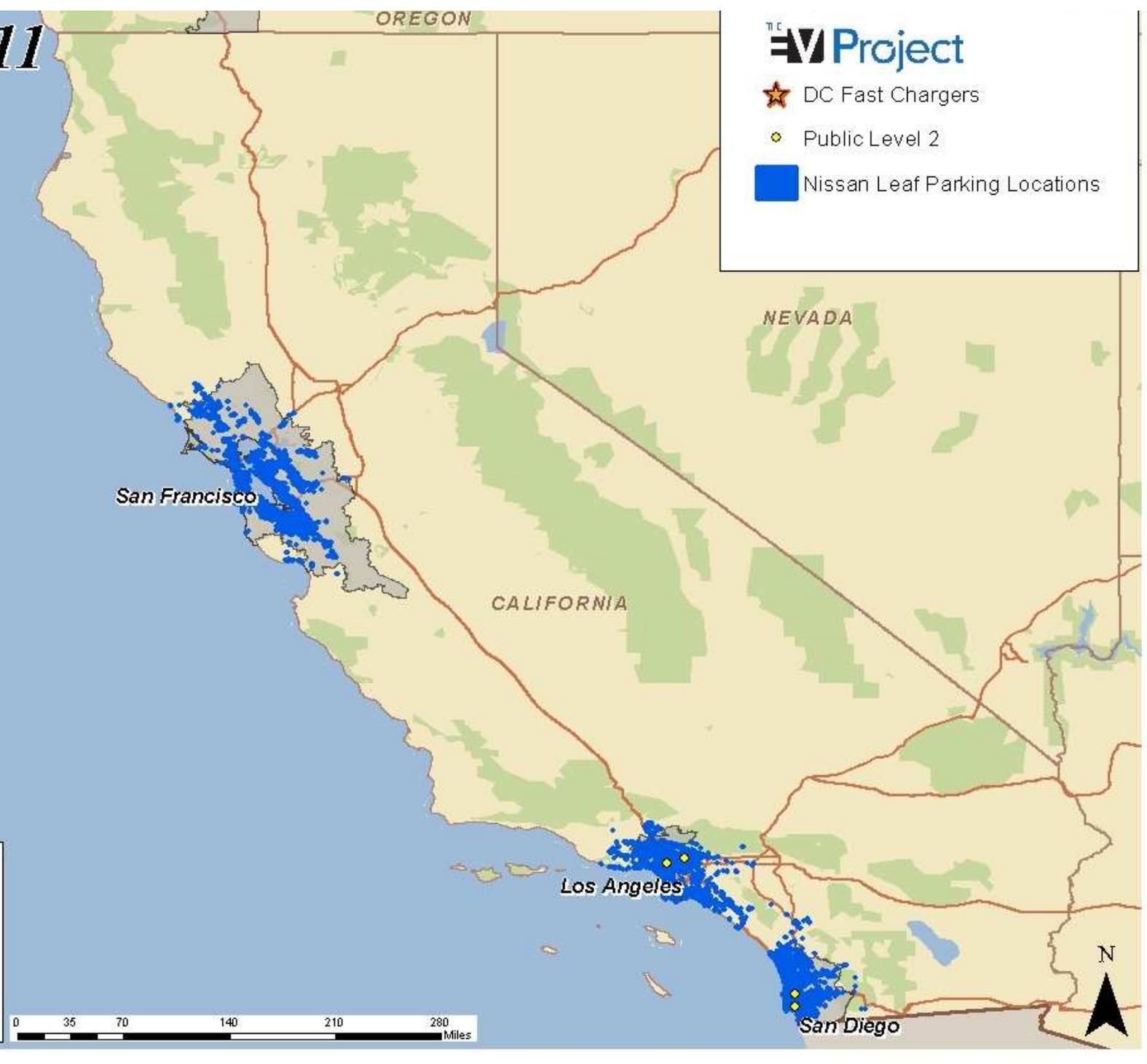
INL/MIS-13-30487

0 35 70 140 210 280 Miles

*Jun 2011*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



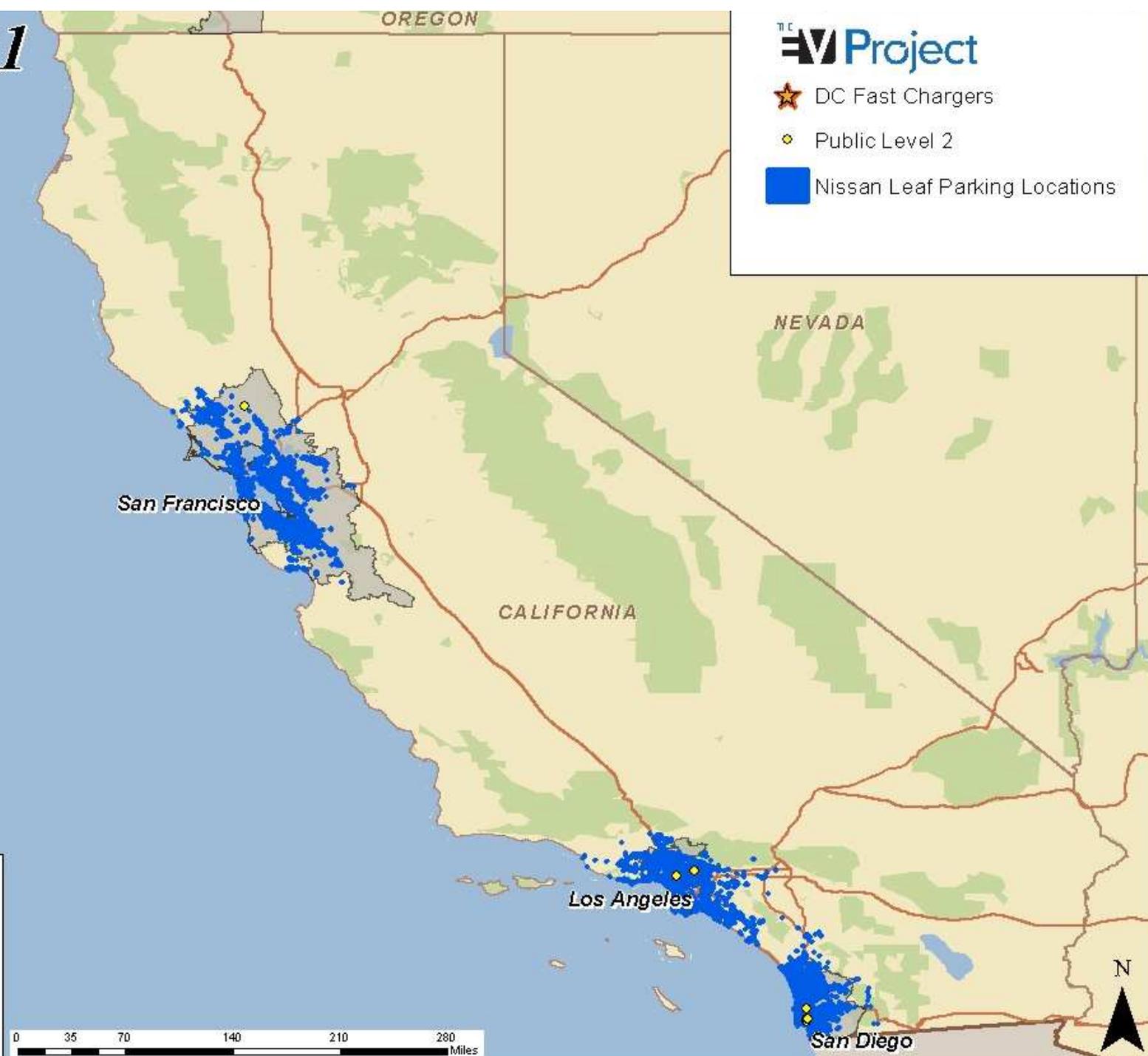
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Jul 2011*

