July 31, 2014

Review of EV Charging Network in Washington

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The second meeting of the Washington State Advisory Panel

CENTER FOR CLIMATE
AND ENERGY SOLUTIONS

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Agenda

10:00 a.m.	Welcome and Introductions
10:15 a.m.	Study Overview and Update
11:15 a.m.	Electric Vehicle (EV) and Market Technology Overview
12:15 p.m.	Lunch
1:00 p.m.	Task 1: Evaluate Current Status of Electric Vehicle Charging in Washington
2:30 p.m.	Wrap-up Summary and Preview of Tasks 2 and 3

Study Overview and Update

Review of project goals and timeline

Directive from Washington State Legislature

The Legislature directed the Joint Transportation Committee to "evaluate the current status of electric vehicle charging stations in Washington, and to make recommendations regarding potential business models for financially-sustainable electric vehicle charging networks and alternative roles for public and private sector participation in those business models. Public sector participation may include public financing, funding, facilitation, and other incentives to encourage installation of electric vehicle charging stations. In conducting the study, the committee must coordinate with the department of transportation and consult with local governments and stakeholders in the electric vehicle industry. The committee may also consult with users of electric vehicles and stakeholders representing manufacturers and operators of electric vehicle charging stations. The committee shall submit an interim report by December 31, 2014, and a final report by March 1, 2015." (ESSB 6001, Sec 204(6))

Project Timeline

Task 1: Evaluate Current Status of EV Charging in Washington

- Establish a stakeholder network
- Construct Public Charging Network Database
- Create interactive maps for charging suitability assessment
- Provide insights into role of public charging networks in encouraging EVs
- Summarize findings

May – August

Task 2: Develop Business Models

- Leverage C2ES's AFV Finance Initiative
- Conduct Business Model Workshop
- Create 2-3 Business Model Summaries

July – November

Task 3: Identify Public & Private Roles

- Execute financial analysis on business model viability
- Identify public sector role in addressing barriers to private investment

October – December

Project Progress

- **May 14: Project Overview presented to Joint Transportation Committee**
- **May 15: Kickoff meeting with JTC Staff Workgroup**
- **June 26: Delivered draft of Public Charging Network Database**
- **June 30: Advisory Panel Webinar**
  - First meeting of the Advisory Panel
  - Overview of C2ES's approach to completing EV Charging Network Assessment
- **July 14: JTC Staff Workgroup to review progress on EV Charging Network Assessment**
- **July 29: EV Charging Network Assessment draft delivered to Advisory Panel**

Public Charging Network Database (1 of 2)

- **Updatable Microsoft Excel-based Tool**
- **Comprehensive statewide collection of EV and Charging Network characteristics by ZIP code and county**
- **Charging locations for public AC Level 2 and DC fast charging stations**
  - U.S. Department of Energy's Alternative Fuel Data Center
- **Time series data on charging usage and vehicle registrations**
  - Department of Licensing provided vehicle data
  - ChargePoint, Idaho National Laboratory and Washington State Department of Transportation provided charging usage data
- **Average Daily traffic for major roads provided by Washington State Department of Transportation**
- **Household incomes provided by U.S. Census Bureau**

Public Charging Network Database (2 of 2)

- **Data Issues**
  - Idaho National Laboratory data is not disaggregated by network
    - Uncertain degree of overlap in ChargePoint America and ChargePoint database limits analysis
    - Expect to receive new data drop by August 4
  - New and previously-owned vehicles not distinguished in Department of Licensing database could contribute to inflating total EVs on the road
  - Understanding distribution of vehicles is difficult because registration entries from the Department of Licensing have many invalid ZIP codes

Electric Vehicle (EV) and Market Technology Overview

A state of play on EV technology and the market at a national and state level

EV Alphabet Soup

Plug-in Electric Vehicle (PEV)

A vehicle that can be powered by a rechargeable battery pack and connects to the electrical grid

Battery Electric Vehicle (BEV)

- Electric drive vehicle that can only be powered by a battery pack
- Example: Nissan LEAF, Tesla Model S

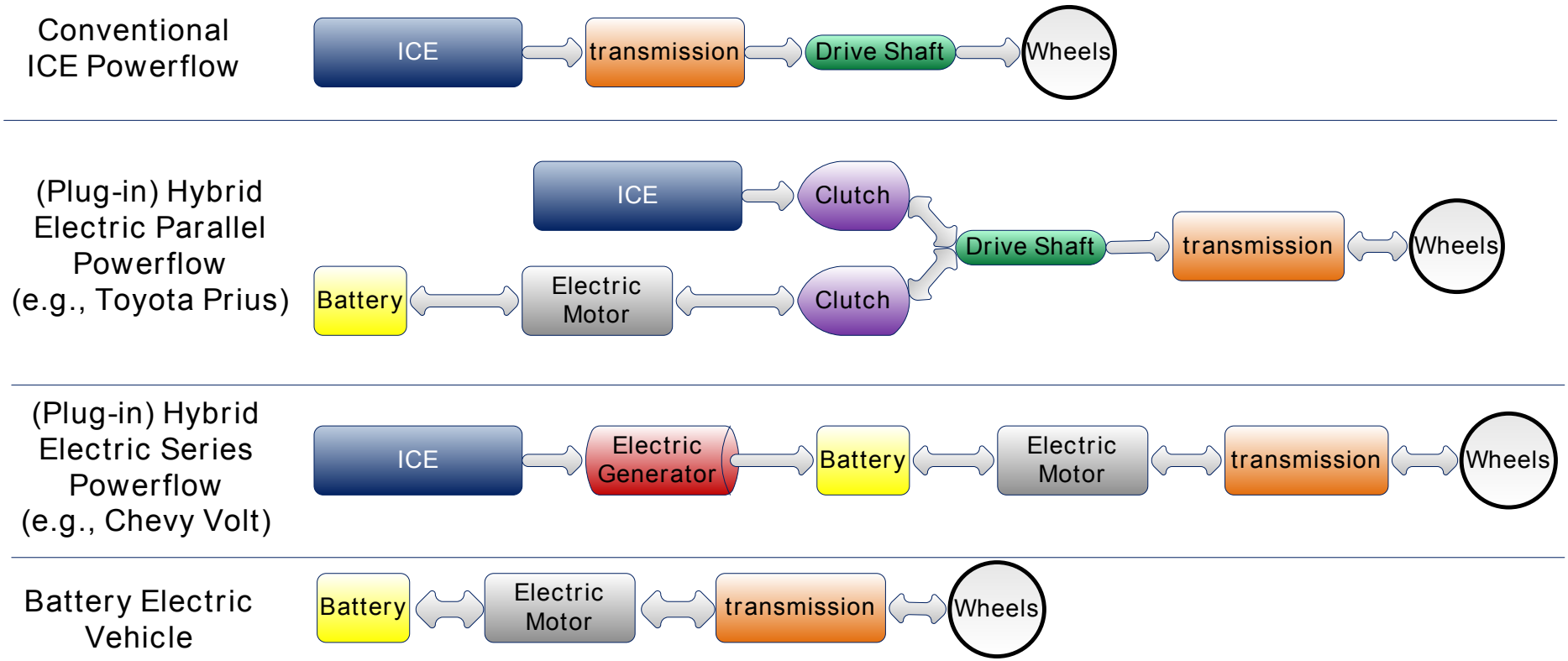
Extended Range Electric Vehicle (EREV)

- BEV with a backup internal combustion engine powered by gasoline, biofuel, etc. (a.k.a. range extender)
- Example: Chevy Volt

Plug-in Hybrid Vehicle (PHEV)

- Electric and conventional drivetrain in one
- Similar to a Prius with a larger battery pack that can be recharged
- Example: Toyota Prius Plug-in

How an EV works compared to an Internal Combustion Engine (ICE) Vehicle



Source: C2ES PEV Literature Review

Energy Efficiency of EVs Exceeds Conventional Vehicles

VEHICLE TYPE		ENERGY DENSITY (WH/KG)	SYSTEM EFFICIENCY	SYSTEM LEVEL ENERGY DENSITY (WH/KG)
TODAY	Conventional Vehicle * (Gasoline)	13,000	21%	2,730
	Electric Vehicle** (Lithium Ion Battery)	100-250	81%	81-203
FUTURE	Conventional Vehicle*** (Gasoline hybrid)	13,000	42%	5,460

* Includes energy loss from internal combustion engine, standby/idle, driveline, and accessories.
** 10% energy loss from electric motor and 10% loss from battery charging. Does not include loss from accessories.
*** Assume doubling of efficiency through advanced drivetrains, engine shut-off when idle, regenerative braking, and more.

Source: C2ES PEV Literature Review

Electric-only Range for EVs Varies

- **Electric-only range varies widely**
  - E.g., Nissan LEAF range can vary from 60 miles to over 100 miles
- **Range is a function of driving conditions, driver behavior, vehicle system efficiency, battery size**
- **Factors that affect driving range:**
  - Mostly, the same things that affect conventional vehicle fuel economy
  - Climate control, hills, aggressive driving, regenerative braking, etc.

