WYOMING INTERCONNECTED ELECTRIC VEHICLE NETWORK STUDY

DECEMBER 2020

PREPARED FOR:

WYOMING DEPARTMENT OF TRANSPORTATION

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1 EXECUTIVE SUMMARY

Battery electric vehicle (BEV) use is growing rapidly worldwide. Differences in geography, investment, and public policy have resulted in widely varying adoption rates among nations and states, but everywhere the trend is up. Over the previous year ending in June, Wyoming had the sixth lowest BEV market share among the 50 states and D.C. This is no coincidence: until recently most EVs were compact commuters with a sub-100 mile range, poorly suited to the state's vast distances and extreme weather. Now every automaker is producing or soon launching long-range vehicles including not only cars, but also all-wheel drive SUVs, vans, and pickup trucks, as well as medium and heavy-duty vehicles. The performance of this new generation of electric vehicles will be a game-changer for interest and adoption in Wyoming and beyond.

Now that EVs are ready for Wyoming, it is time to prepare the state's highway corridors for EVs. Comprehensive high-speed charging is needed to support anything more than local trips. Wyoming's participation in the Federal Highway Administration's Alternative Fuel Corridors Program and the 8-state *Regional Electric Vehicle Plan for the West* MOU sets the foundation for this undertaking. In support of the goals outlined by these efforts, the Wyoming Department of Transportation convened this project team to explore what is necessary to enable convenient EV travel along major routes in the state.

This study's approach is pragmatic with each step informing the next:

- Set today's baseline
- Establish minimum standards at the station and site level to ensure basic functionality
- Reach beyond minimums to optimize the driver experience and long-term value of the infrastructure investment
- Propose and prioritize specific geographic target zones for charging along each designated route
- Estimate conceptual station budget ranges based on minimum and reach configurations
- Build a phased program budget based upon proposed target zones and estimated station costs
- Identify potential opportunities for partnerships and funding support

Deploying charging across America's highways is a huge undertaking. One recent report found that between government, utilities, and private companies, over $4.8 billion has been invested or committed to public EV infrastructure in the U.S.[1], and this is just the start. While the estimated cost range for corridor electrification in Wyoming is more modest, the state has seen little investment to date and committed capital will not be sufficient to meet state goals. Beyond dollars, suitable real estate and reliable station operators will be needed. Success will depend upon collaboration and partnerships. No single entity will be able to implement this full vision, so this plan focuses on recommendations that encourage consistent coverage and a high-quality driver experience in a collaborative, multi-provider ecosystem.

2 INTRODUCTION: BACKGROUND & GOALS

2.1 STATE COMMITMENTS

The state of Wyoming has thus far participated in two major related programs that promote electrification of its highways: The Federal Highway Administration's (FHWA) Alternative Fuel Corridors Program, and the "REV West" MOU with seven neighboring western states. These efforts focus on the same primary corridors within Wyoming. This report is in service of the goals established by both.

In 2017 WYDOT applied for designation of Wyoming's interstates as "EV Corridor-Pending" under the FHWA's Alternative Fuel Corridors Program Round 2. This program was created under the direction of Section 1413 of the Fixing America's Surface Transportation (FAST) Act. Wyoming's designation included I-80, I-25, and I-90 for their entire lengths within the state of Wyoming. Per the FHWA definitions, "corridor-pending" indicates public DC fast charging more than 50 miles apart, at sites no greater than 5 miles off the highway. The more stringent "corridor-ready" designation requires public DC fast charging stations separated by 50 miles or less, no more than 5 miles off the highway, and providing both CCS and CHAdeMO connectors. Tesla charging stations utilize a proprietary connector serving only their vehicles, thus are not considered "public" for FHWA corridor purposes[2].