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



Idaho National Laboratory

05/01/2014

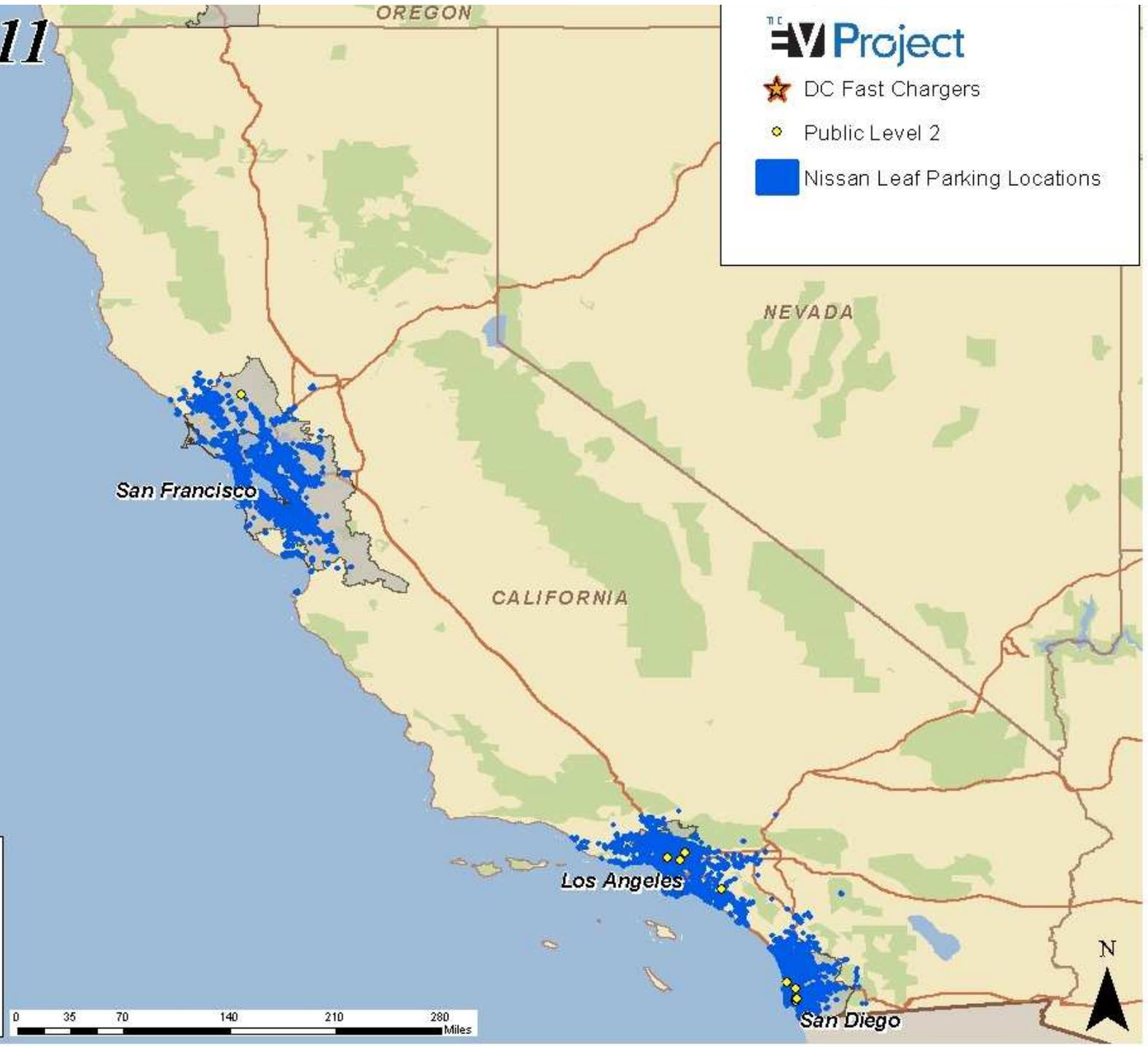
INL/MIS-13-30487

0 35 70 140 210 280 Miles

*Aug 2011*

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



Sep 2011

OREGON

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

San Diego



Idaho National Laboratory

05/01/2014

INL/MIS-13-30487



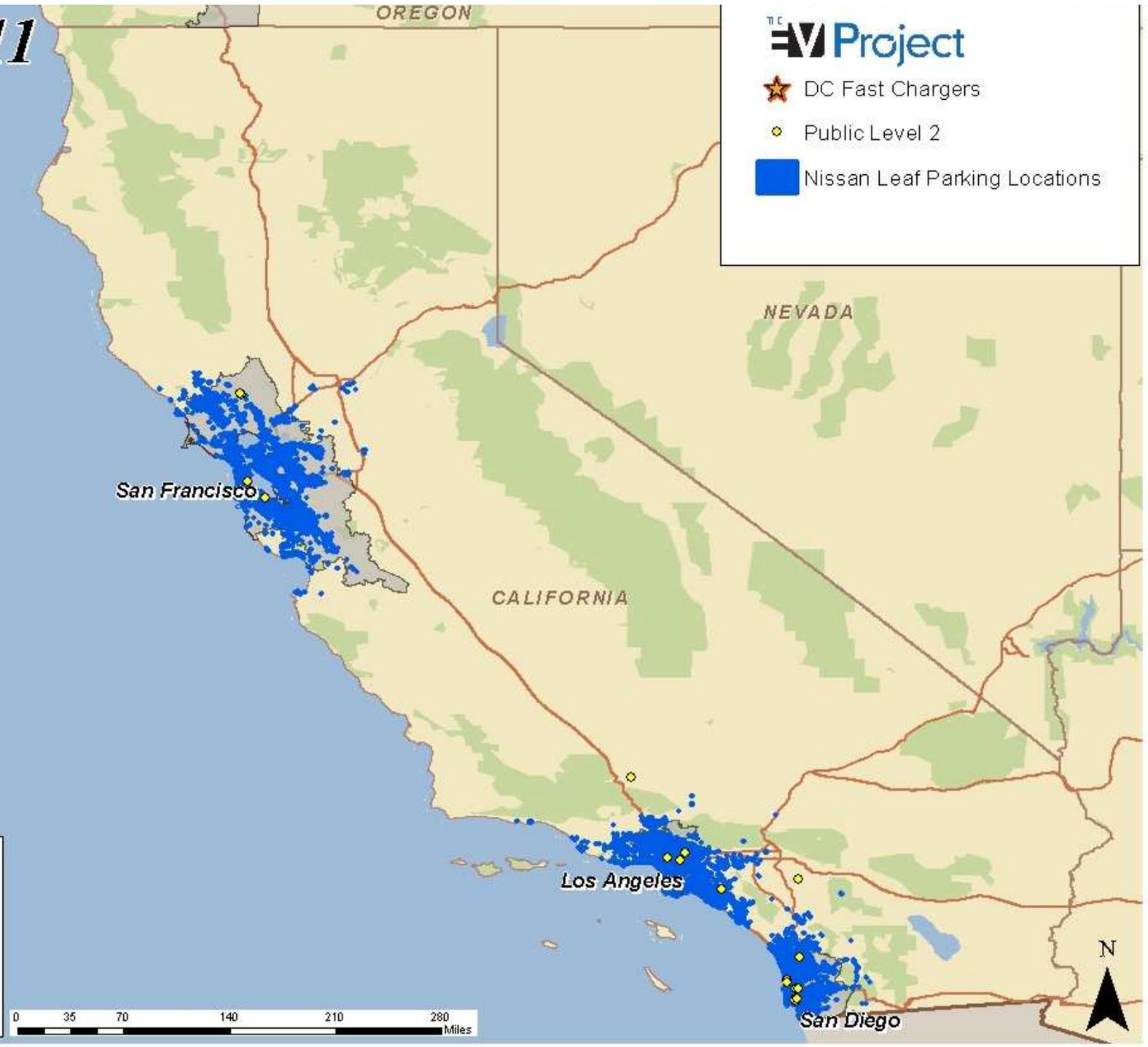
N



*Oct 2011*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



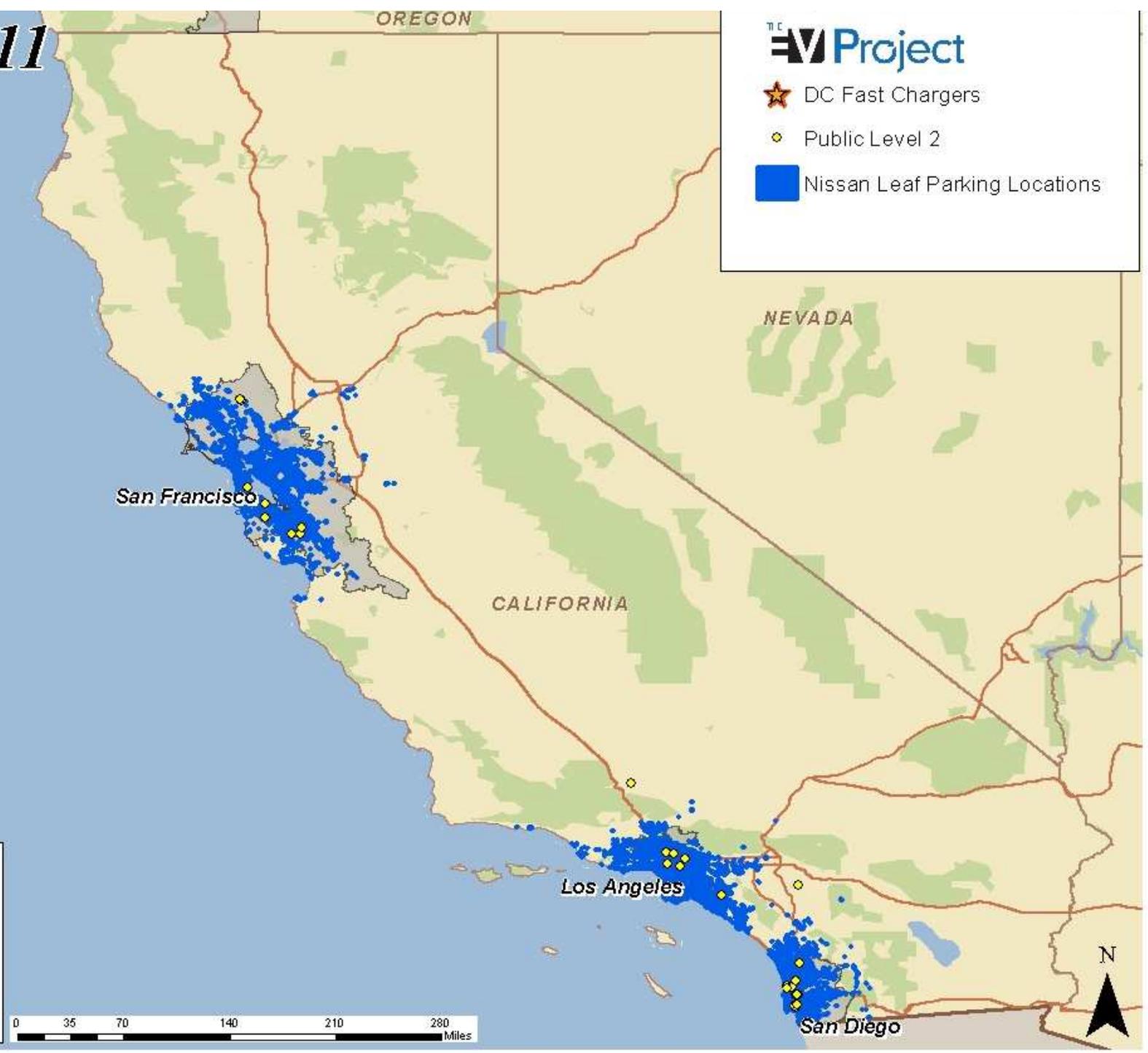
**INL**  
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Nov 2011*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



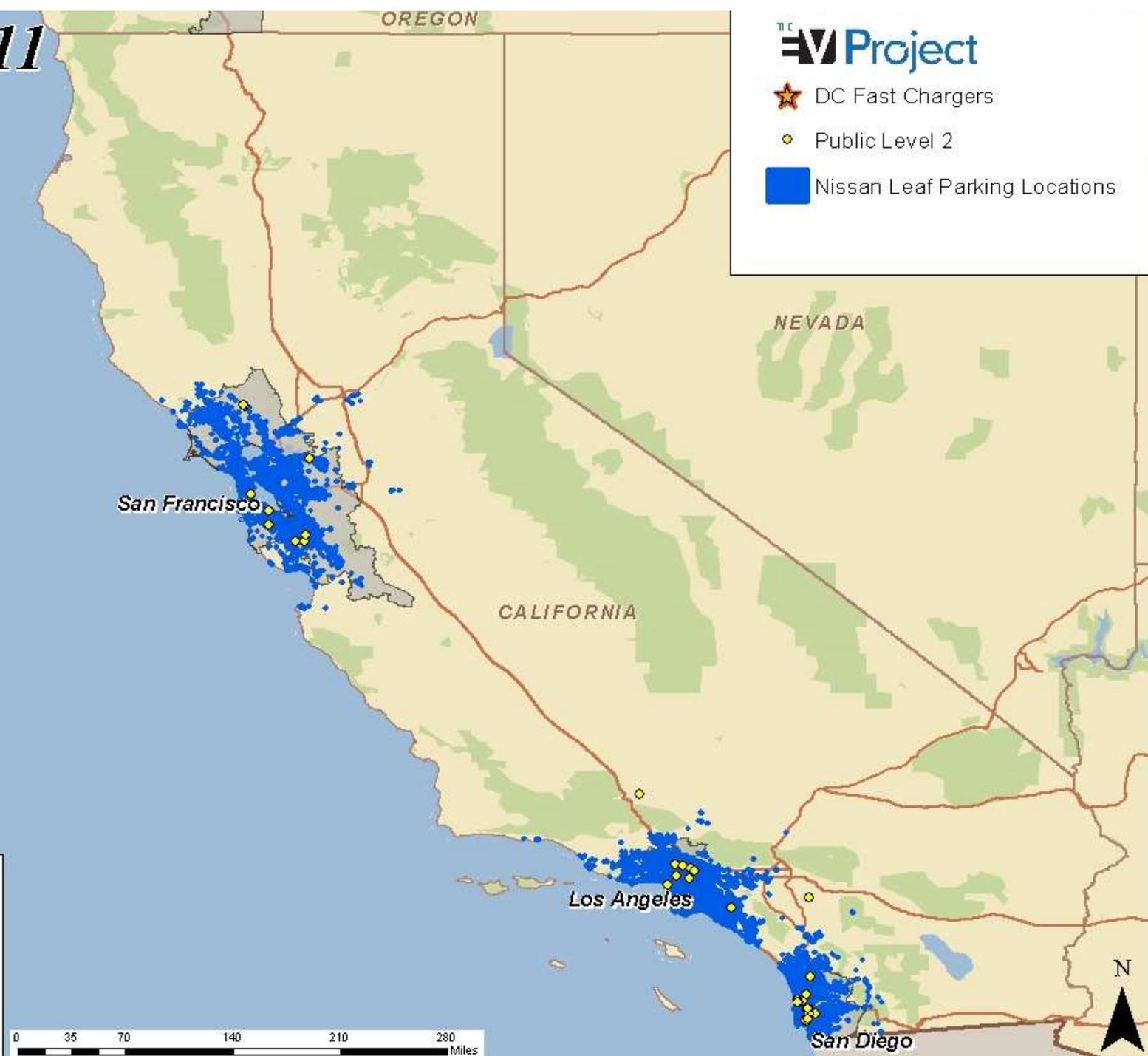
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Dec 2011*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



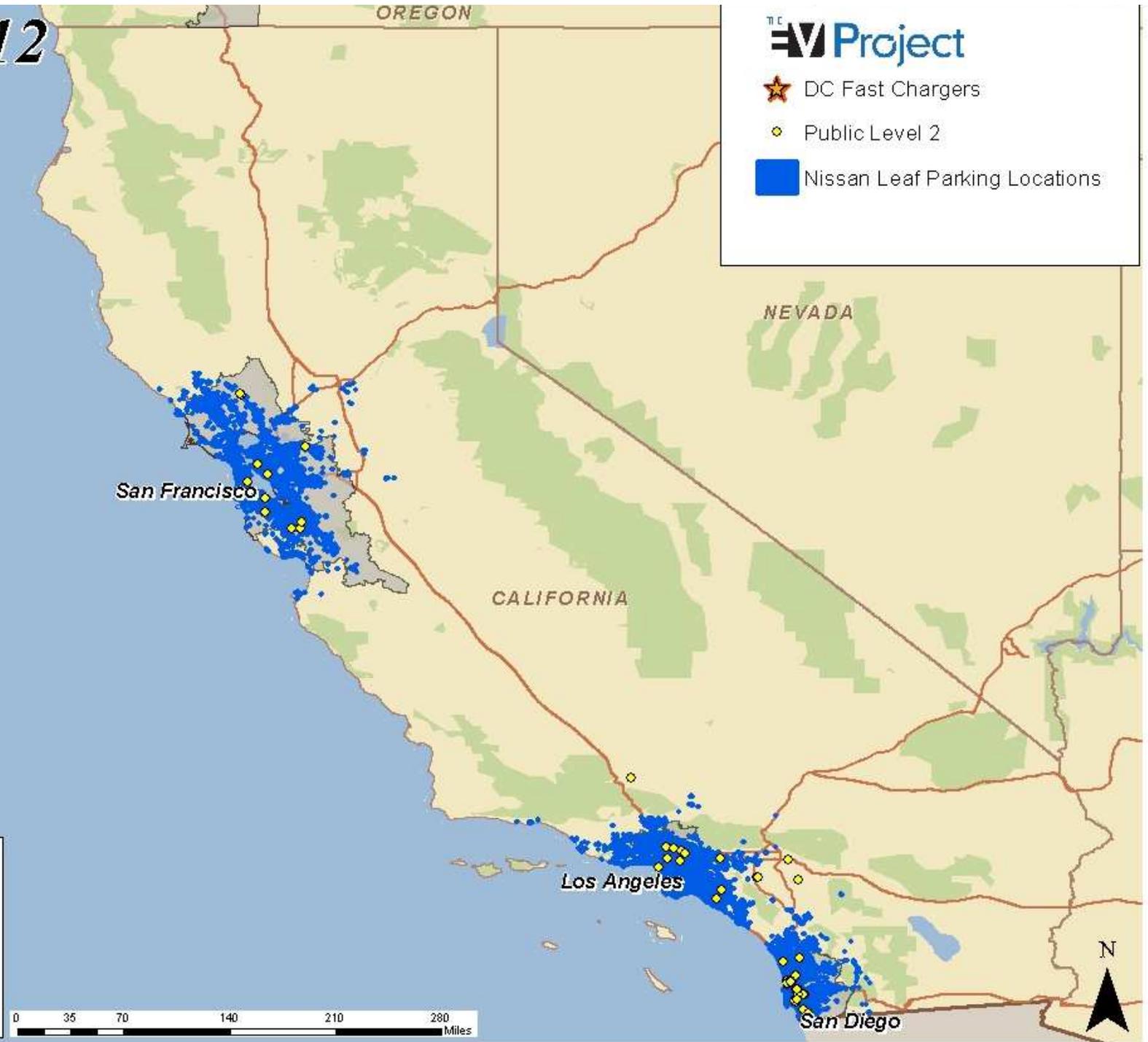
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