Toyota Prius Plug-in
Electric Range: 11 miles
Total Range: 540 miles

Chevy Volt
Electric Range: 38 miles
Total Range: 380 miles

Nissan LEAF
Electric Range: 84 miles
Total Range: 84 miles

Tesla Model S
Electric Range: 265 miles
Total Range: 265 miles

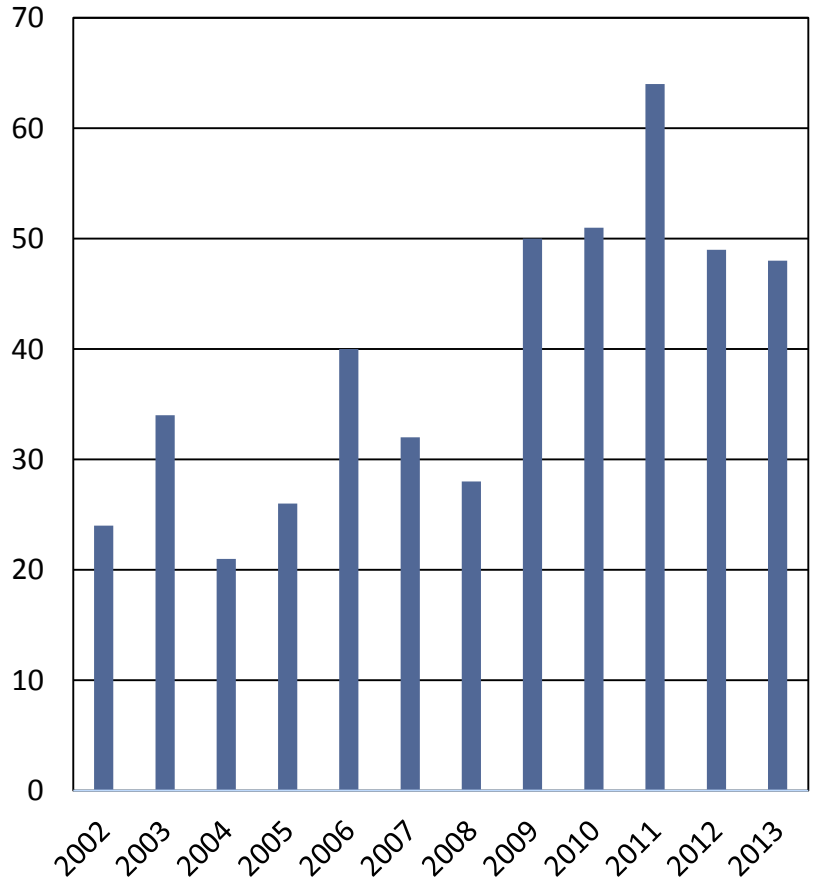
Understanding Charging Needs

Low – AC 120V *"AC" LEVEL 1*	Medium – AC 240V *"AC" LEVEL 2*	High – DC Fast Charge *"DC" LEVEL 2*
• Uses standard outlet • Power requirements are like a toaster • Adapter comes with the car • Accommodates average daily driving needs • Very low cost installation, often free • *Fully charge a Nissan LEAF: 17 hours*	• Requires high-voltage circuit • Power requirements are like a clothes dryer • Charging stations can cost about $500 • Installation costs vary widely (~$1,500) • *Fully charge a Nissan LEAF in 3.5-7 hours*	• Requires very high voltage circuit & 3-phase power • Power requirements are up to max power for 15 homes • No common standard for electric vehicles (CHAdeMO, SAE, Tesla) • Very high installation cost (~$100k) • Equipment costs vary widely • *80% charge a Nissan LEAF in < 30 minutes*

Many State and Federal Policies Exist to Encourage EVs

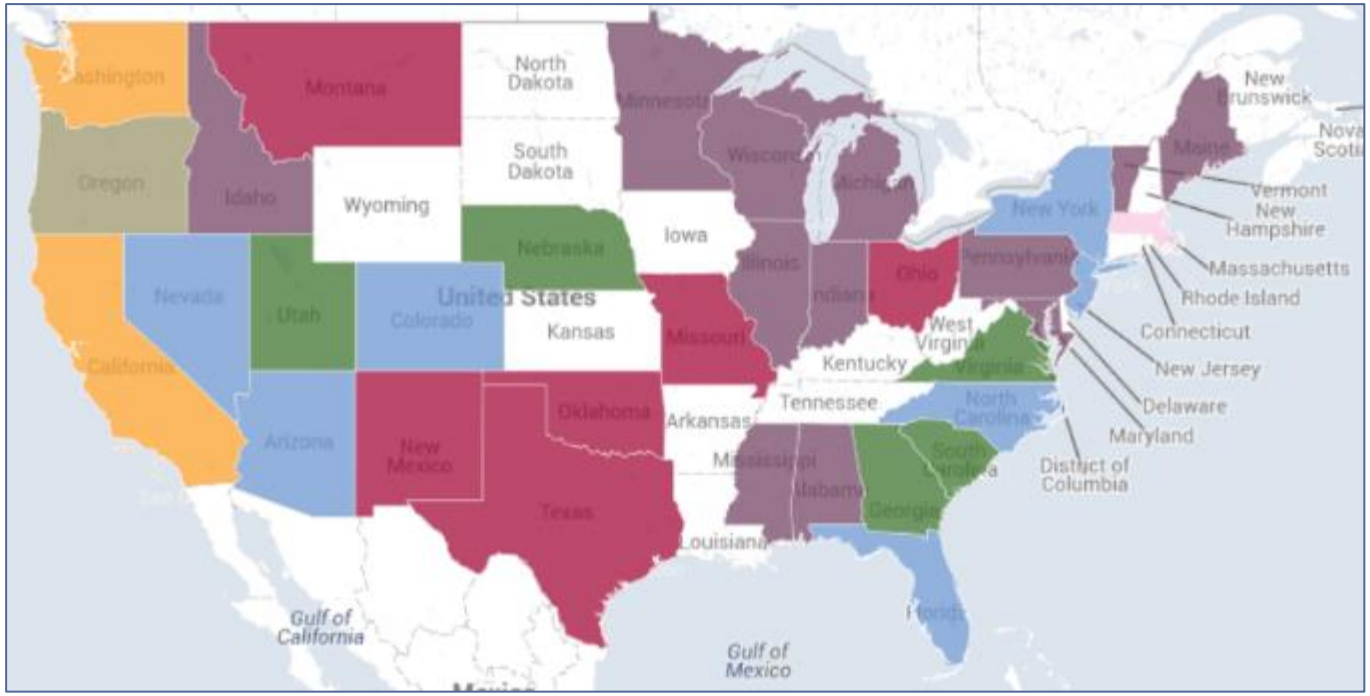
- **Federal programs and incentives drive investments**
  - EPA/NHTSA vehicle standards
  - Federal vehicle tax credit for EVs: $7,500
- **10 U.S. states participate in Zero Emission Vehicle (ZEV) Program**
  - ZEV Program key driver for automaker investments
  - Requires 15% of new vehicles made for sale be ZEVs in 2025

Number of new state policies and incentives on EVs



Most States Have Some EV Policy Incentives

- Financial Incentive
- Financial Incentive, Preferred Access
- Financial Incentive, Preferred Access, Vehicle Acquisition
- Financial Incentive, Preferred Access, Vehicle Acquisition, Infrastructure Requirement
- Financial Incentive, Vehicle Acquisition
- Financial Incentive, Vehicle Acquisition, Infrastructure Requirement
- Preferred Access, Vehicle Acquisition
- Vehicle Acquisition



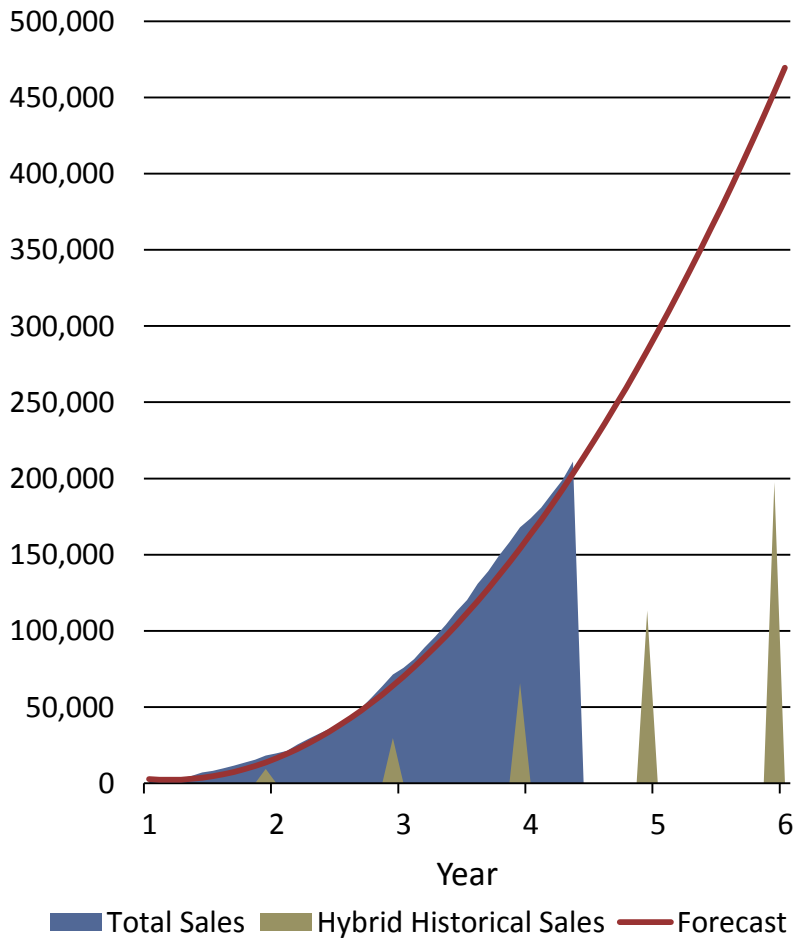
Source: C2ES Map

Washington has Many Policies to Encourage EVs

- Alternative Fuel Vehicle (AFV) Tax Exemption
- EV Infrastructure and Battery Tax Exemptions
- Alternative Fuel Loans and Grants
- EV Demonstration Grants
- EV Charging Regulation Exemption
- Local Government EV Infrastructure Requirements
- EV Promotion and Infrastructure Development
- EV Charging Infrastructure Availability
- Low Carbon Fuel and Fuel-Efficient Vehicle Acquisition Requirement