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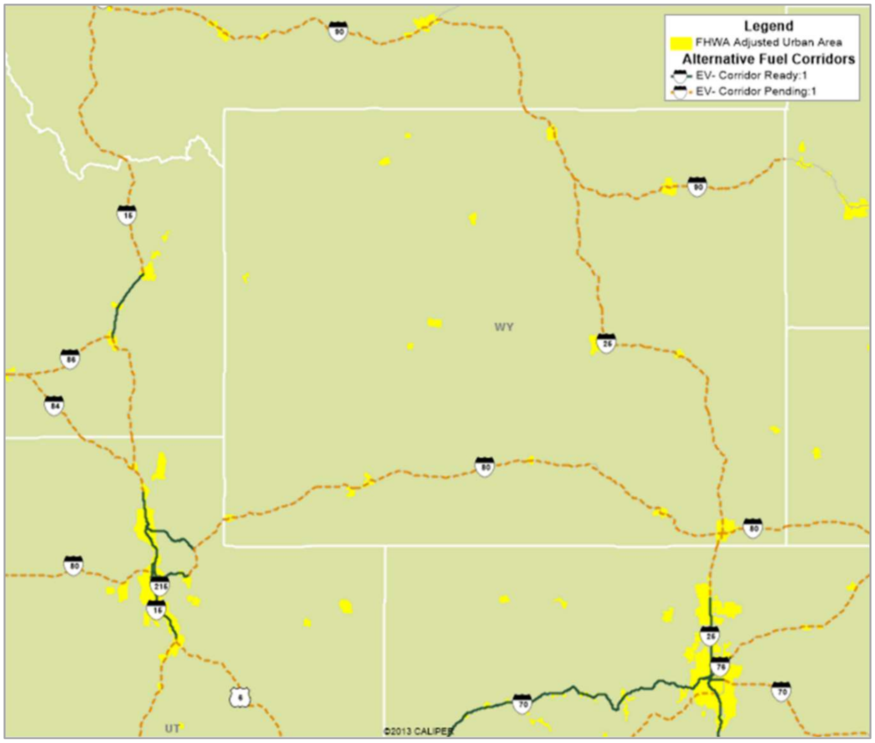
[1] Conner Smith, Investment in Public EV Charging in the United States, Atlas Public Policy, 2020, https://www.atlasevhub.com/wp-content/uploads/2020/02/Investment-in-Public-EV-Charging-in-the-United-States.pdf

[2] https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/resources/faq/#s4



FHWA EV Corridor Status, as of Oct 2020[3]

Note: Full-size versions of all maps are supplied in the Appendix.

In coordination with and in support of the FHWA corridor designation, Governor Mead joined the governors of Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, and Utah to sign the October 2017 *Regional Electric Vehicle Plan for the West*, or "REV West" Memorandum of Understanding[4]. This agreement simply stated the signatory states' desire to coordinate and collaborate for mutually beneficial corridor electrification projects in order to, "make it possible to seamlessly drive an electric vehicle across the Signatory States' major transportation corridors." The same corridors submitted for FHWA "EV Corridor-Pending" – all interstate highway segments within Wyoming – were specifically listed on the MOU, in addition to segments in adjoining states. While non-binding, this agreement recognized the interconnected nature of the participating states' transportation systems and the unique geographic challenges to EV corridor deployment in the largely rural Intermountain West. One principal outcome of this collaboration was outlining a suite of voluntary minimum standards (discussed in detail in a subsequent section). In December of 2019 Governor Gordon and Governors of the other participating states reaffirmed their commitment to the REV West goals by signing an updated

[3] https://hepgis.fhwa.dot.gov/fhwagis
[4] https://www.naseo.org/Data/Sites/1/revwest_mou.pdf

MOU[5]. This regional collaboration is already inspiring significant infrastructure development in the region, and this report will help support Wyoming's contribution under this effort and the FHWA's Alternative Fuel Corridors Program.

2.2 CURRENT STATUS OF EVS AND CHARGING IN WYOMING

Wyoming currently trails neighboring states in both EV adoption and charging infrastructure availability. The two are interdependent: consumers are reluctant to purchase electric vehicles when they do not see infrastructure in their communities and along their regular routes, and charging operators are reluctant to invest in infrastructure when there are not yet sufficient vehicles in a market to promote economic utilization rates. Electric vehicle and charger capabilities have also hampered adoption in Wyoming until very recently. In short: Wyoming is a big state with long distances separating population centers. The first generation of EVs and chargers was not well suited to the challenge, but EV technology is finally ready for Wyoming with longer ranges and faster charge times. Now it is time to jump start electric transportation in the state.