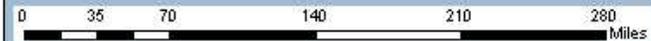
*Jan 2012*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



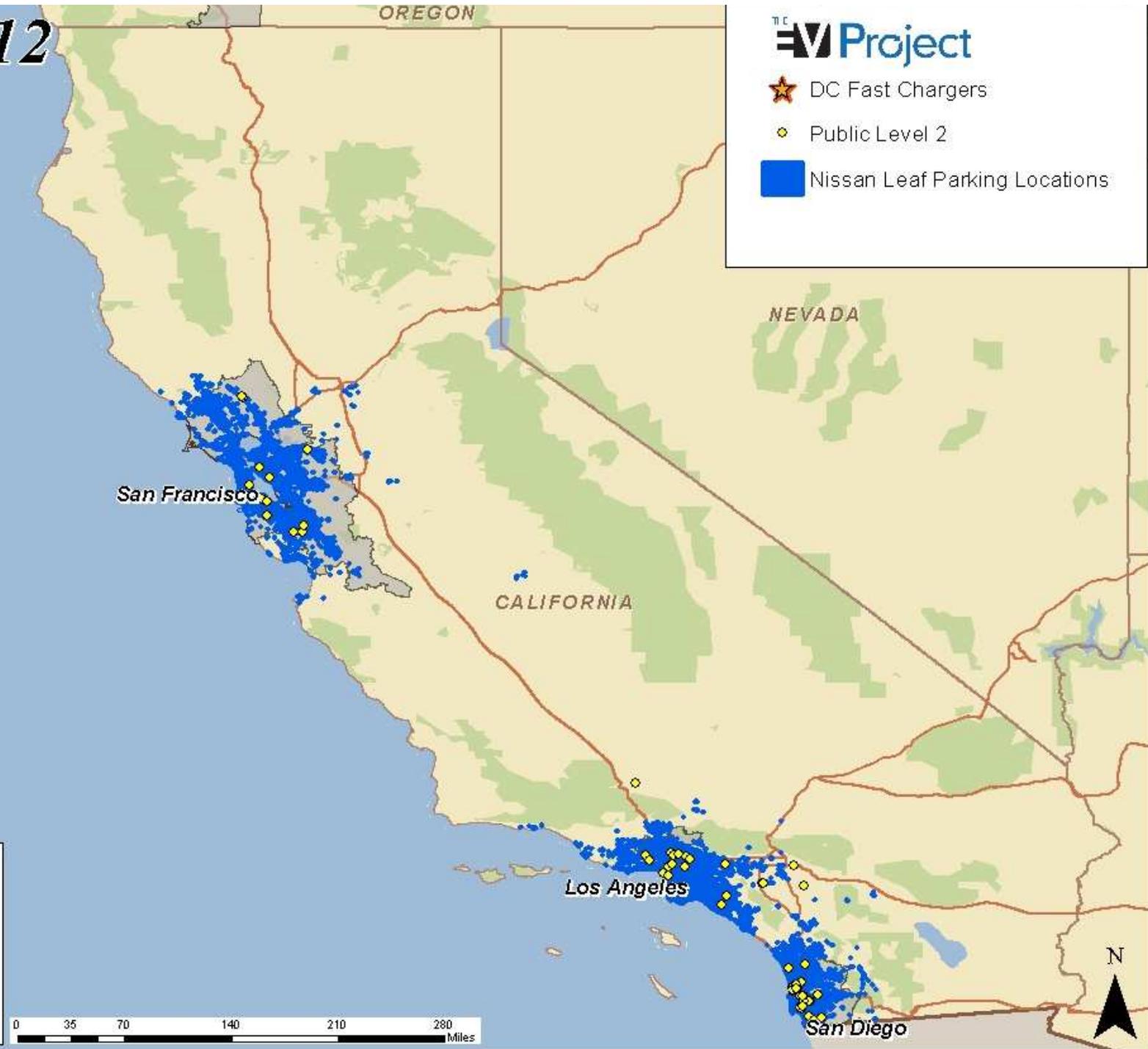
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Feb 2012*

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



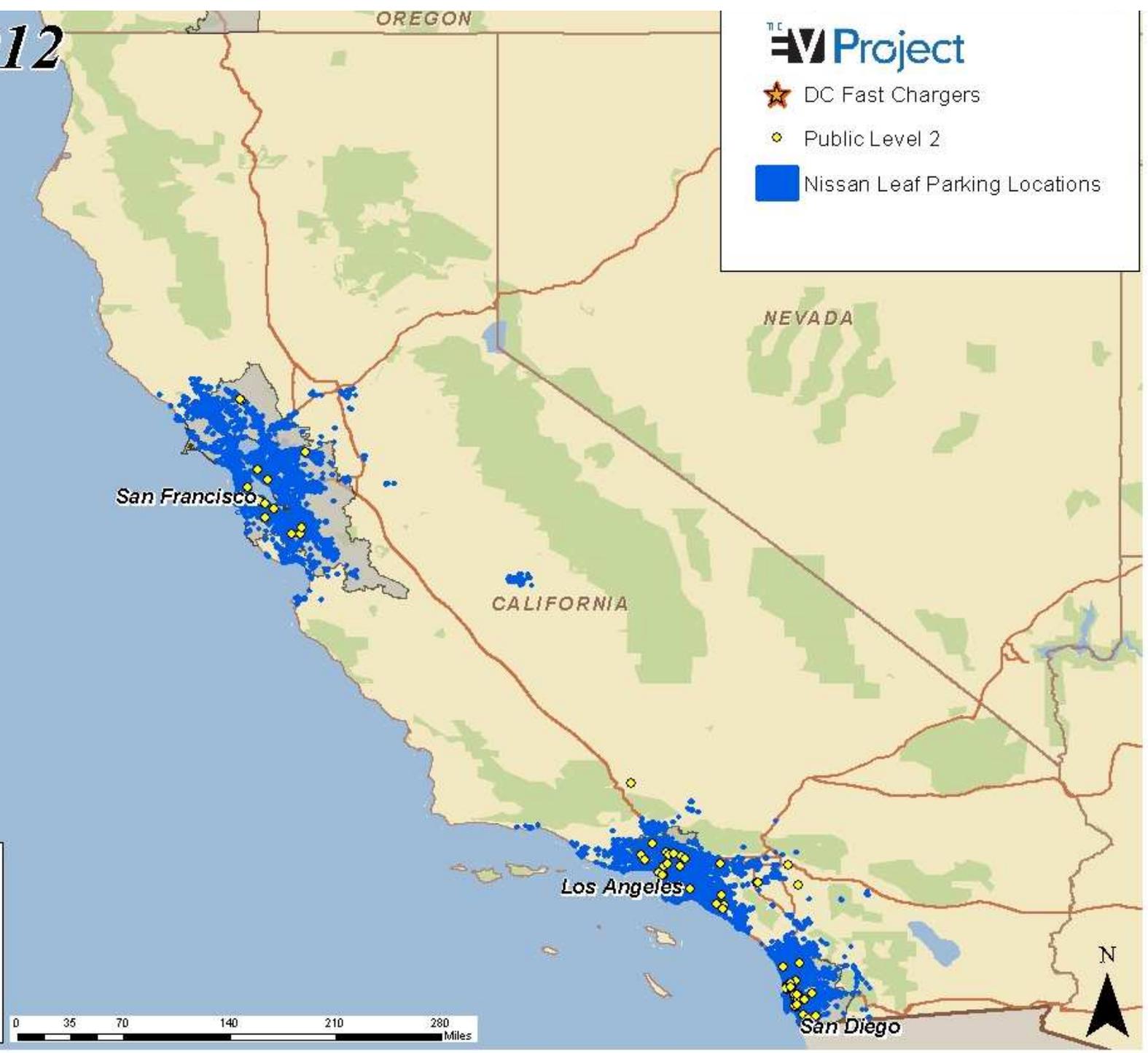
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Mar 2012*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



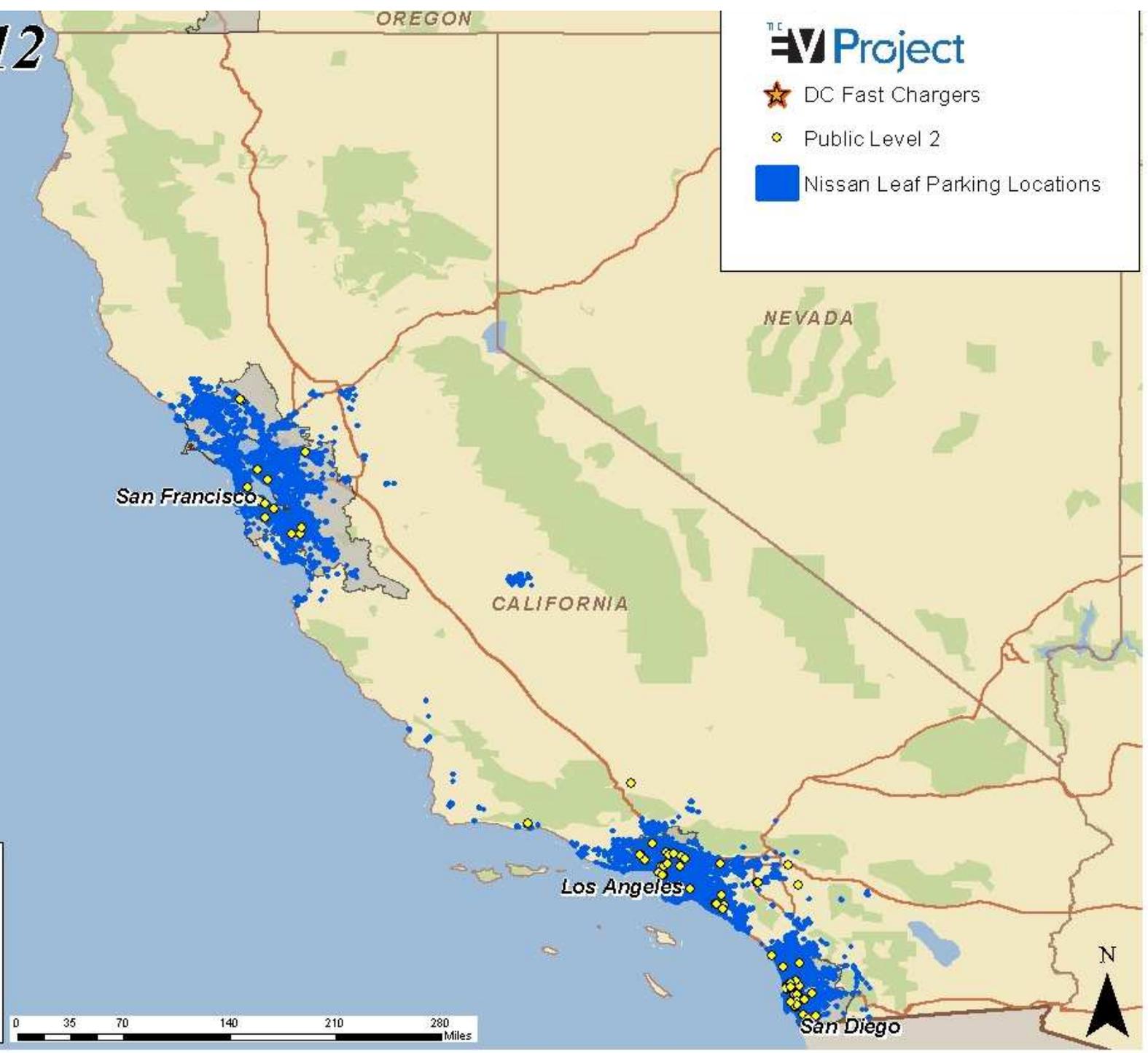
**INL**  
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Apr 2012*

TC **EV Project**

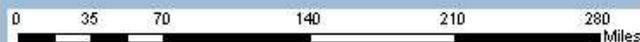
- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