U.S. EV Market Summary

- **EV sales are rising slowly**
  - Over 200,000 EVs sold in United States since late 2010
  - Lion's share of sales in California
  - Only 1% of new passenger vehicle sales
  - Seventeen models sold in June 2014



Washington State EV Market Summary

- Over 8,000 EVs registered in Washington
- More than half are registered in King County
- Twelve models registered as of December 2013

	2011	2012	2013
PHEVs Registered	125	1,056	2,493
BEVs Registered	1,121	1,871	5,655
Total EVs	1,246	2,927	8,148
Total Passenger Vehicles	4,315,782	4,284,923	4,401,768

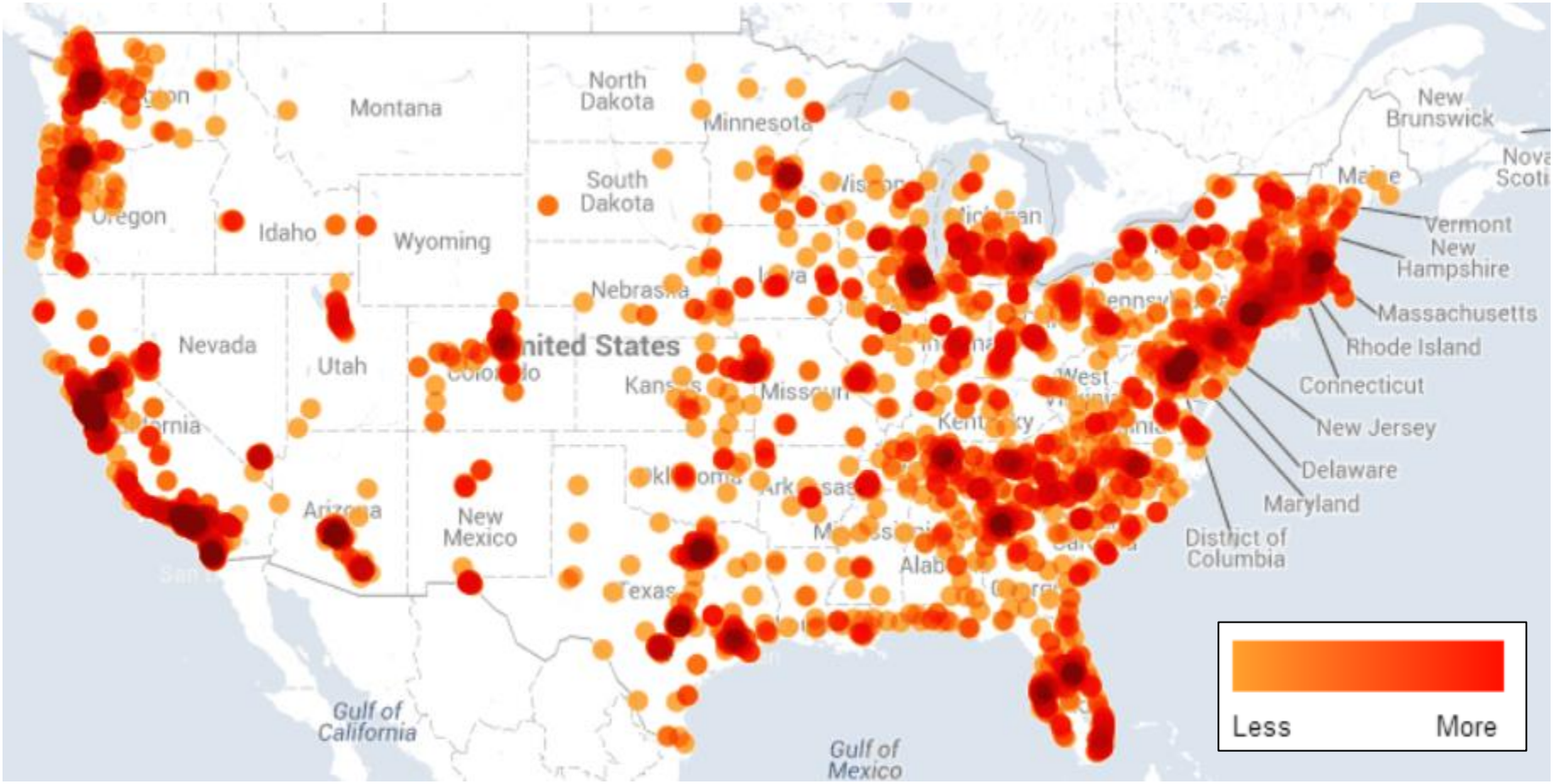
Source: Washington State Department of Licensing, compiled by C2ES

U.S. Charging Market Summary

- **Over 8,500 public charging locations nationwide**
  - 2,503 AC Level 2 charging locations on West Coast (30%)
  - 268 DC fast charging locations on West Coast (45%)

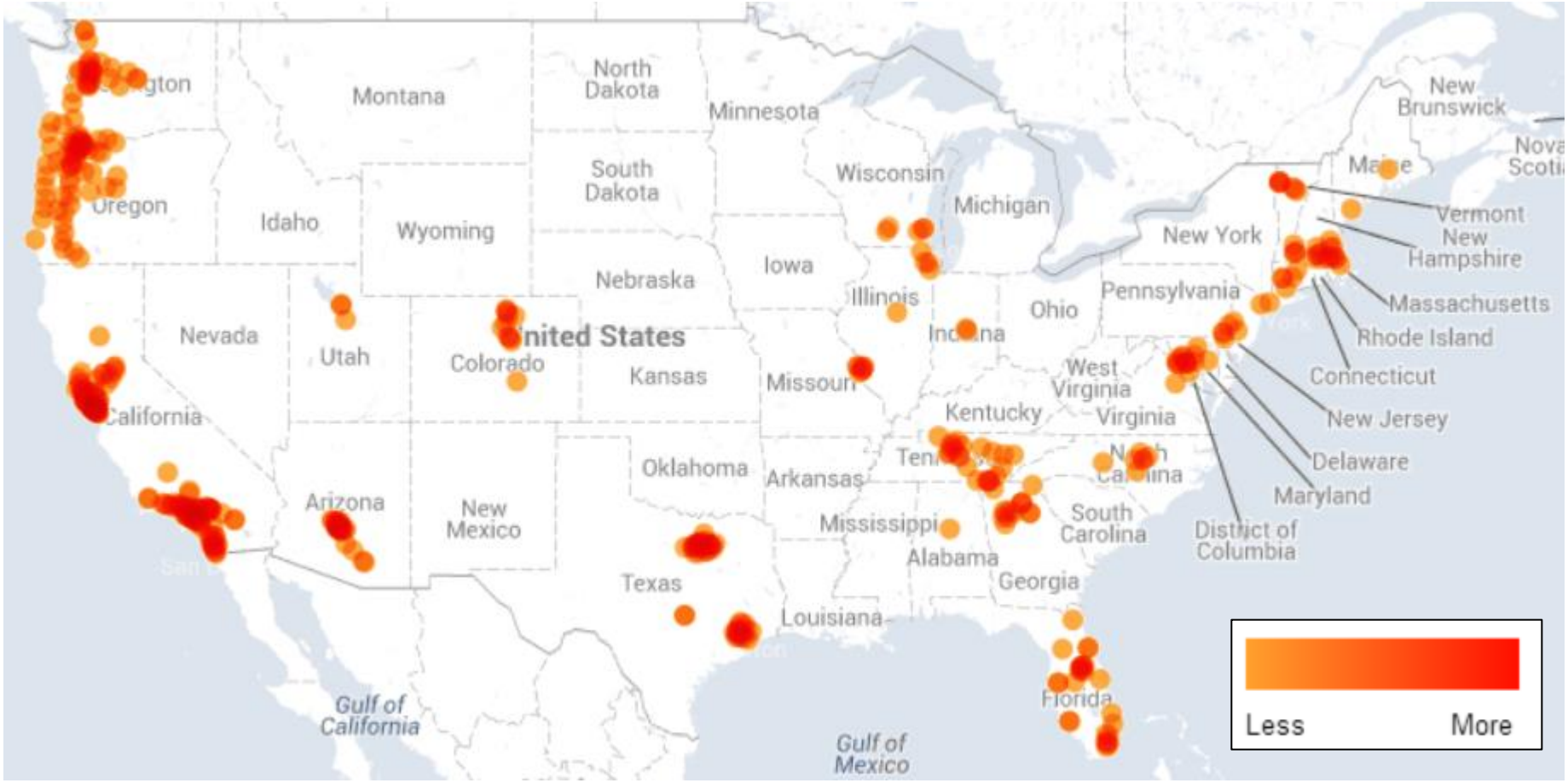
	AeroVironment Network	Blink Network	ChargePoint Network	Other or None	Tesla Network	Total
DC Fast Charging Locations	54	99	75	267	104	599
AC Level 2 Charging Locations	58	1,558	3,314	3,062	2	7,994