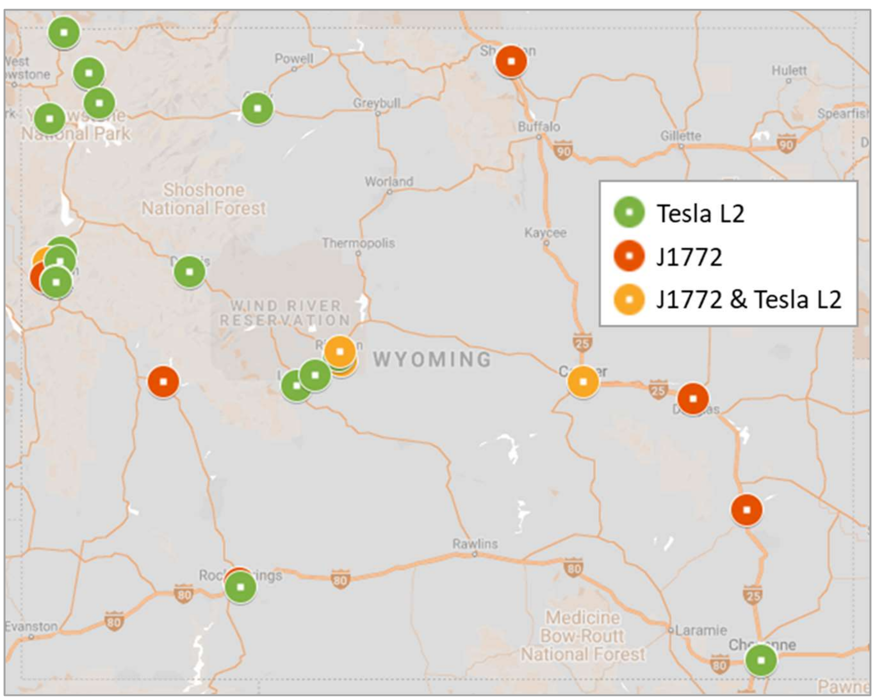
Electric vehicles are just beginning to take off in Wyoming. From 2011 through June 2019 Wyoming had the second lowest total BEV sales among all states. For the rolling year ending June 2019, the state had the sixth lowest BEV market share at just 0.29% of new sales[6]. For comparison, over the same period California leads with 5.73%, while four REV West states (Colorado, Arizona, Nevada, Utah) are in the top 12 nationally with 1.5-2.5% of new sales. Encouragingly however, compared to the previous year Wyoming's market share nearly doubled in the year ending in June 2019. 2018 annual sales exceeded the total BEVs sold in the previous five years, and the first six months of 2019 did so again. All indications point toward rapid growth of EV ownership nationwide and in the Intermountain West, encouraged by several recent developments.

Until recently most EVs available in the US were 2WD compact commuters offering less than 100 miles of range. The exceptions offering range approaching that of conventional vehicles were expensive luxury cars, out of grasp for many consumers. Since the first mainstream EV – the Nissan Leaf – launched ten years ago, battery cost reductions have enabled much greater range. Now every major automaker has released or announced EVs with vastly improved capabilities. This new generation of EVs features 200 to 400 miles of range and significantly faster charging rates – both essential to enabling long distance trips. Beyond driving range,

[5] https://www.naseo.org/Data/Sites/1/revwest_mou_2019_final.pdf
[6] https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/