Idaho National Laboratory

05/01/2014

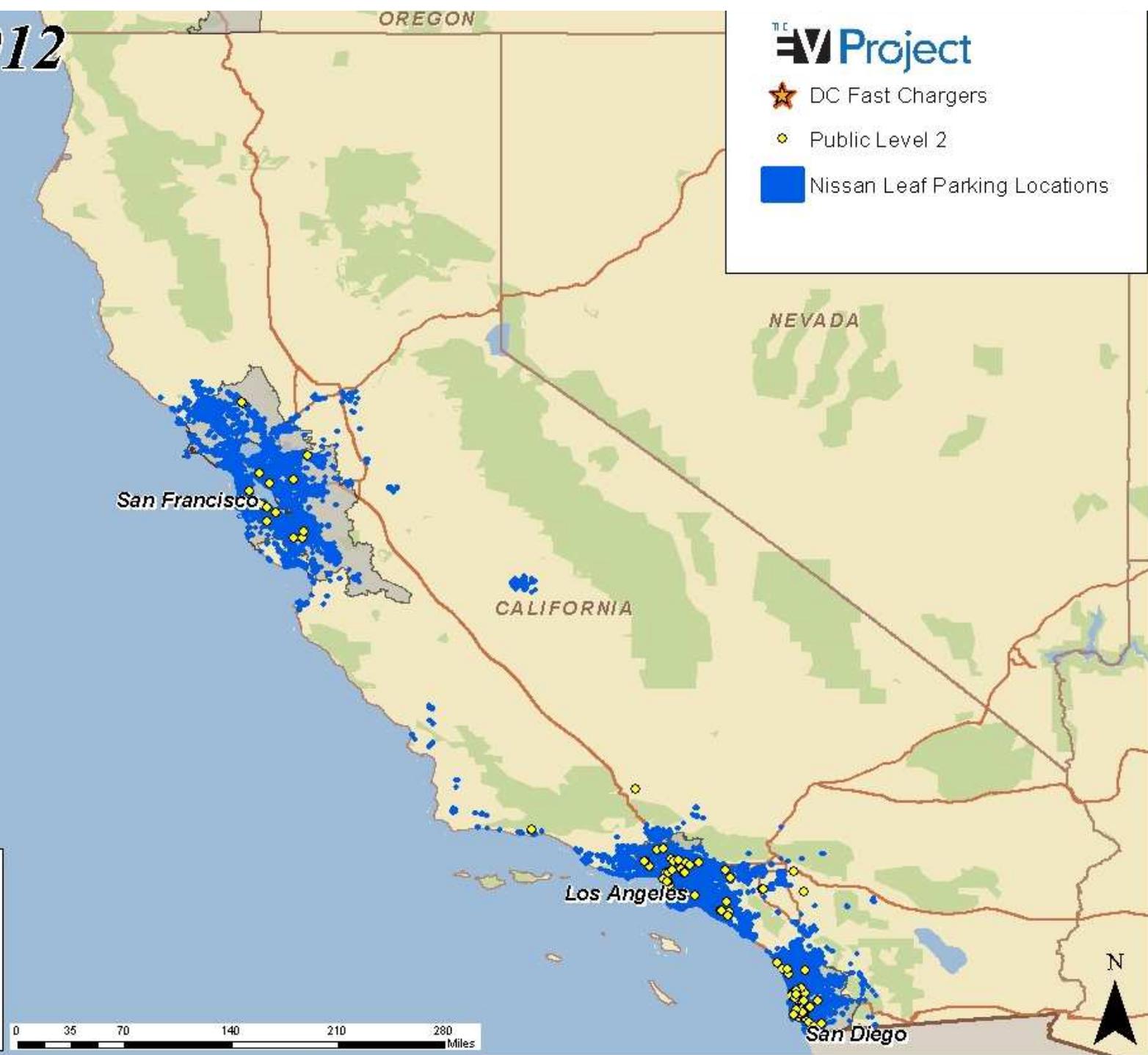
INL/MIS-13-30487



*May 2012*

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



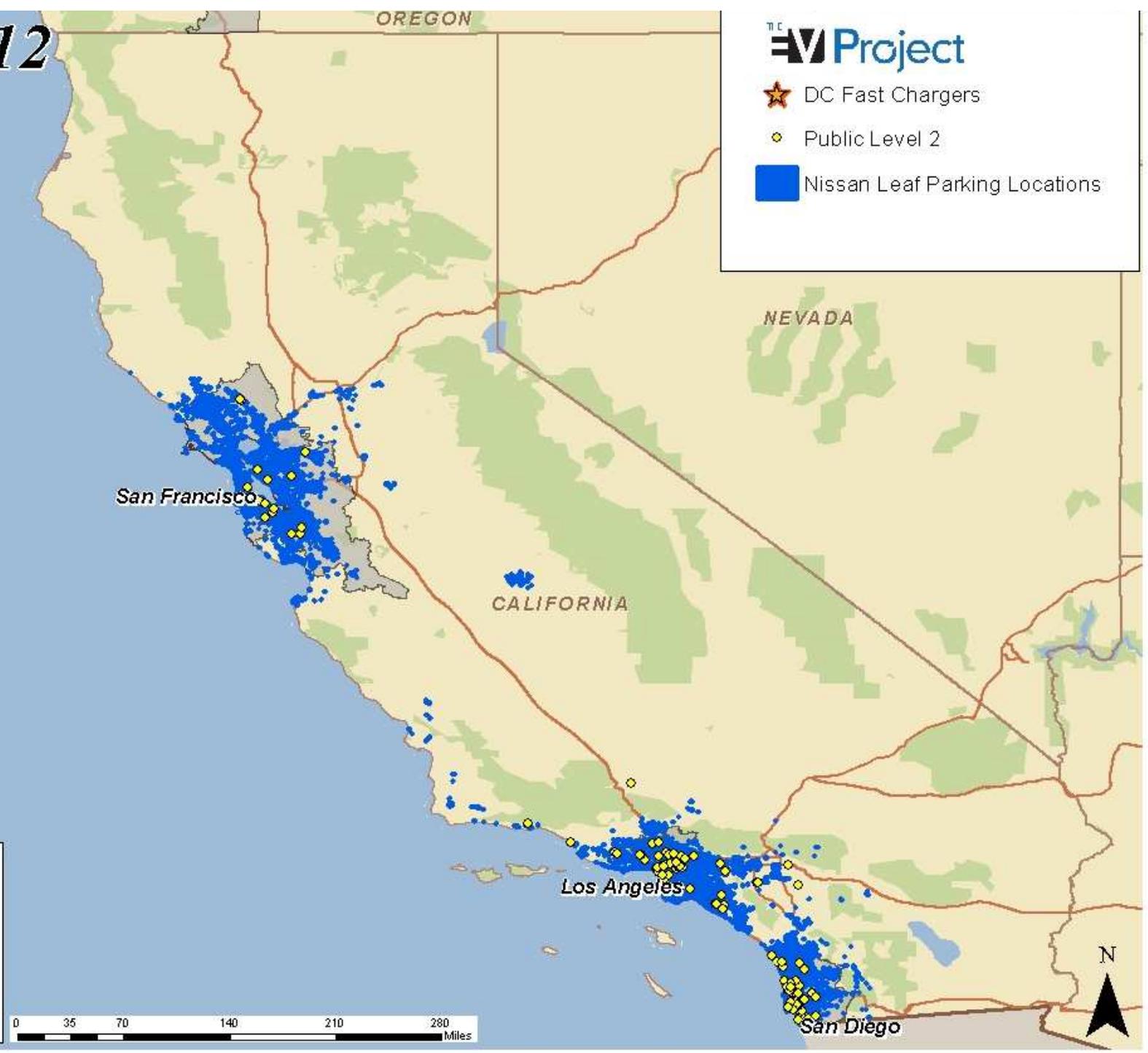
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Jun 2012*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



**INL**  
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Jul 2012*

OREGON

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

San Diego

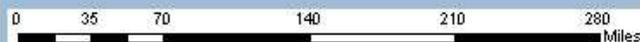
N



Idaho National Laboratory

05/01/2014

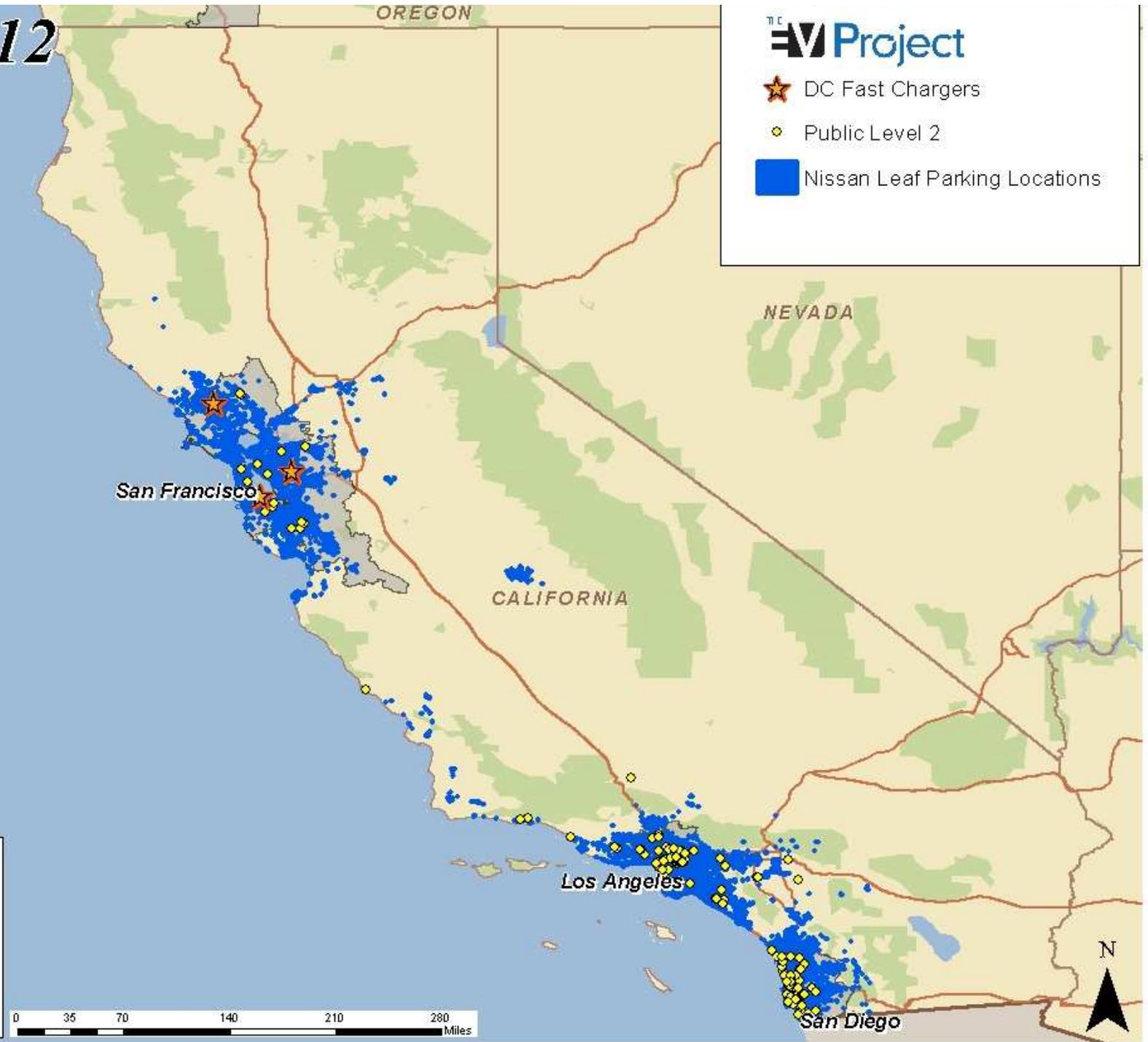
INL/MIS-13-30487



Aug 2012

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



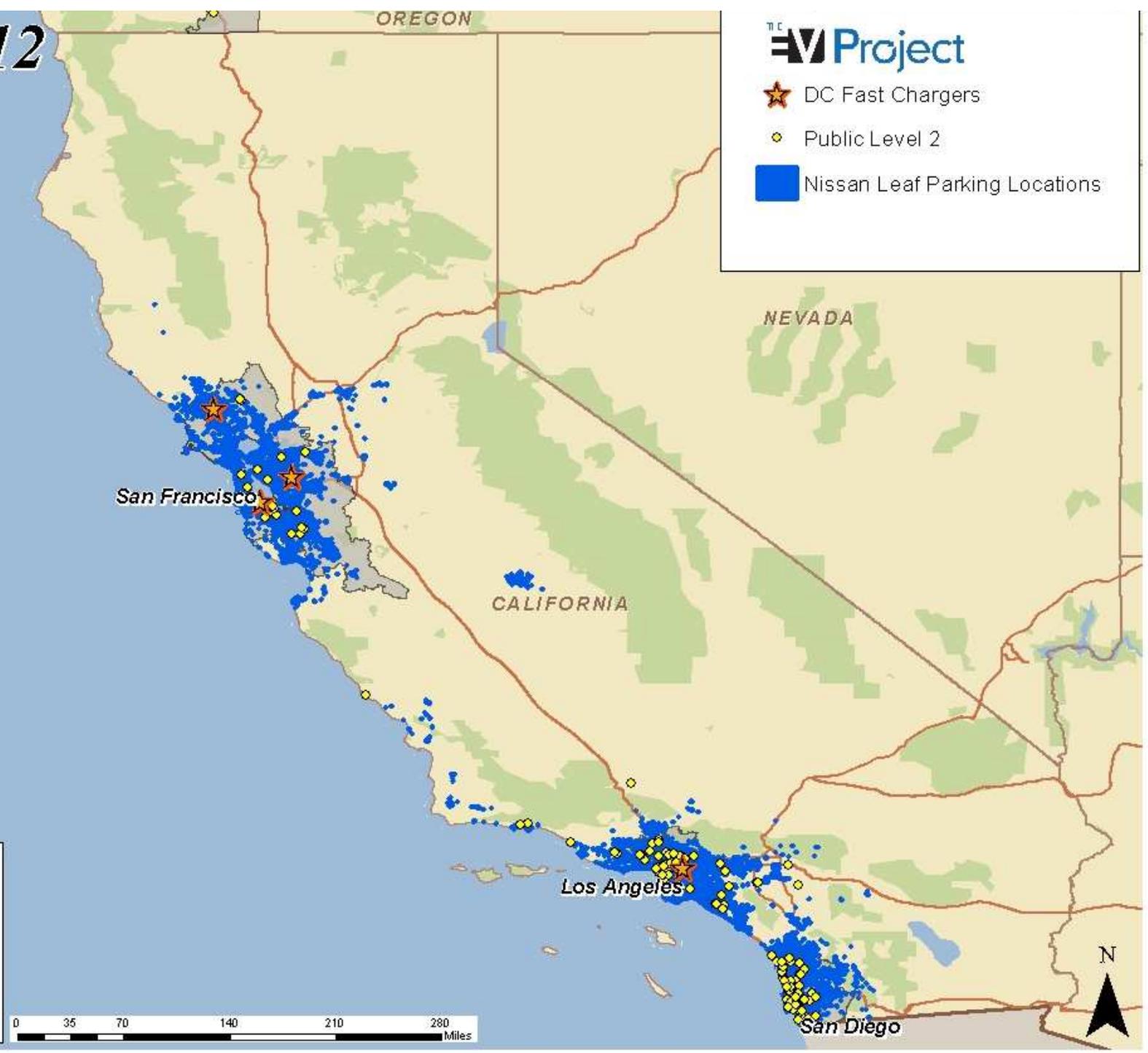
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