Public AC Level 2 Charging Stations



Source: U.S. Department of Energy, compiled by C2ES

Public DC Fast Charging Stations



Source: U.S. Department of Energy, compiled by C2ES

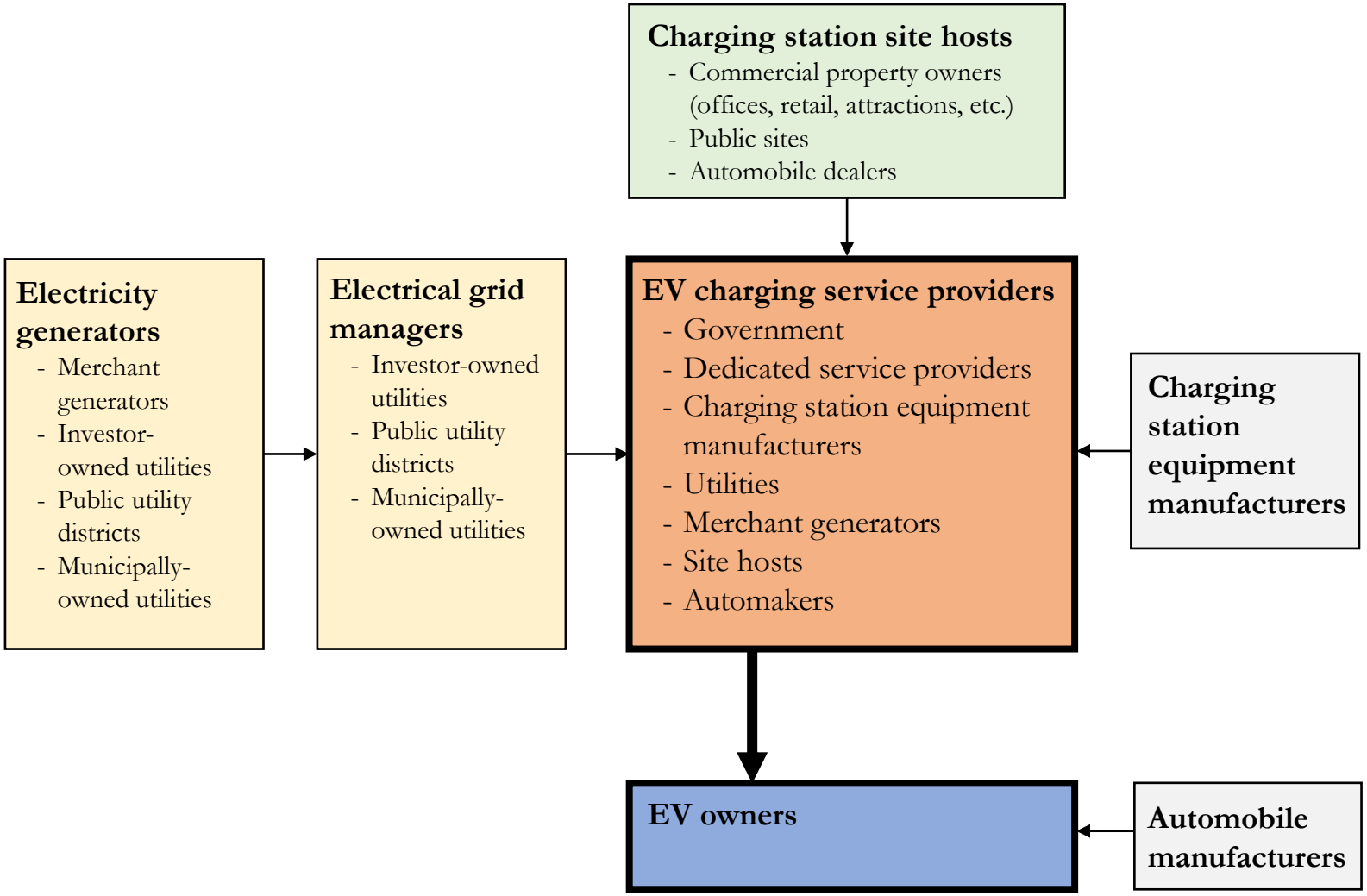
Task 1: Evaluate Current Status of Electric Vehicle Charging in Washington

Highlight the essential components of an EV charging station business model. Examine the characteristics of Washington's current public charging network.

The Challenge of Expanding the Private Sector Role in Offering EV Charging Services

- **Substantial costs**
  - Capital cost: $500 to $5,000 for a Level 2 charging station or $50,000 to $150,000 for a DC fast-charging station
  - Financing cost: Access to adequate financial capital needed
  - Operating cost: electricity costs associated with powering DC fast chargers or sites with multiple Level 2 chargers
- **Uncertain, elusive revenue**
  - Charging demand: demand low and uncertain as EV market develops
  - Price: limited willingness to pay due to competition with residential electricity
  - Indirect revenue sources: (i.e. increased retail sales near public chargers) opportunities uncertain and not well recognized

What must be provided in an EV charging network?



What Entities Are Positioned to Provide EV Charging Services?

- Dedicated charging service companies
- Charging equipment manufacturers
- Property owners acting as site hosts
- Automakers
- Electric utilities
- Electricity generators
- State and local governments

How Would These Entities Derive Value from Providing Such a Network?

- **Monetary value**
  - Station user fee revenue
    - Flat fee per charging session
    - Fee based on the time spent parked or connected to the charger
    - Fee based on the amount of energy used
    - Subscriptions, membership fees, or permits
  - Ancillary revenue
    - Increased sales revenue at retail locations
    - Increased sales of EVs
    - Vehicle-to-building and vehicle-to-grid power services
- **Value of public benefits**
  - Public health, environmental, economic development, and energy security benefits

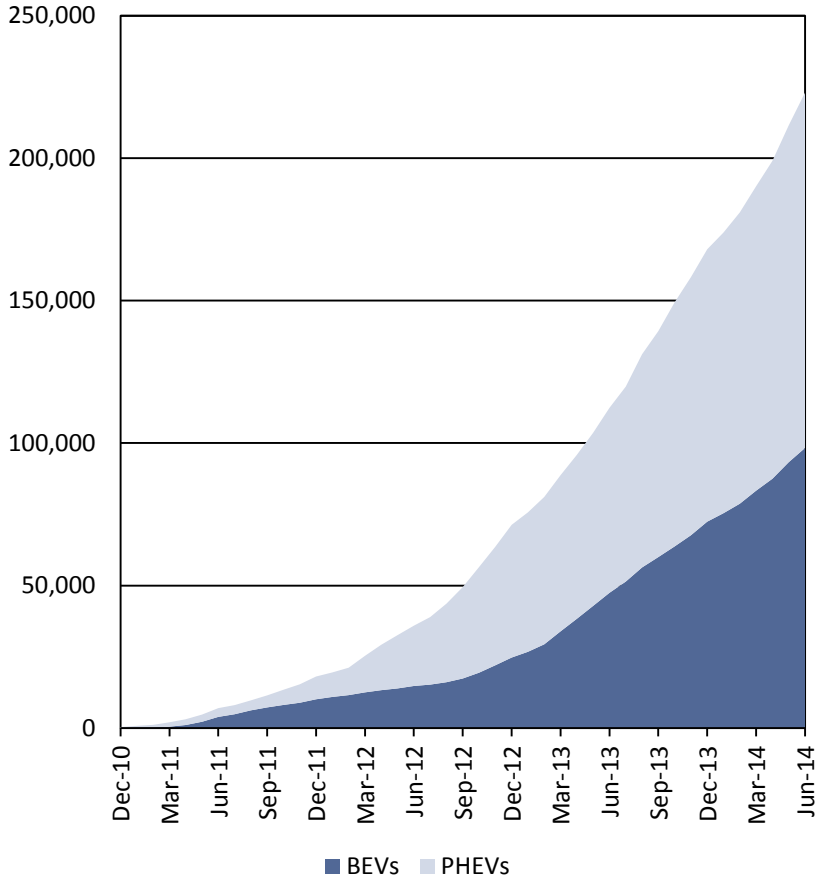
What sources of financial capital are available to fund station deployment

- **Private sources**
  - Available cash-on-hand
  - Private financing (commercial loans or leases)
  - Third-party investment partners
- **Public sources (for direct deployment or subsidies)**
  - Tax revenues
  - Electric utility ratepayer funds
  - Electric utility shareholder revenues

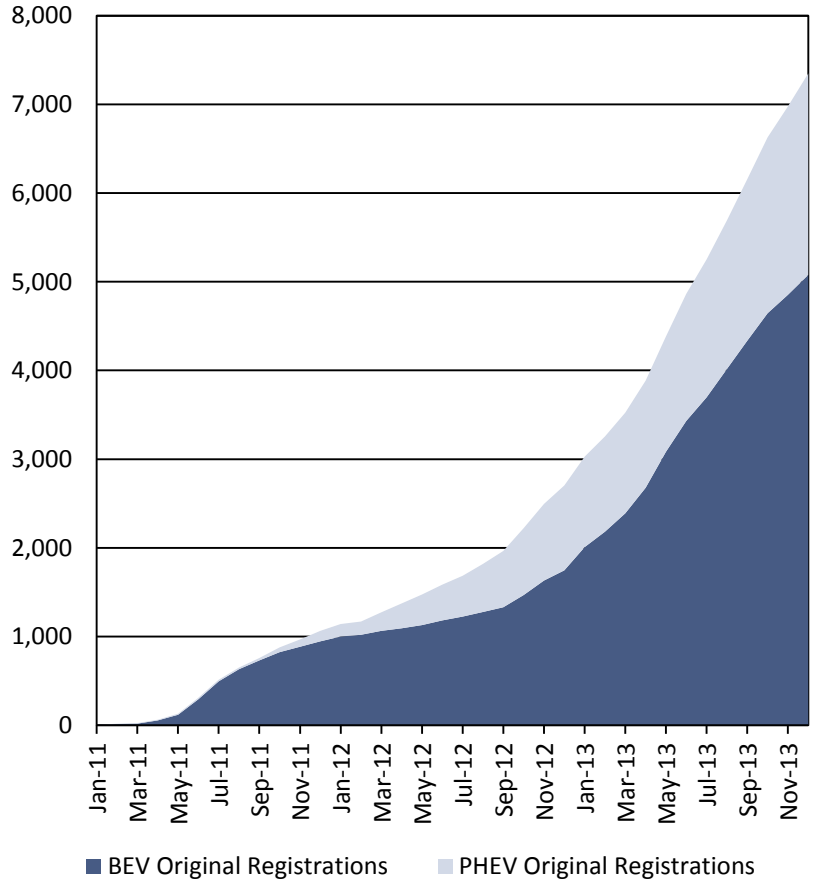
The Washington EV Market

BEVs are more popular in Washington than elsewhere

Cumulative U.S. Sales of BEVs and PHEVs



BEVs and PHEVs original registrations in Washington



Understanding EV sales in Washington

- **Popularity of BEVs over PHEVs could be from incentives**
  - Sales tax exemption is > $1,000 “discount” at the dealer
  - Automakers have said > $1,000 off the sticker price increases sales
- **Georgia example**
  - $5,000 tax credit
  - Atlanta is Nissan LEAF’s largest market for many months
- **Other possible explanations**
  - Consumer preference
  - Dealer incentives
  - Prevalence of public charging