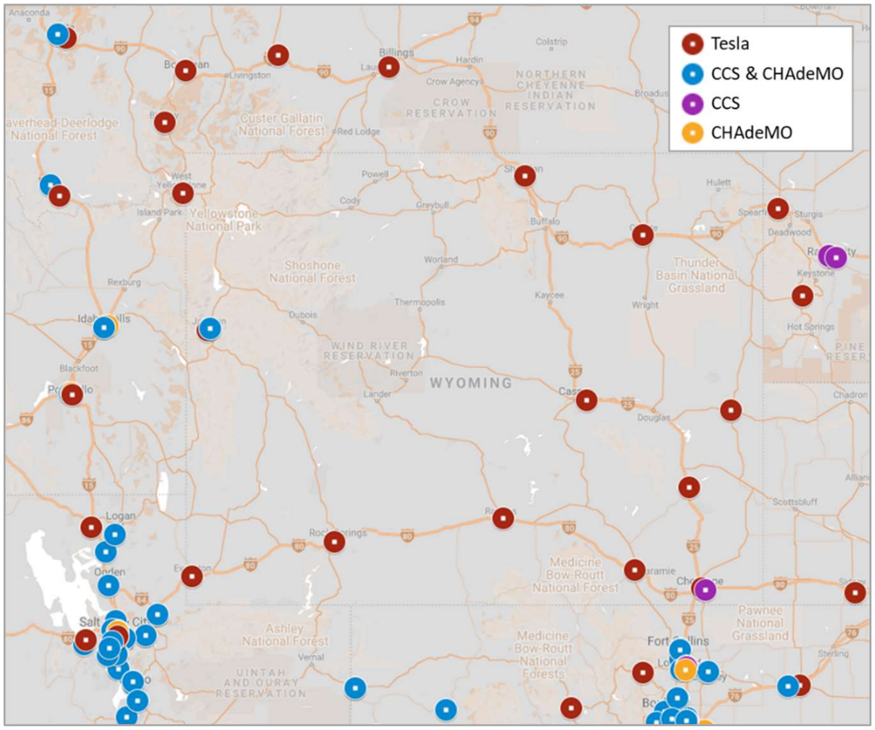
manufacturers are now offering a variety of vehicle types to suit the spectrum of consumer preferences and usage needs: over 200 different EV models have already been announced for sale by 2025[7]. This includes larger sedans, vans, and critical to adoption in the Intermountain West, all-wheel drive CUVs, SUVs and even pickup trucks. At least eight manufacturers have announced electric pickups for introduction in 2021-2022.

Parallel to improvements in EV driving range, DC fast charging has made a step change in the past several years. Early fast charger deployments from 2011 to 2016 were capable of up to 50 kW peak output – great for a top up while shopping in a metro area, but too slow to make long road trips practical. While 50 kW chargers are still being deployed, and are ideal for certain applications, the focus has shifted to higher power for corridors. This increase in power – to 100, 150, and even 350 kW charging – enables large-battery long-range EVs to fill up and get back on the road quickly. Essentially, the larger the battery, the higher charger power is needed to maintain the same charging session duration. The longer the road trip, the more charging speed matters (as explored in detail later in this report). Thousands of high-speed chargers have recently been installed across U.S. highways, enabling convenient road trips for EVs beyond Tesla.



Level 2 Charging Locations in Wyoming, Oct. 2020[8]

[7] https://www.iea.org/reports/global-ev-outlook-2020
[8] Map created with source data from https://afdc.energy.gov/stations/#/find/nearest



DC Fast Charging Locations in Wyoming & Surrounding States, Oct. 2020[9]

Longer range, faster charging, and expanding consumer choice will all contribute to increased electric vehicle adoption in Wyoming and across the Intermountain West. Now that EVs are ready for Wyoming, the challenge becomes getting Wyoming ready for EVs. The first priority is clear: comprehensive public charging infrastructure. When this project team convened in the fall of 2019, Level 2 charging deployments were still rare, and there was not yet a single public DC fast charging station in the entire state. Tesla's proprietary network had deployed ten stations covering I-80, I-90, part of I-25, as well as Jackson and a Black Hills connector. As of summer 2020, Wyoming's first public universal (CCS & CHAdeMO) fast charging station was placed in service in a public garage in Jackson, offering four 50 kW chargers. Tesla has also recently filled its last major gap along I-25, completing basic interstate coverage for the network in Wyoming. High Country Harley-Davidson of Cheyenne also installed a 25 kW CCS charger in support of the brand's new electric motorcycle launch. Even more Level 2 stations have been installed across the state. These are great signs of progress, but there is a lot of ground still to cover.