Sep 2012

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



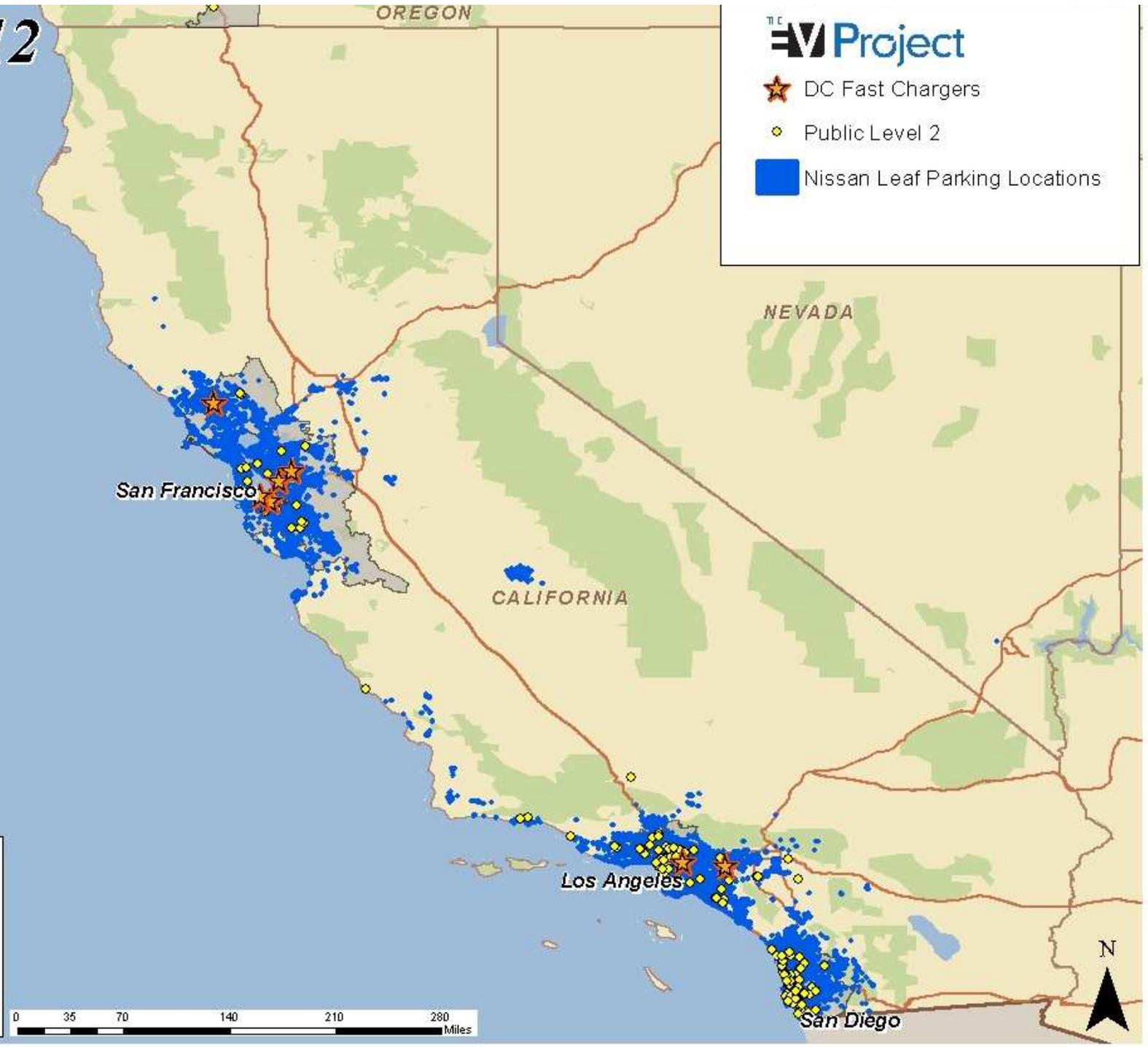
**INL**  
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487

0 35 70 140 210 280 Miles

*Oct 2012*

**TC EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



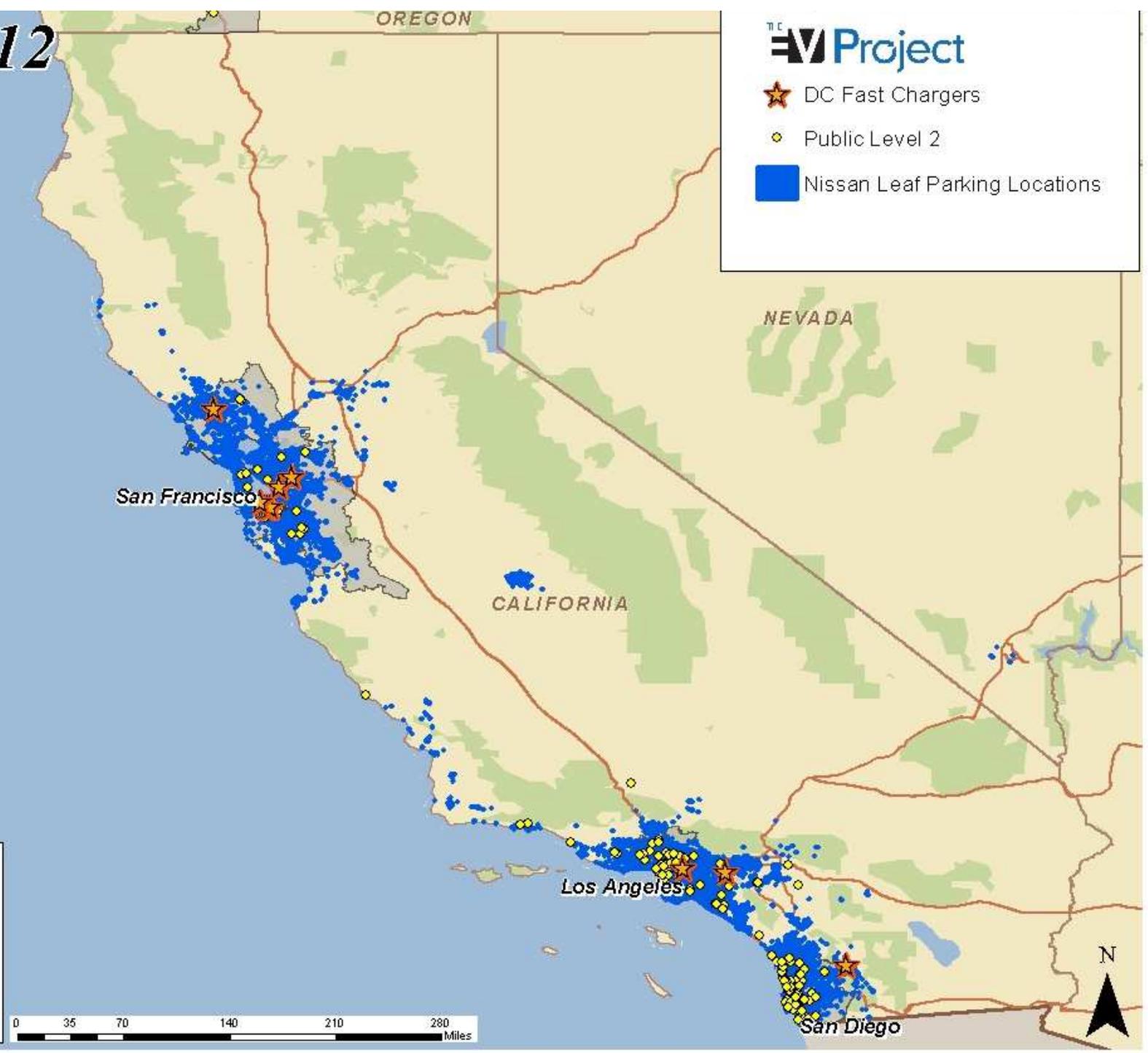
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Nov 2012*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



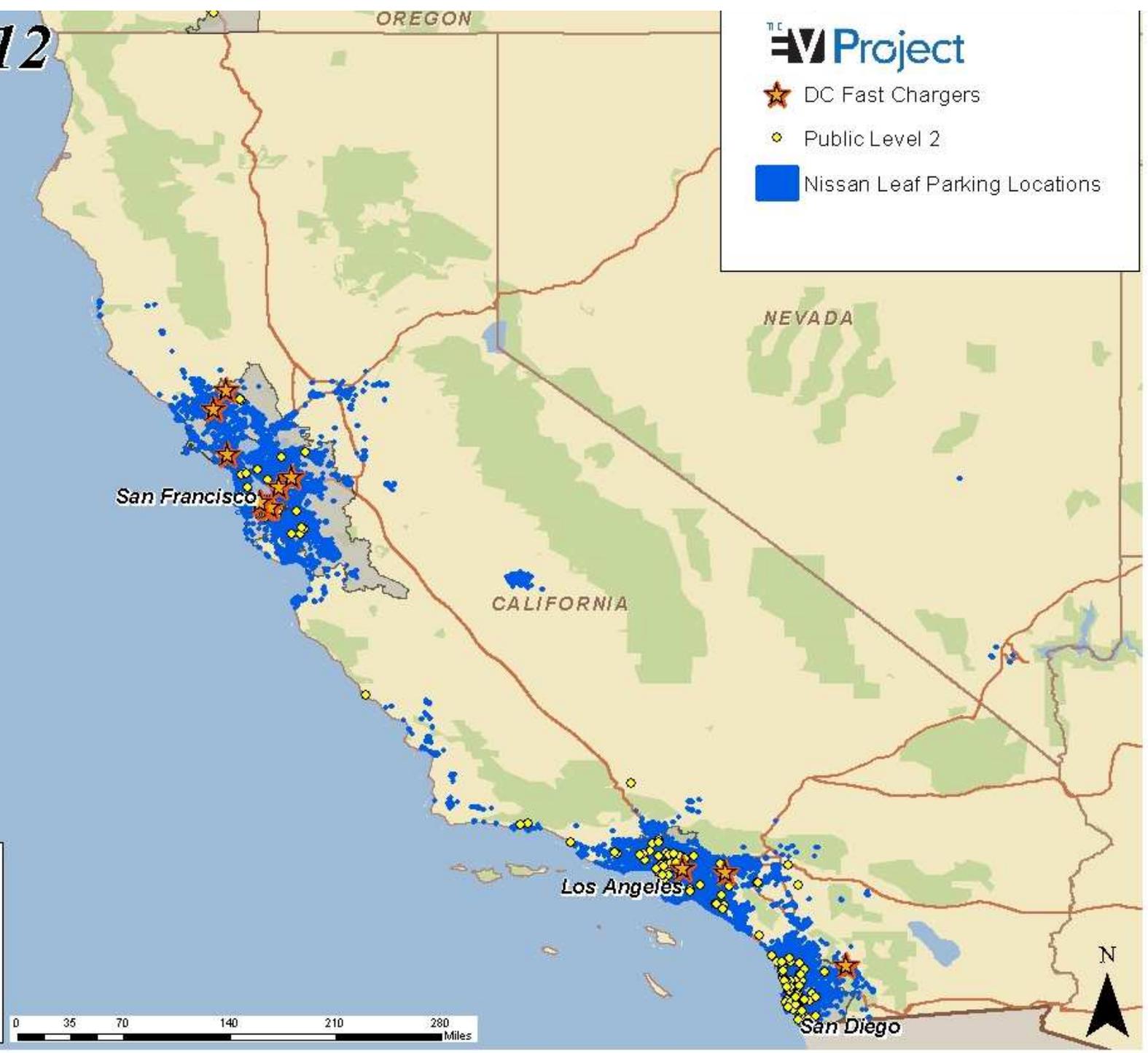
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487