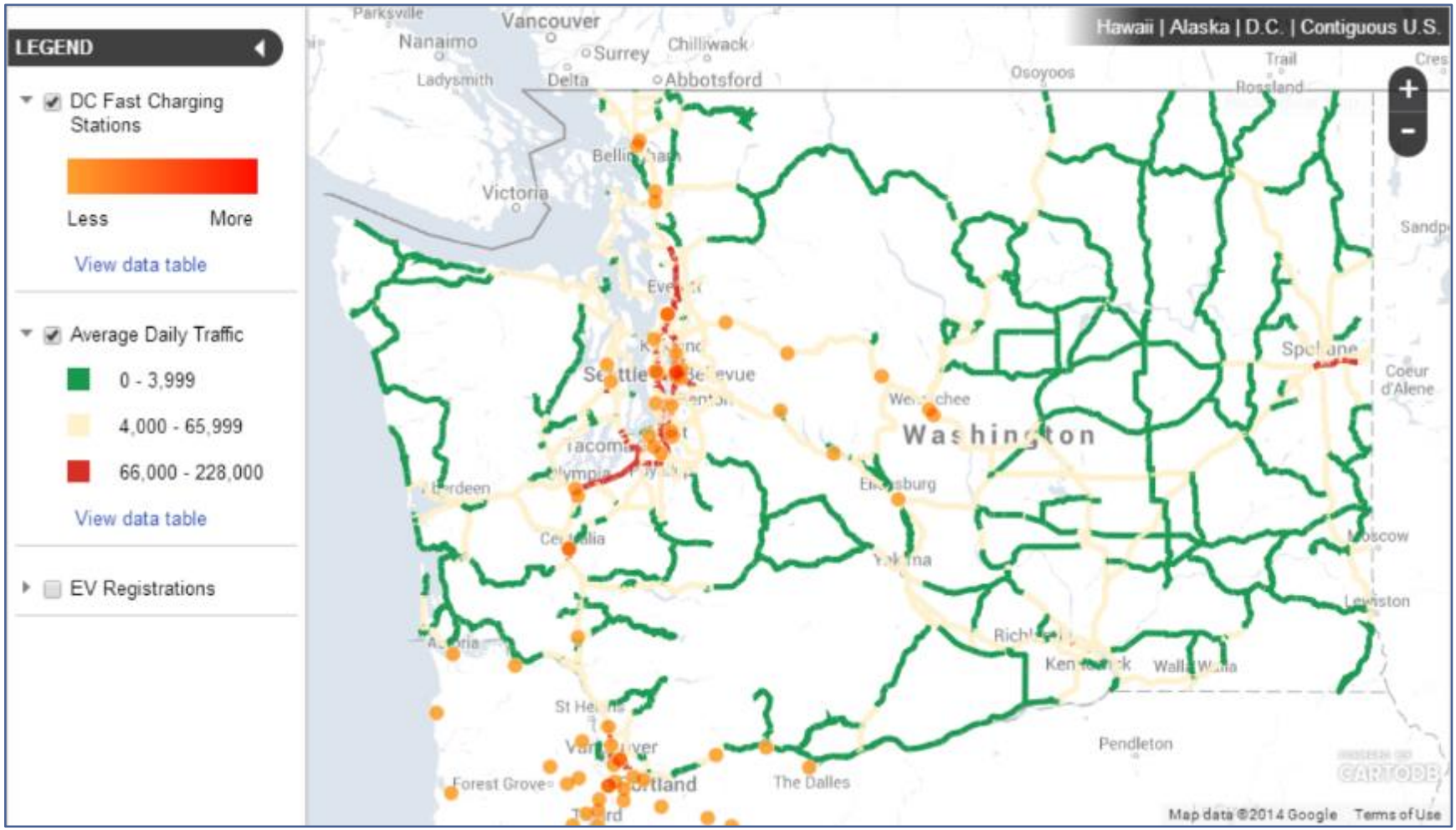
Top 5 Counties for EV registrations

COUNTY	BEVS REGISTERED	PHEVS REGISTERED	EVS REGISTERED	POPULATION (%)	BEV (%)	PHEV (%)	EV (%)	DC FAST CHARGING LOCATIONS (%)	AC LEVEL 2 CHARGING LOCATIONS (%)
Clark	22	14	36	6.3%	5%	6%	5%	15%	3%
King	285	122	407	28.8%	55%	32%	55%	43%	60%
Kitsap	24	17	41	3.7%	5%	4%	5%	5%	3%
Pierce	37	25	62	11.8%	8%	11%	8%	5%	11%
Snohomish	45	40	85	10.6%	11%	11%	11%	8%	8%

Registered EVs in Washington State by County

DC Fast Charging Network Assessment

DC Fast Charging Network Overview

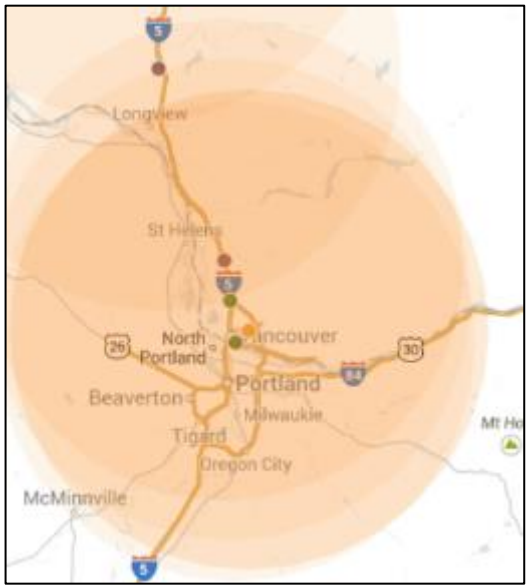


DC Fast Charging Network Summary

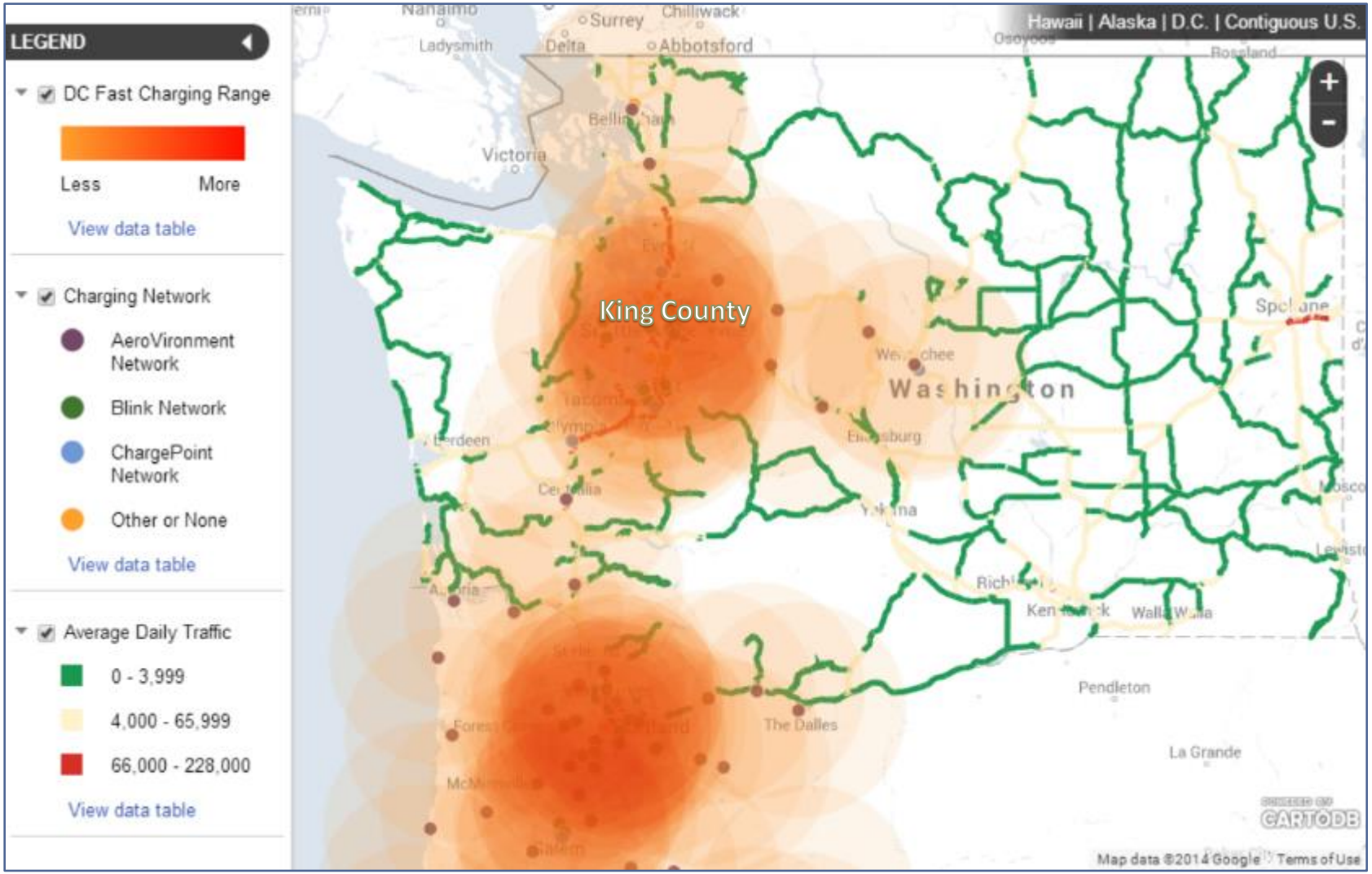
- **42 DC fast charging locations**
  - Concentrated in Puget Sound region with some stations located along U.S. 2, I-90, and I-5
- **All public charging locations allow for one port to be used at a time**
  - Drivers looking to “charge and go” run risk waiting for an extended period
- **16 locations only have a station with one port so drivers run risk of station being out of service**
- **AeroVironment and Blink make up over 60% of DC fast charging locations**
  - Blink Network stations are concentrated in King County
  - AeroVironment Network stations are spread throughout 10 counties