[9] Map created with source data from https://afdc.energy.gov/stations/#/find/nearest

2.3 BENEFITS OF ELECTRIFYING WYOMING HIGHWAYS

A coordinated corridor charging network as outlined in this report will serve multiple user groups including local, regional, national, and business.

Local: First and foremost, electrifying Wyoming highways will empower Wyoming residents, for whom it is still inconvenient to adopt EVs, by supporting their local and regional trips. While private vehicles do most charging at home, a lack of public infrastructure is consistently one of the top barriers to drivers who otherwise would consider and EV.

Regional: Electric corridors will welcome regional EV drivers traveling for work and recreation. While in 2020 Wyoming still has relatively low EV adoption, neighboring states Utah and Colorado are already well on their way with EV policies, infrastructure, and adoption. This is most advanced in the urban Front Range and Wasatch Front, but spreading statewide. As of mid-2019, over 5,000 BEVs had sold in Utah[10]. By fall 2020, Colorado had nearly 21,000 BEVs on the road[11], and the state had announced plans to reach 940,000 EVs in the state by 2030[12]. In both Utah and Colorado, state policy, utility programs, and charging network investments promote adoption, and many of these drivers will want to bring their EVs to Wyoming recreation destinations.

Cross-country: Connecting the interstates continues and enhances Wyoming's historic role linking major cross-country transportation routes from the Oregon and California Trails to the Pony Express, Transcontinental Railroad, and Interstate 80 itself. At present, there is public fast charging available along nearly all of I-80 from New York City to San Francisco, most of it built in just the last two years. The remaining gaps preventing continuous travel include a couple of segments in Nevada where development plans have been announced, and the entire state of Wyoming. This summer Electrify America announced completion of the first two coast-to-coast universal public fast charging corridors along I-15/I-70 and I-10/I-8[13]. It is time to connect I-80.

Business: Corporate fleets are beginning to electrify as more and more appropriate vehicles become available in order to realize lower total cost of ownership and environmental benefits. While much fleet charging will take place at private depot

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[10] https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/
[11] https://www.atlasevhub.com/materials/state-ev-registration-data/
[12] Colorado Energy Office, Colorado Electric Vehicle Plan, April 2020: https://drive.google.com/file/d/1-z-lNQMU0pymcTQEH8OvnemgTbwQnFhq/view
[13] https://media.electrifyamerica.com/en-us/releases/100

facilities, many fleets will rely on public infrastructure when their vehicles need to make longer trips. There are active fleet electrification programs in both Utah and Colorado, as well as efforts supported by groups like Clean Cities in Wyoming. Note this study focuses on infrastructure for light duty vehicles; medium and heavy-duty vehicles will need dedicated infrastructure.

Electric vehicles are now capable of long-distance trips and drivers do not want to be limited by a lack of charging. Fortunately, the same infrastructure can meet the needs of all four categories. This plan serves local, regional, and long-distance EV trips throughout Wyoming.

Beyond the local, regional, and national transportation benefits, there are significant potential health and economic advantages to enabling electrification in the State of Wyoming. While evaluating these benefits is outside the scope of this effort, a recent report by the American Lung Association included state-by-state estimates for the year 2050. According to this report, electrification of transportation could save Wyoming over $46.5 million in health care costs, avoid 4 premature deaths and 67 asthma attacks, and prevent 252 lost work days per year[14]. The national total for 2050 was estimated at $72 billion in health care cost savings, over 6200 avoided premature deaths, over 93,000 asthma attacks avoided, and over 416,000 prevented lost work days. Accelerating the transition to electric transportation brings these economic, public health, and quality of life benefits to Wyoming residents.