0 35 70 140 210 280 Miles

*Dec 2012*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



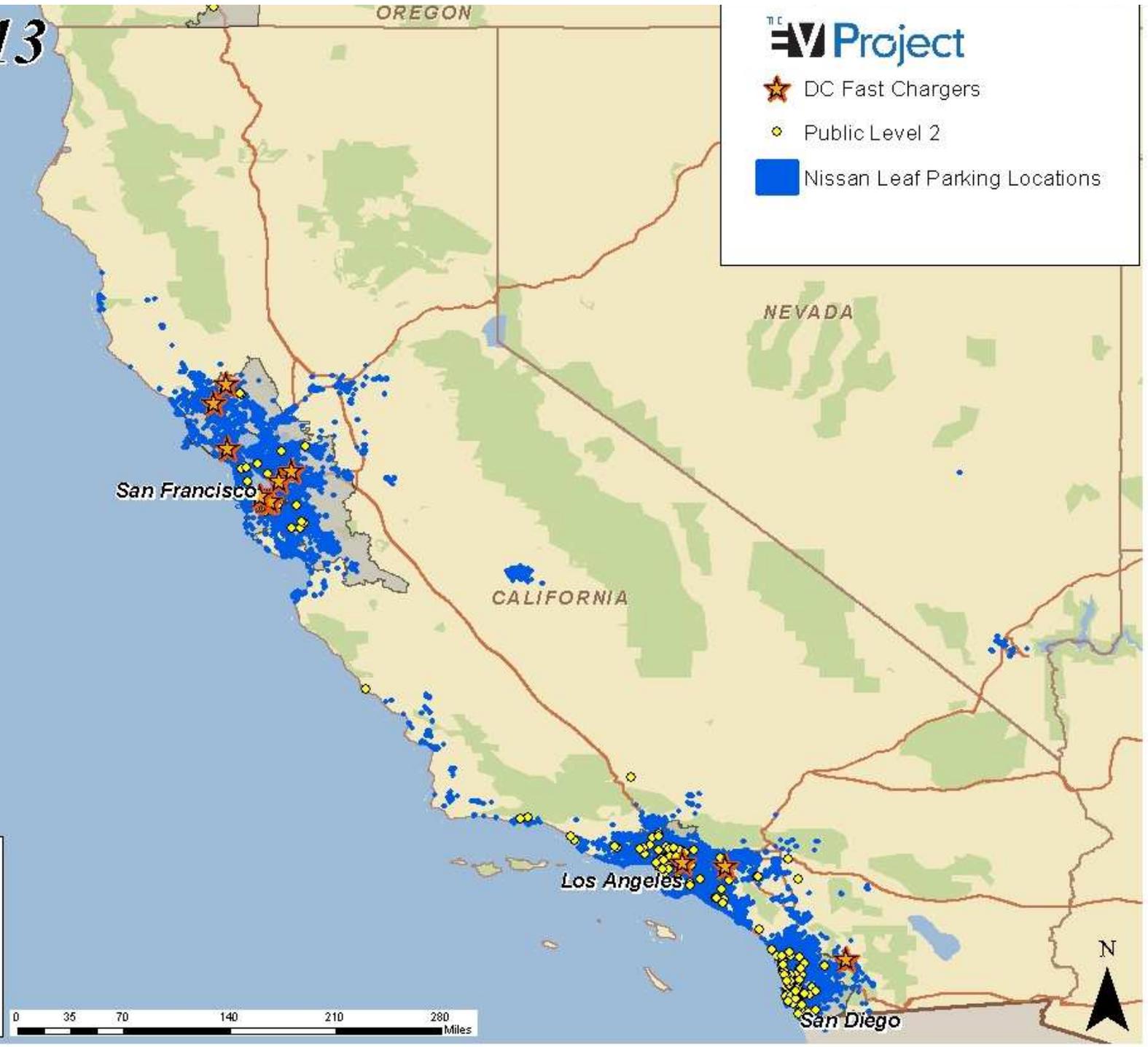
**INL**  
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487

0 35 70 140 210 280 Miles

*Jan 2013*

**TC Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



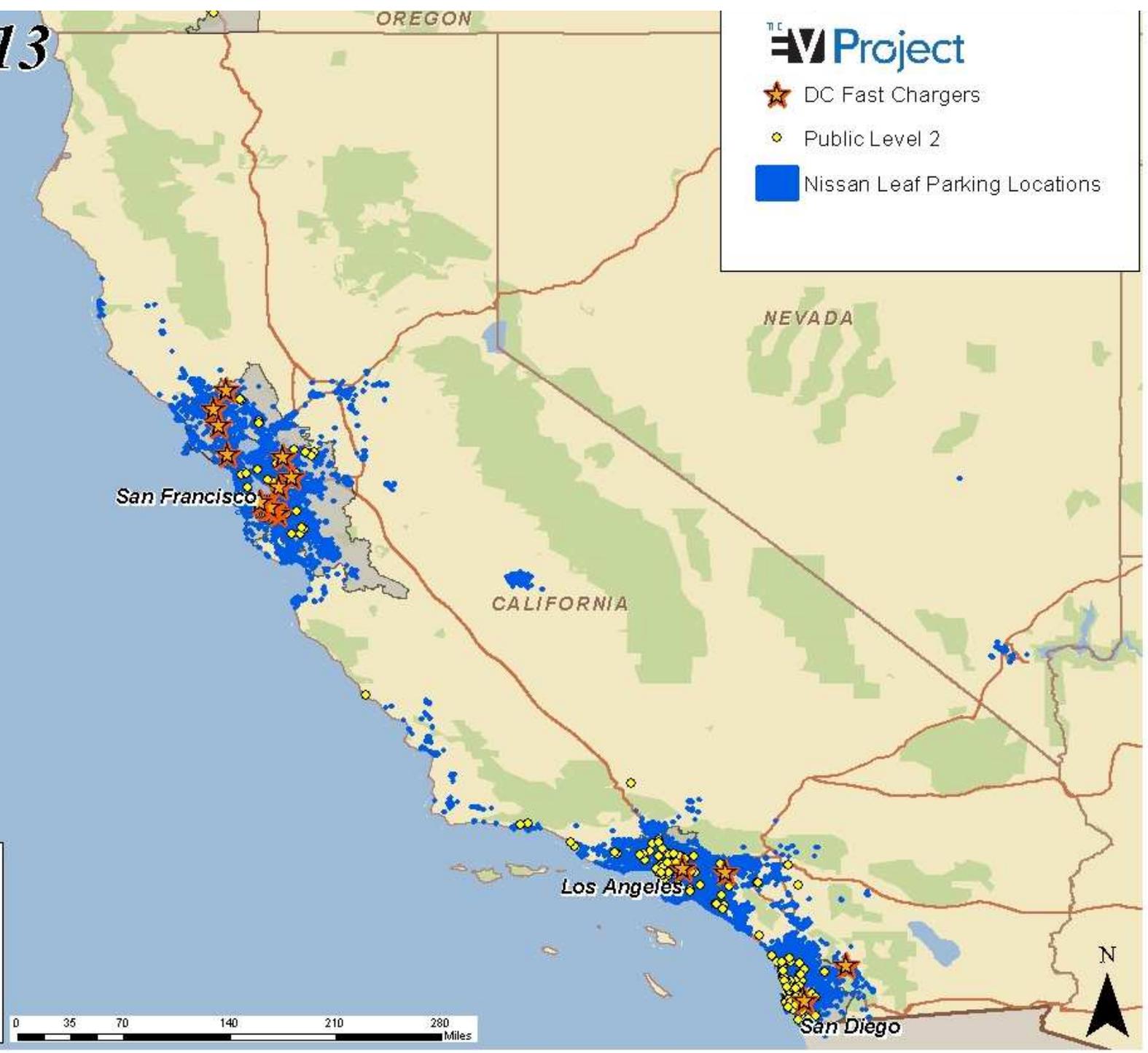
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Feb 2013*

**TC** **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



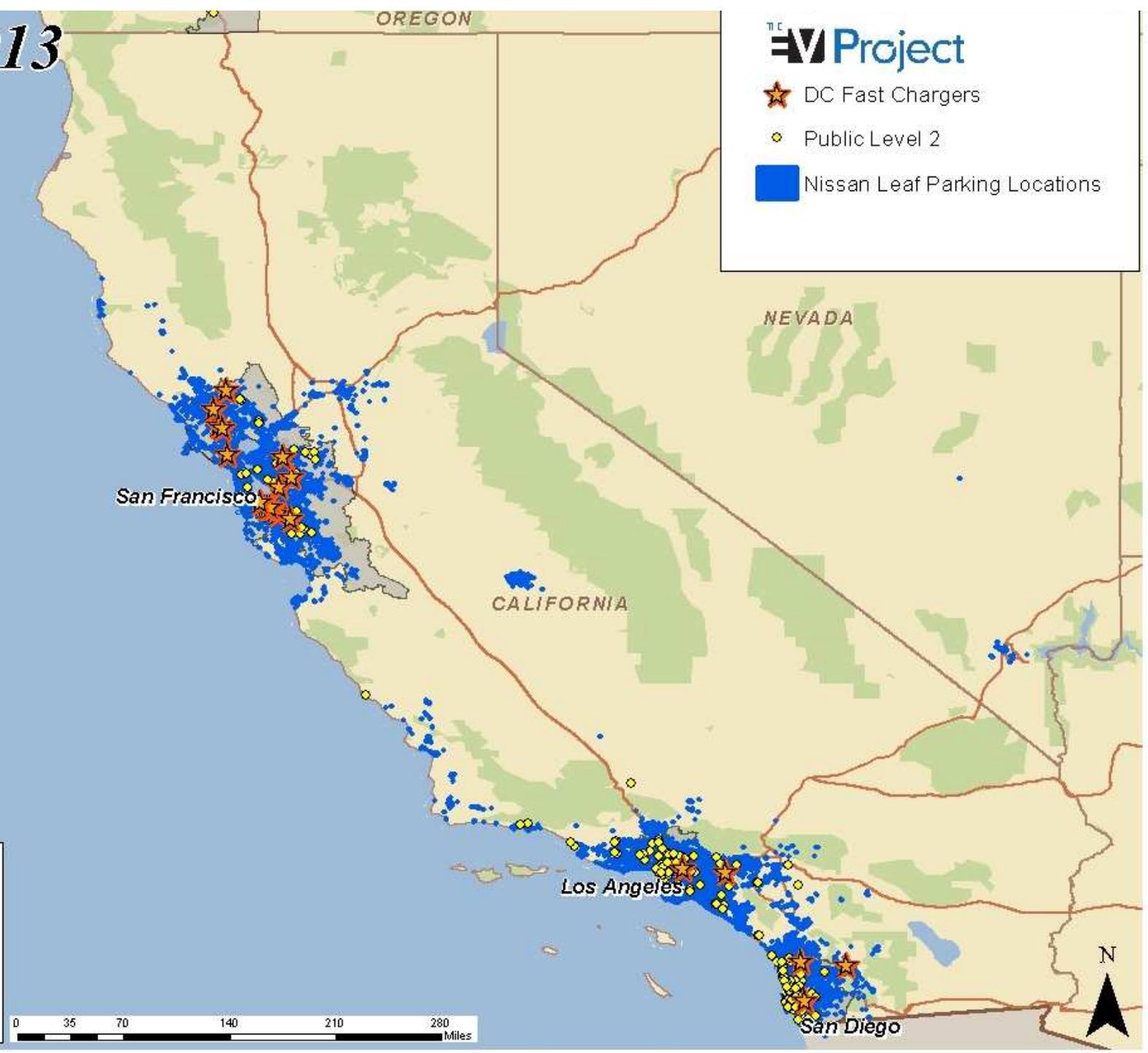
**INL**  
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Mar 2013*

**TC** **Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



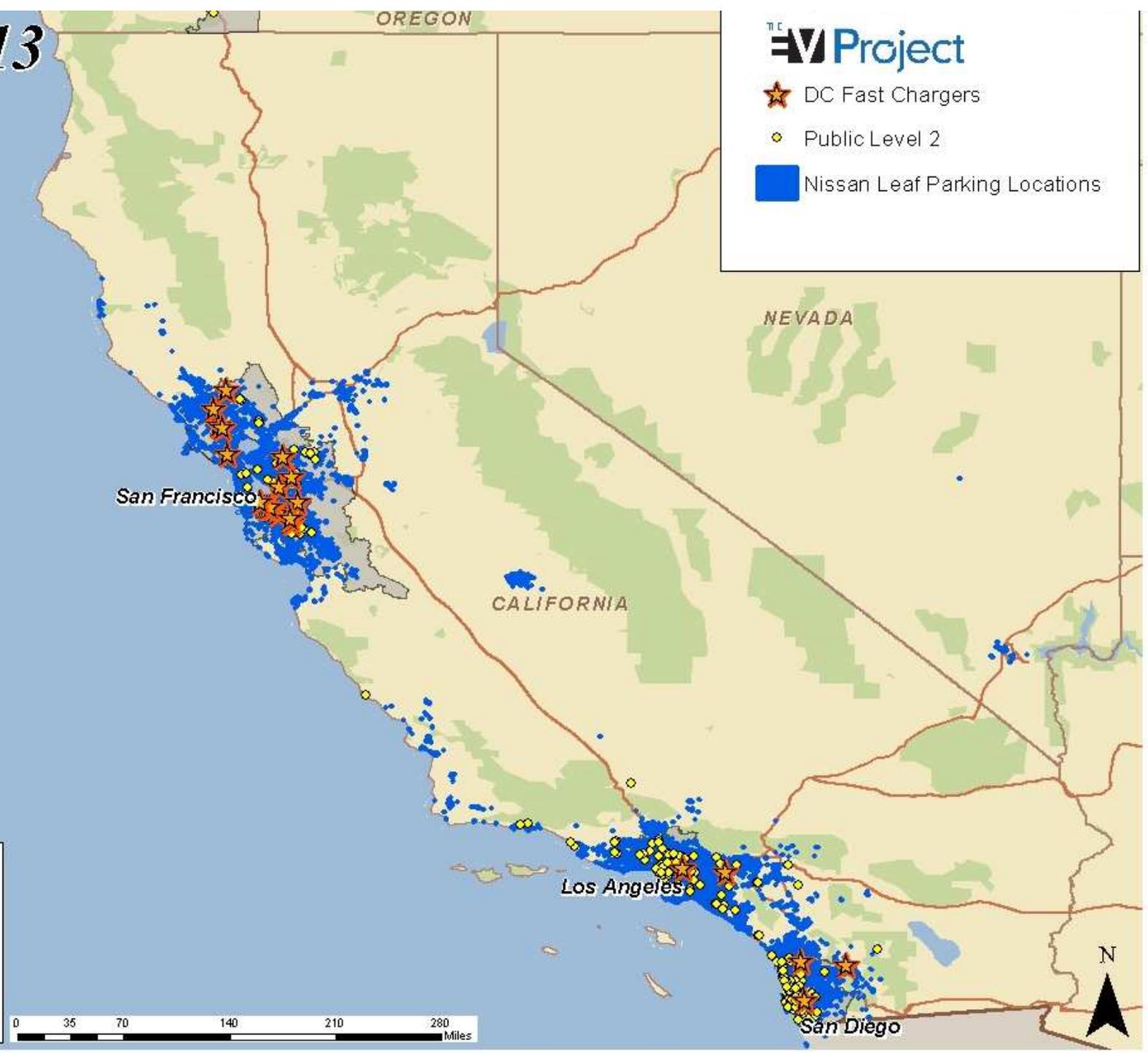
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Apr 2013*