Using Maps to Demonstrate Expected Travel Range of a Charging Location

- Fixed-size circles can convey expected travel from a charging location at a glance
- Overlap of several locations denoted by a darker orange color indicates a greater likelihood that a charging location will be available in that area



Expected Travel from DC Fast Charging



Travel Accessibility

- **King County**
  - Largest concentration of stations with 33% of total locations, or 30% of total charging ports
  - Blink Network operates nine locations (64% of total)
- **Some corridor travel possible**
  - Bellingham to Vancouver (north to south along Interstate 5),
  - Everett to Wenatchee (west to east along U.S. 2)
  - Seattle to Ellensberg (west to east along Interstate 90)
- **Inaccessible places**
  - West to east travel statewide using DC fast charging is not possible
  - No DC fast charging stations in or around Spokane
  - Access to the Pacific coast is limited
  - Segments of I-90, U.S. 395, I-82, and Route 12 have moderate daily traffic (6,000 to over 20,000 vehicles), but have little or no DC fast charging

Travel Simulations

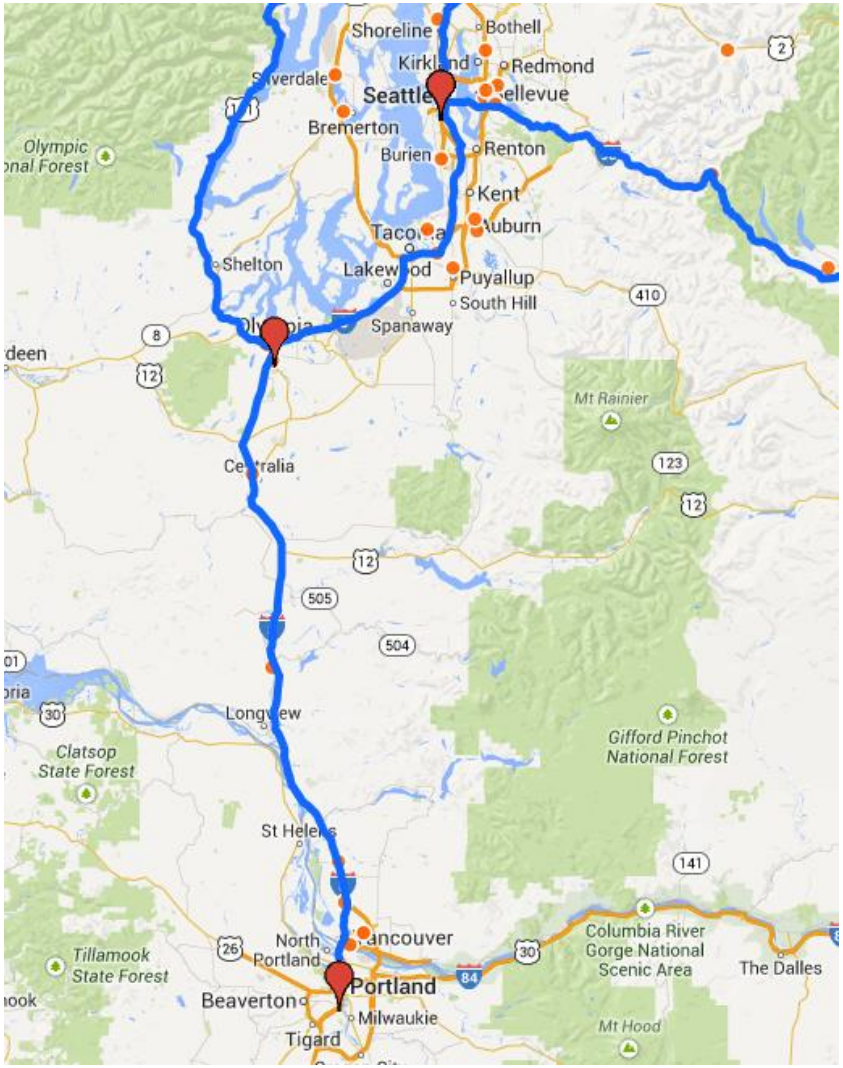
Simulation Overview

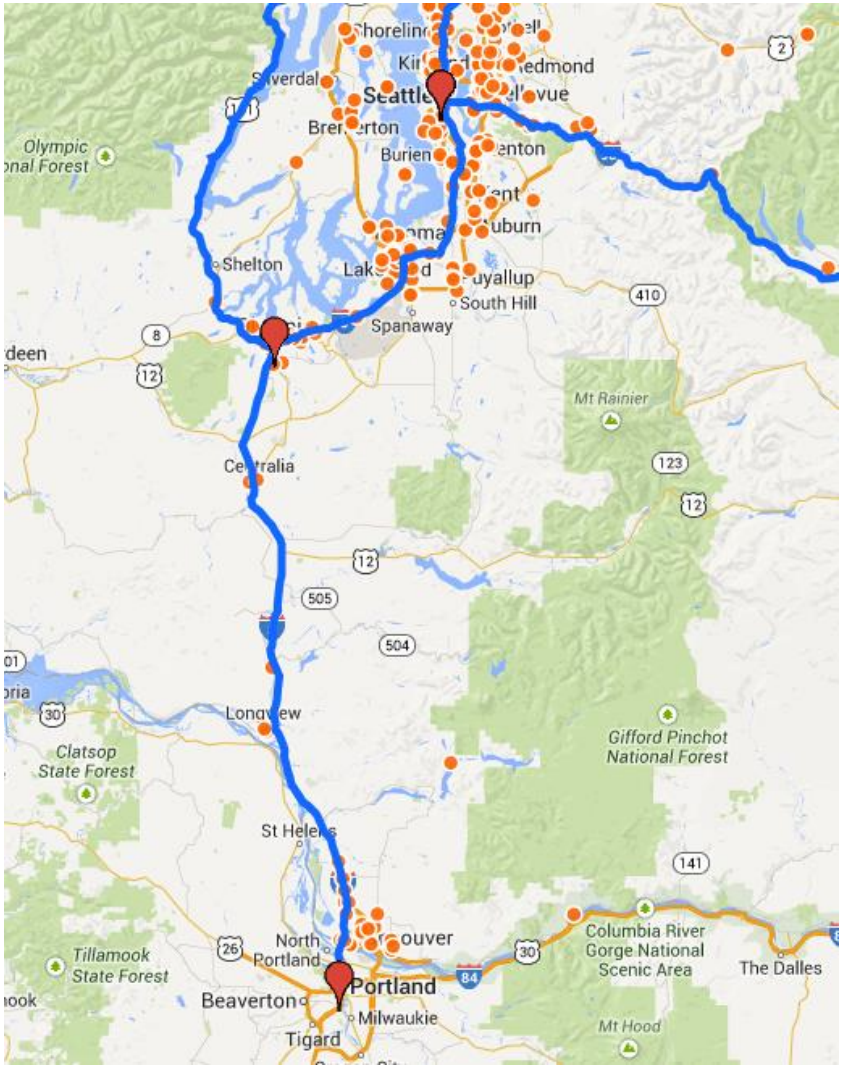
- **4 routes simulated**
  - Seattle and Portland
  - Seattle and Bellingham
  - Seattle and Spokane
  - Olympia and Port Angeles
- **Gauge coverage of existing public charging stations**
  - Determine if travel was possible along route using only on public charging stations
  - Areas with high charging station density and areas with low charging station density
  - Noticeable coverage gaps that would be critical to completing travel along preferred routes

Simulation Assumptions

- **PHEV with 40 miles of electric range**
- **BEV with 80 mile range**
- **Travel at speed limit**
- **Make trip with minimum number of stops to recharge**
- **Start trip with a full charge**
- **BEV charging assumptions**
  - DC Fast Chargers is 0.5 hours at 30 kW (53 miles)
  - AC Level 2 is 2.25 hours at 6.6 kW (52 miles)
- **PHEV charging assumptions**
  - DC Fast Charger is 0.3 hours at 30 kW (32 miles)
  - AC Level 2 is 1.5 hours at 6.6 kW (35 miles)

Simulation 1: Seattle & Portland along I-5





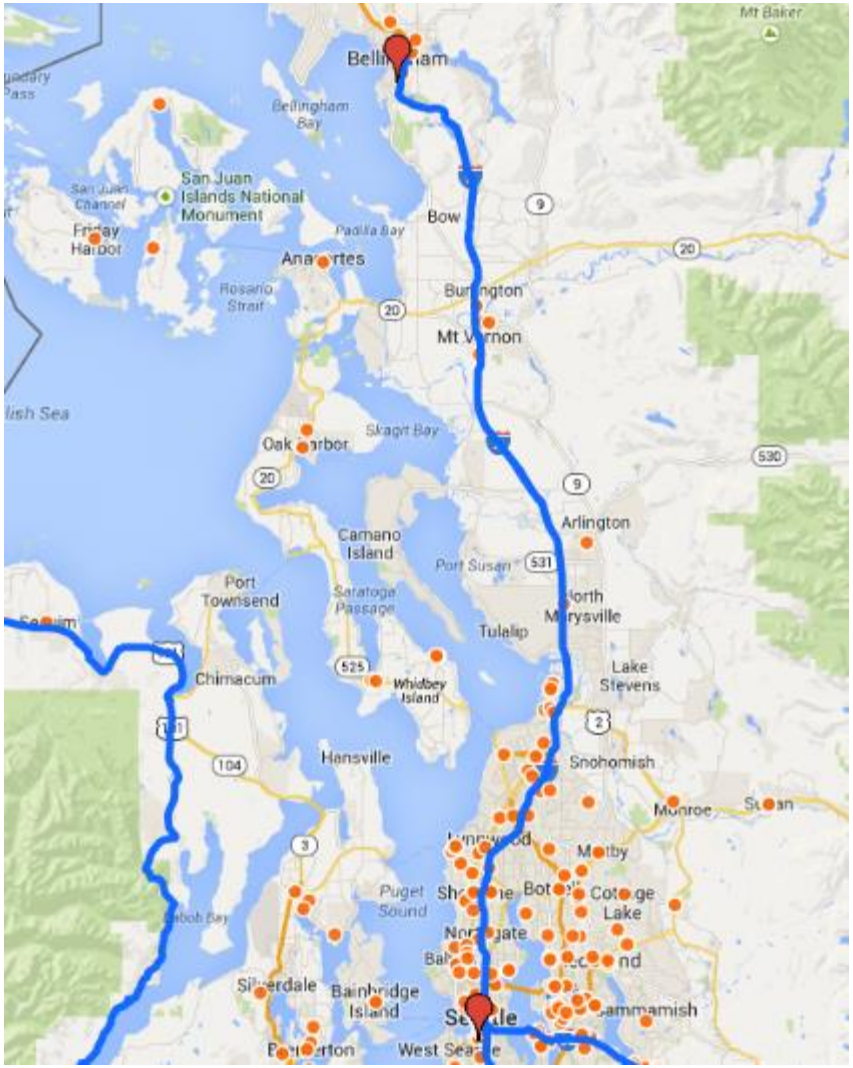
Simulation 1 Results: Seattle & Portland along I-5

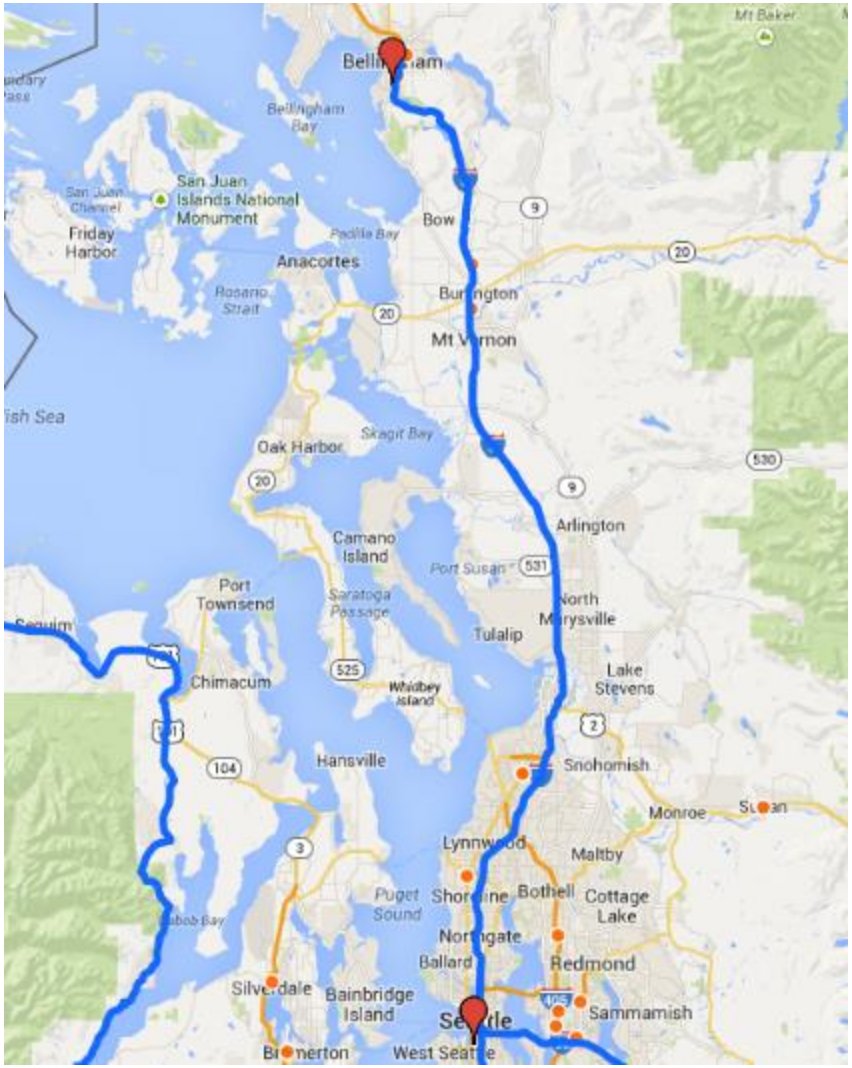
CHARGING TYPE	VEHICLE	MILES TRAVELED	NUMBER OF CHARGING STOPS	DRIVE TIME (MIN)	CHARGE TIME (MIN)	TOTAL TIME (MIN)
N/A	Gasoline Powered	173	N/A	170	N/A	170
DC Fast Charging	BEV-80	175	2	184	60	244
DC Fast Charging	PHEV-40	178	5	184	90	274
AC Level 2	BEV-80	178	2	178	270	448
AC Level 2	PHEV-40	178	5	188	675	863

Simulation 1 Results: Seattle & Portland along I-5

- **Public charging infrastructure worked for all simulations**
  - Higher concentration of public charging stations in Puget Sound region than in southern portion of the route
- **Total trip travel is longer for EVs along preferred route because of charging time**
  - DC Fast charging: 4-4.5 hours, charge time is about 1/3 of total drive time
  - AC Level 2: 10-14 hours, charge time is about 70 to 80% of total drive time
- **Additional public charging stations are needed along southern portion of route between Centralia and Longview**
  - Reduce reliance on charging stations in Castle Rock and Ridgefield to complete trip
  - One public DC fast charging station between Centralia and Ridgefield—in Castle Rock—an essential stop for a BEV to complete trip
  - Due to lower battery capacity, PHEVs would need to make 2 essential charging stops in Castle Rock and Ridgefield to complete trip

Simulation 2: Seattle & Bellingham along I-5





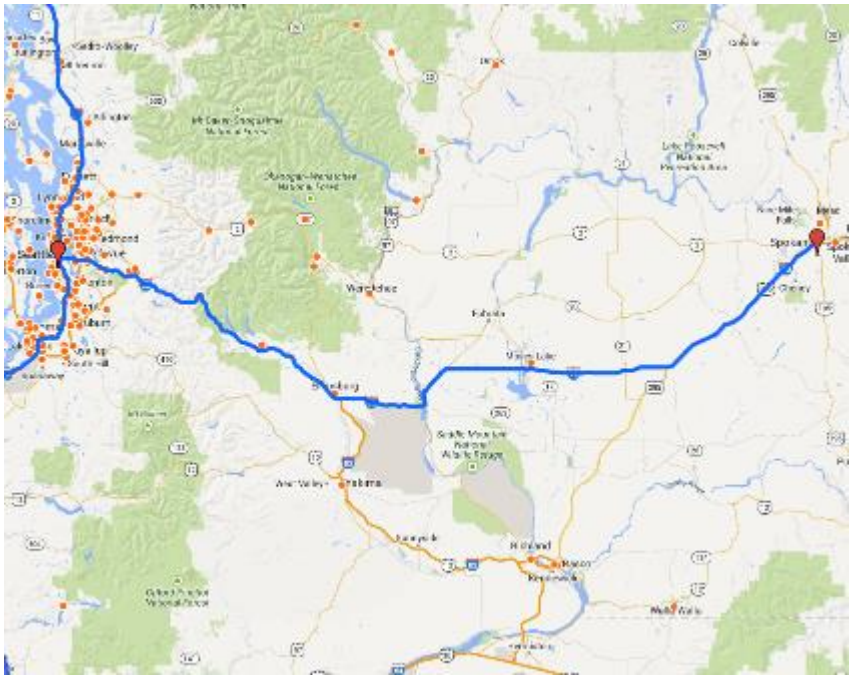
Simulation 2 Results: Seattle & Bellingham along I-5