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



Idaho National Laboratory

05/01/2014

INL/MIS-13-30487

0 35 70 140 210 280 Miles

*May 2013*

TC **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

San Diego



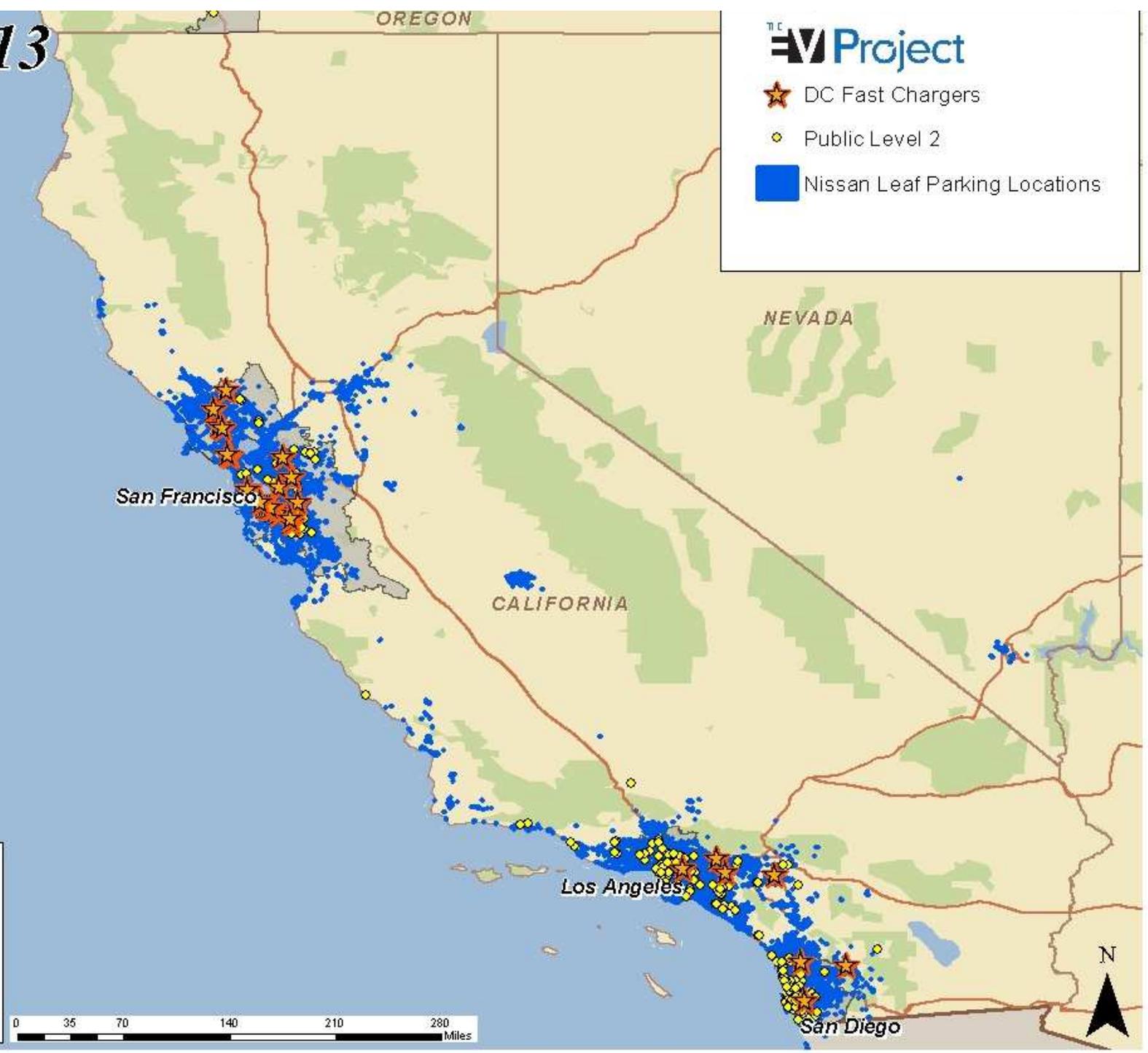
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Jun 2013*

**TC** **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations



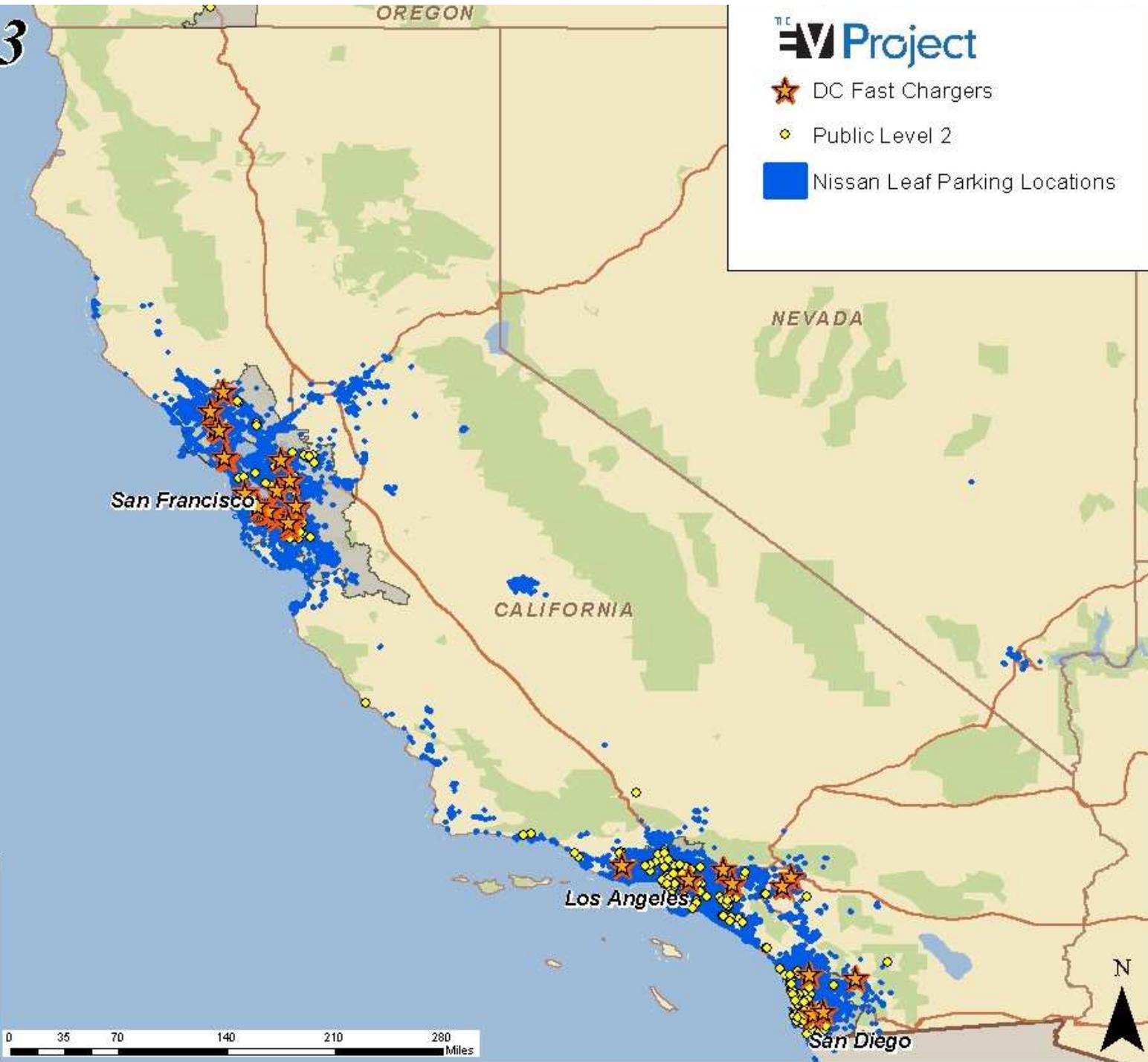
Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Jul 2013*

TC  Project

-  DC Fast Chargers
-  Public Level 2
-  Nissan Leaf Parking Locations



Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487

0 35 70 140 210 280 Miles

Aug 2013

TC  Project

-  DC Fast Chargers
-  Public Level 2
-  Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

San Diego



Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



Sep 2013

TC  Project

-  DC Fast Chargers
-  Public Level 2
-  Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

San Diego



Idaho National Laboratory  
05/01/2014  
INL/MIS-13-30487



*Oct 2013*

**TC** **EV Project**

- ★ DC Fast Chargers
- Public Level 2
- Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

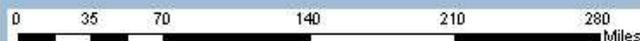
San Diego



Idaho National Laboratory

05/01/2014

INL/MIS-13-30487



*Nov 2013*

TC  Project

-  DC Fast Chargers
-  Public Level 2
-  Nissan Leaf Parking Locations

San Francisco

CALIFORNIA

NEVADA

Los Angeles

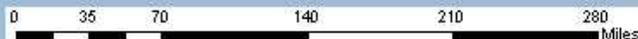
San Diego



Idaho National Laboratory

05/01/2014

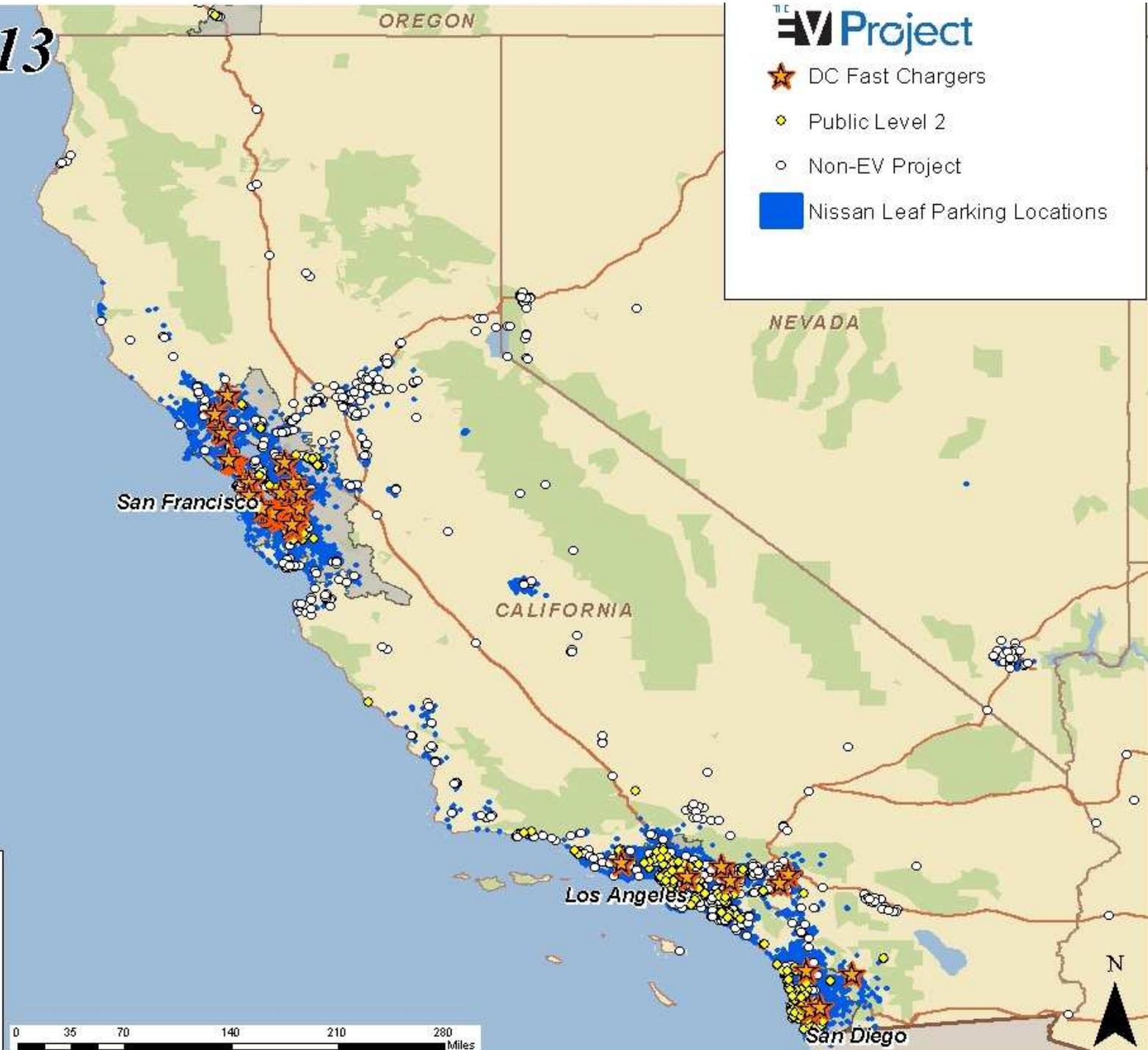
INL/MIS-13-30487



*Nov 2013*

**EV Project**

- ★ DC Fast Chargers
- ◆ Public Level 2
- Non-EV Project
- Nissan Leaf Parking Locations