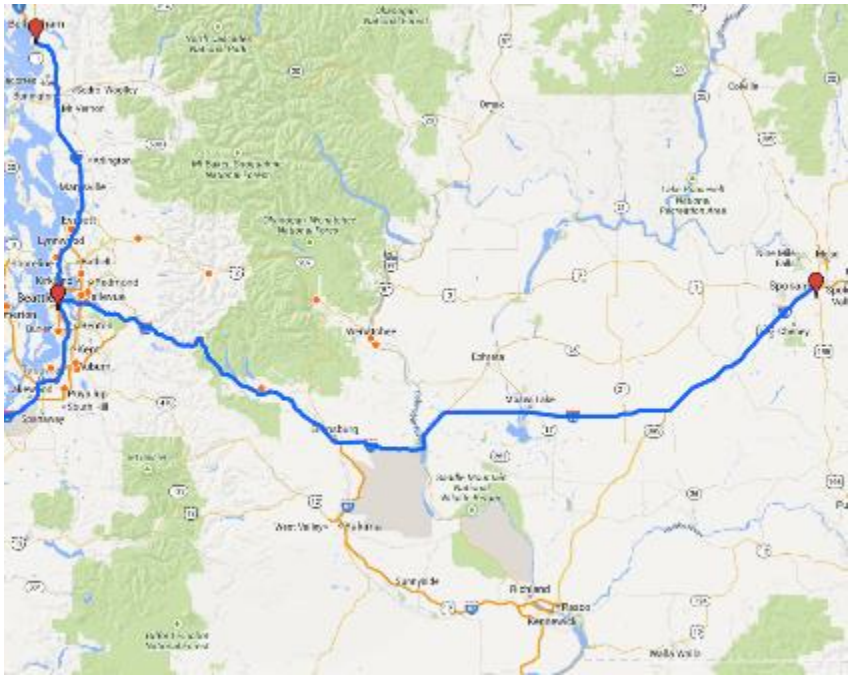
CHARGING TYPE	VEHICLE	MILES TRAVELED	NUMBER OF CHARGING STOPS	DRIVE TIME (MIN)	CHARGE TIME (MIN)	TOTAL TIME (MIN)
N/A	Gasoline Powered	88.7	N/A	90	N/A	90
DC Fast Charging	BEV-80	89.2	1	89	30	119
DC Fast Charging	PHEV-40	X	X	X	X	X
AC Level 2	BEV-80	90.3	1	93	135	228
AC Level 2	PHEV-40	90.3	2	94	270	364

Simulation 2 Results: Seattle & Bellingham along I-5

- **Public charging infrastructure worked for all but one simulation**
  - Higher concentration of public charging stations in Puget Sound region than in northern portion of route
- **Total trip travel is longer for EVs along preferred route because charging time**
  - DC Fast charging: 2 hours charge time for BEVs is about 25% total drive time. PHEV unable to complete travel along preferred route.
  - AC Level 2: 4-6 hours, charge time is about 60-74% of total drive time
- **Additional public DC fast charging stations are needed between Everett and Burlington to allow a PHEV to travel preferred route making exclusive use of DC fast charging network**
  - Lower concentration of DC fast chargers than AC Level 2 chargers along preferred route
  - No DC fast chargers and 15 AC Level 2 chargers between Everett and Burlington

Simulation 3: Seattle & Spokane along I-90





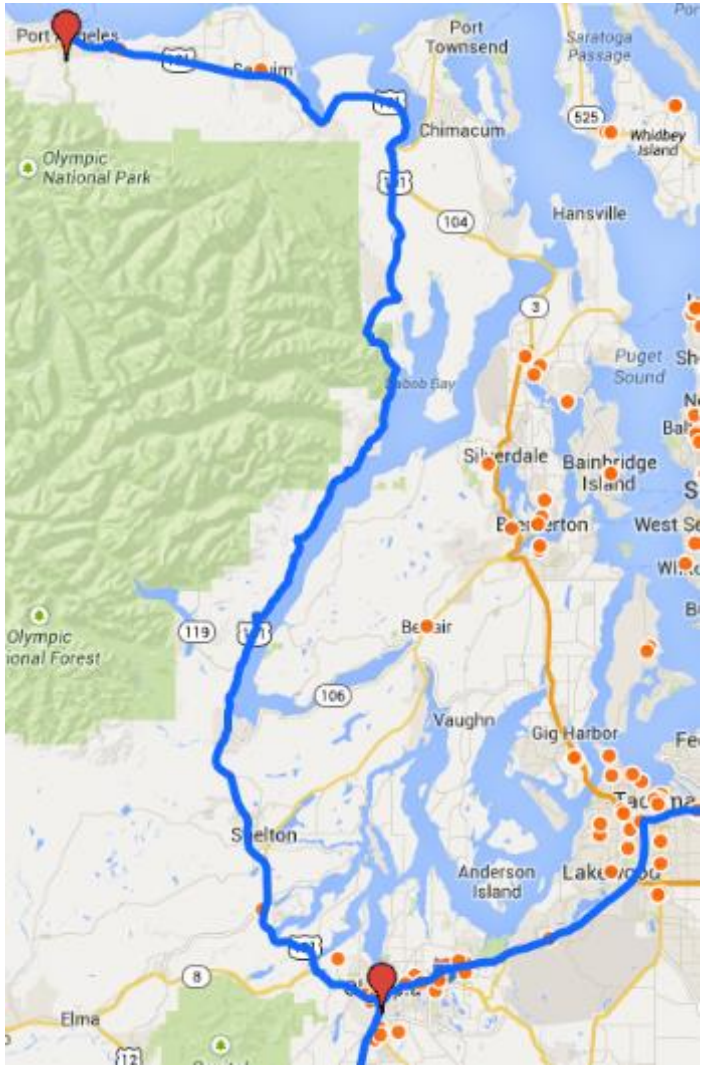
Simulation 3 Results: Seattle & Spokane along I-90

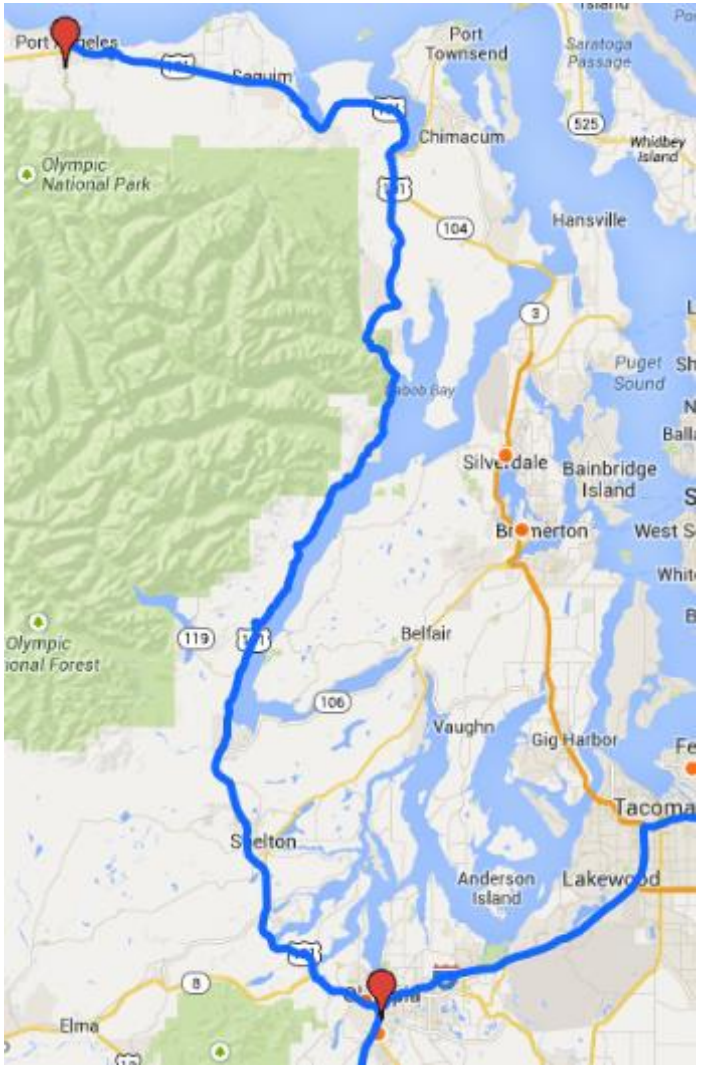
CHARGING TYPE	VEHICLE	MILES TRAVELED	NUMBER OF CHARGING STOPS	DRIVE TIME (MIN)	CHARGE TIME (MIN)	TOTAL TIME (MIN)
N/A	Gasoline Powered	173	N/A	170	N/A	170
DC Fast Charging	BEV-80	X	X	X	X	X
DC Fast Charging	PHEV-40	X	X	X	X	X
AC Level 2	BEV-80	X	X	X	X	X
AC Level 2	PHEV-40	X	X	X	X	X

Simulation 3 Results: Seattle & Spokane along I-90

- **Public charging infrastructure is not in place to fully complete travel between Seattle and Spokane in any simulation**
  - Higher concentration of public charging stations along western half of preferred route versus the eastern half
- **Lack public charging stations in eastern half of preferred route prevents an EV from completing trip**
- **Additional public charging stations are needed between Ellensburg and Spokane to facilitate EV travel between Seattle and Spokane**
  - As least 3 DC fast charging spaced at least 60 miles apart
  - 5 AC Level 2 charging stations spaced at least 35 miles apart

Simulation 4: Olympia & Port Angeles along US-101





Simulation 4 Results: Olympia & Port Angeles along US-101N

CHARGING TYPE	VEHICLE	MILES TRAVELED	NUMBER OF CHARGING STOPS	DRIVE TIME (MIN)	CHARGE TIME (MIN)	TOTAL TIME (MIN)
N/A	Gasoline Powered	120	N/A	137	N/A	137
DC Fast Charging	BEV-80	X	X	X	X	X
DC Fast Charging	PHEV-40	X	X	X	X	X
AC Level 2	BEV-80	X	X	X	X	X
AC Level 2	PHEV-40	X	X	X	X	X

Simulation 4 Results: Olympia & Port Angeles along US-101N

- **Public charging infrastructure is not in place to complete travel between Olympia and Port Angeles using US-101N in any simulations**
  - Alternate routes are possible
  - Public charging stations are concentrated around Olympia along preferred route
- **Additional public charging stations are needed between 100-mile stretch road between Port Angeles and Shelton**
  - At least 2 DC fast charging stations and 2 AC Level 2 charging stations are necessary to facilitate travel for an EV along US-101N

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