Idaho National Laboratory

05/01/2014

INL/MIS-13-30487

## ***Additional Information***

Publications coming soon:

- Leaf vs. Volt eVMT
  - Leaf away-from-home infrastructure usage vs. eVMT
  - Usage of public EVSE at different venue types
  - Workplace charging case studies and driver behavior
  - PEV travel on the OR/WA I5 corridor
  - EVSE installation costs
  - and more
- 
- For all EV Project and ChargePoint America publications, visit

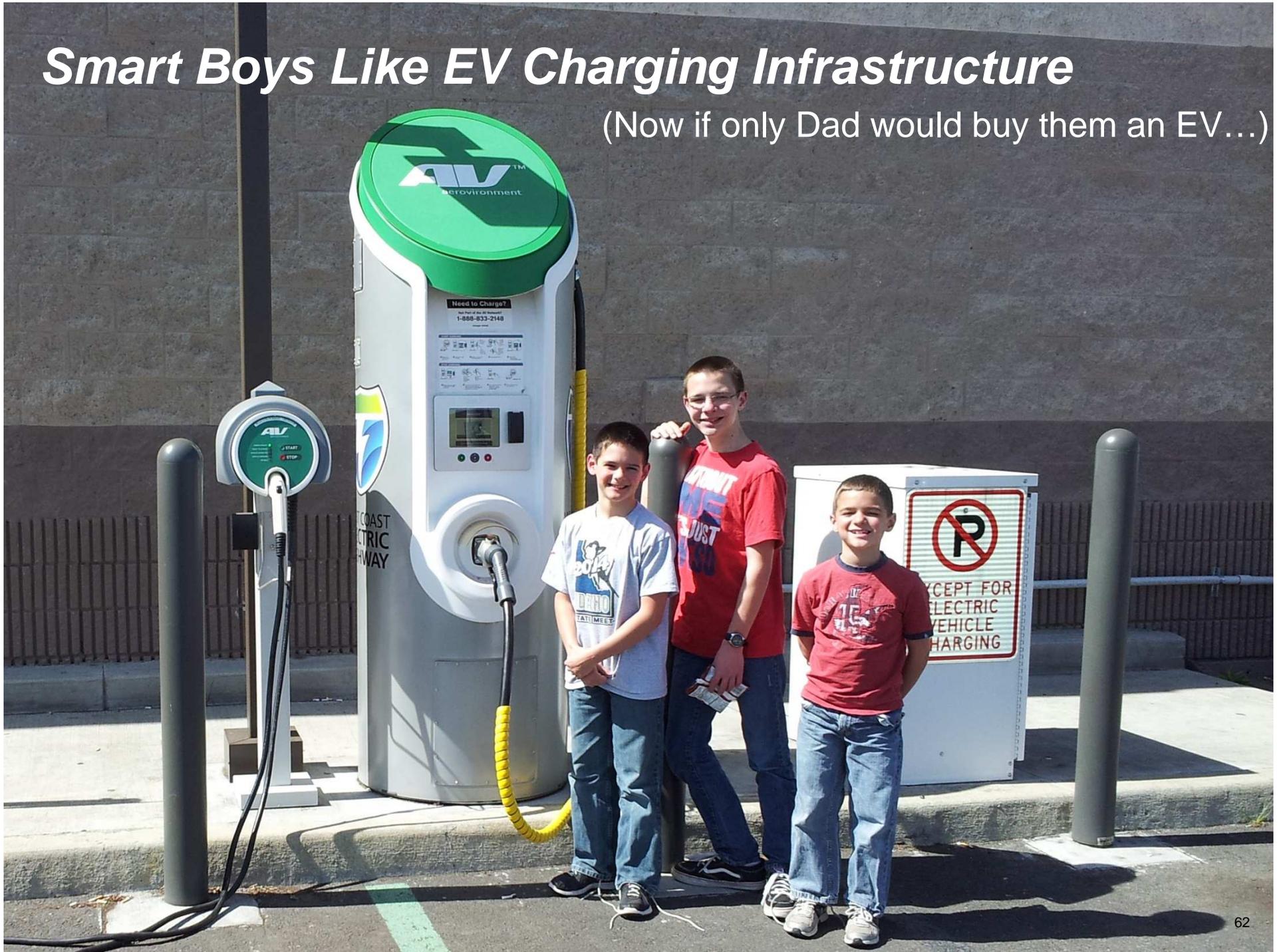
[avt.inl.gov/evproject.shtml](http://avt.inl.gov/evproject.shtml)

[avt.inl.gov/chargepoint.shtml](http://avt.inl.gov/chargepoint.shtml)

INL's funding for this work comes from DOE's Vehicle Technologies Office

# Smart Boys Like EV Charging Infrastructure

(Now if only Dad would buy them an EV...)



## ***Additional Information***

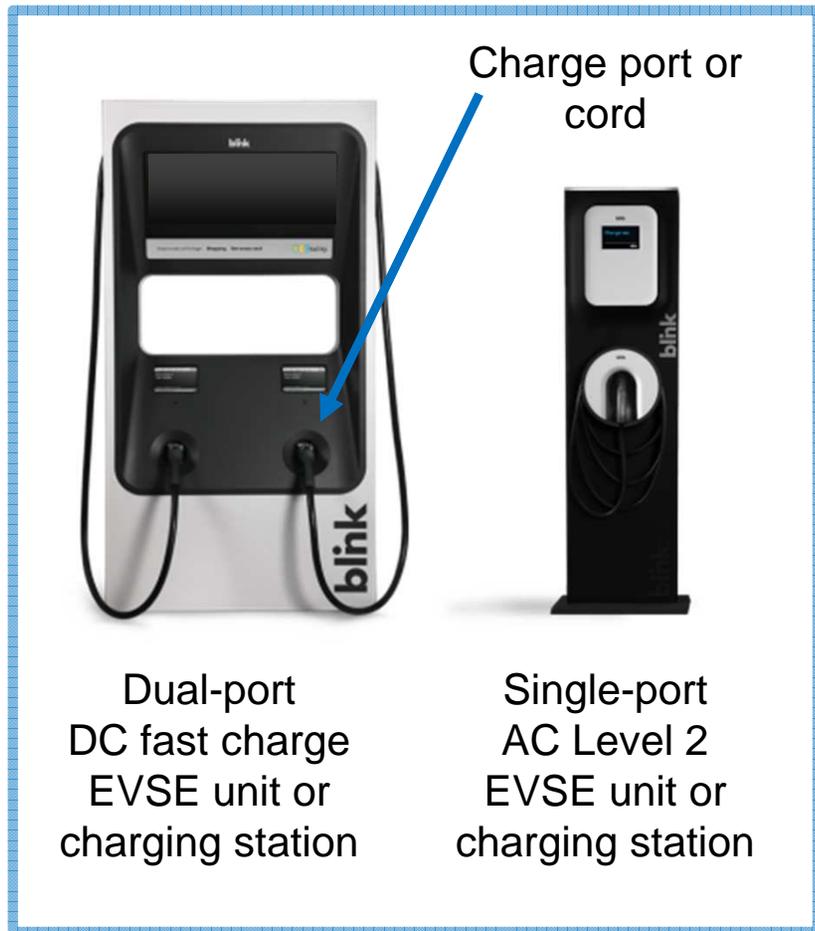
## ***Measures of “Goodness”***

There are numerous ways to assess how “good” public charging sites are:

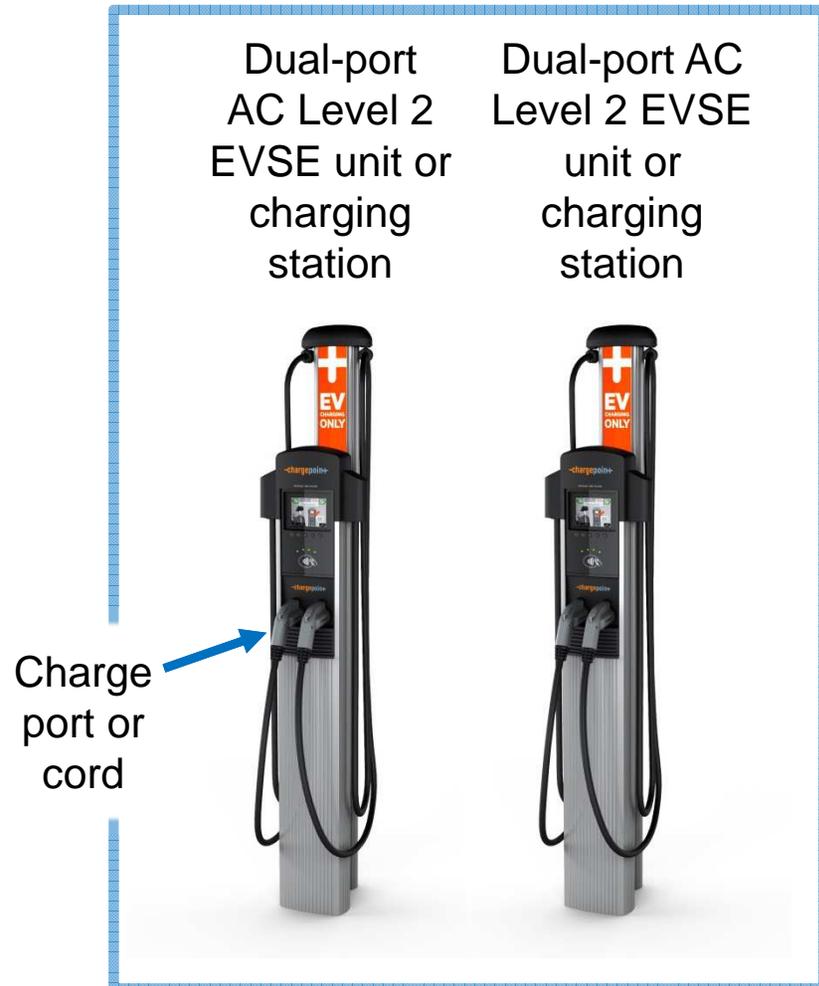
- Charging frequency: number of charge events per day or week
- Charging time: hours connected
- Charging energy: kWh consumed / EV miles provided
- Parking time: time spent in parking space / in store
- Charging site host may want electric vehicle supply equipment (EVSE) for other reasons, such as image or cool factor
- etc.

# Terminology

Charging site



Charging site



## Charging Site Location Considerations

- EVSE installations with respect to Americans with Disabilities Act (ADA) requirements are not consistent

“Charger is between 2 handicap spaces. To charge and not get ticketed you need to park behind the charger in any of 3 spaces closest to the elevator / entrance in non EV dedicated spots. Good Luck.”

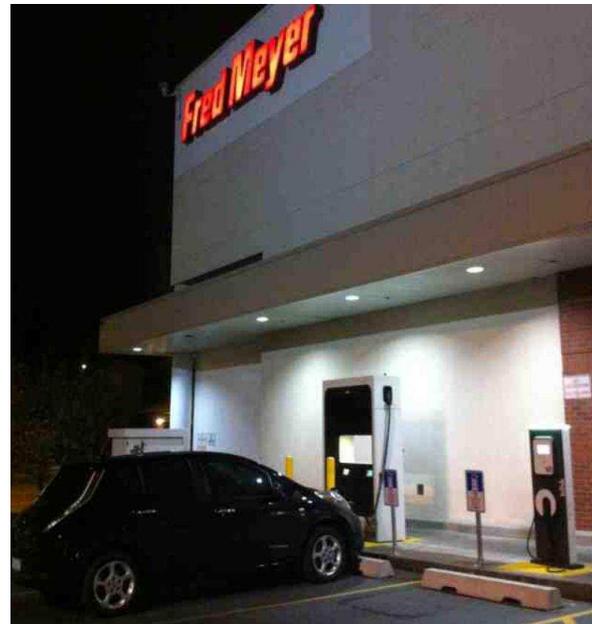
– Comment from plugshare.com user

- Parking lot or garage may have
  - limited hours of operation
  - parking fees
  - restricted access



## Charging Site Location Considerations

- Parking spaces in front of charging units may not always be accessible
  - Construction
  - Non-electric vehicle in parking spot (“you’ve been ICE’d”)
  - Electric vehicles in parking spots but not charging



Fred Meyer in  
Seattle, WA

Photos from  
[plugshare.com](http://plugshare.com)

## Charging Site Location Considerations

- Charging unit maintenance and reliability is a big factor

“Both sides [of the DC fast charger] and level 2 not working. Had no electricians left. AAA couldn't send out the EV rescue truck because according to them they didn't have a tech trained to use it on hand. I ended up towing my car home. Not a good night.”

– Comment from plugshare.com user