2.4 FOCUS OF THIS STUDY

This report's primary goal is to evaluate Wyoming's REV West and FHWA Alt-Fuels-designated corridors and provide pragmatic recommendations for how to best meet these goals from a functional standpoint. Looking beyond the designated "Primary" corridors, WYDOT also requested analysis of key "Secondary" highways connecting the interstates to high-traffic destinations, specifically recreation areas in the northwest of the state. These additional secondary routes connect I-80 to Grand Teton and Yellowstone National Parks via US-191, US-287, and US-89, and I-25/I-90 to the parks via US-16. Considering these secondary routes is important for two reasons. First, how these routes will ultimately connect to the interstate highways is critical to planning a resource-efficient initial rollout of charging along both routes. Second, electrifying only the interstates will not serve the needs of the many drivers who use them to access the parks and other recreation areas.

[14] The Road to Clean Air: Benefits of a Nationwide Transition to Electric Vehicles. American Lung Association. https://www.lung.org/clean-air/electric-vehicle-report

In terms of vehicle type, this analysis focuses on serving light duty (Class I and most Class II) Battery Electric Vehicles (BEVs), which are 100% dependent on electricity for fuel and capable of DC fast charging. Plug-in Hybrids (PHEVs) are not included because they rely on existing gas stations for long distance trips; they do not need new infrastructure for road trips and very few feature fast charging. Among BEVs, this study focuses on modern longer-range models, those capable of traveling at least 200 miles on a charge. 200-400-mile range is becoming the new standard for EVs in North America and is necessary to provide a good user experience for longer road trips due to both vehicle range and charging times. Long trips in older sub-100-mile EVs are not practical for the driving public. As such, this study is focused on enabling trips across Wyoming for BEVs with a range greater than 200 miles.

Electric vehicle charging is a very broad topic, and this report is not intended to cover every facet. Topics outside the scope of this work include but are not limited to: medium and heavy duty vehicle charging, fleet charging, home charging, multifamily residential charging, workplace charging, and the mechanics of how to administer any available funds. These topics are important to enabling EV adoption in the state, and worthy of their own focused efforts.

This report, at its core, strives to answer one key question: what basic infrastructure is necessary to make it possible for long-range electric vehicles to practically travel the major highways of Wyoming? This will include recommendations at the station/site level, as well as a suggested phased master plan, taking into account local geography and host availability. These recommendations should be viewed as the starting point – a catalyst – allowing those who already have EVs to utilize them more fully, and even more importantly, allowing potential EV drivers to imagine themselves behind the wheel and ultimately choose electric. As the market evolves and the number of EVs on the road grows, the proposed network will need to be bolstered. More locations, more chargers, and maybe new types of equipment and standards will be needed. At that point, the market can continue development and expansion to support the early movers who help bring this plan to life.

3 STATION AND SITE PLANNING

3.1 CHARGING TYPES AND STANDARDS

To discuss charging station target specifications and site selection criteria, it is necessary to establish EV charging basics. Electric Vehicle Supply Equipment (EVSE, or charging hardware) is designed to suit a wide range of situations based on available power capacity and required output, or charging speed, expressed in kilowatts (kW). This plays a major role in determining what type of charger is appropriate for a given use case based on driver dwell time, installation and operational cost, and vehicle compatibility. EVSE used in the United States can be classified in several ways.

Charging Type and Speed

Level 1 AC Charging (L1), or "trickle charging," utilizes 120V AC power, typically from a 15- or 20-amp dedicated circuit, and outputs about 1.4 kW. Many electric vehicles are sold with a portable Level 1 charger, included for home and/or mobile charging, that plugs into a standard 120V receptacle. Permanently mounted Level 1 chargers are also available for long dwell time public charging. Level 1 EVSE are typically very inexpensive to deploy per plug because the power requirements are so low; in many cases the necessary electrical circuits are already present, avoiding expensive upgrades. Charging speed, however, is slow. Level 1 adds approximately 4.6 miles of range per hour of charging. For road trips, L1's application is a last-resort emergency backup.

Level 2 AC Charging (L2) is often utilized for workplaces, multifamily housing, and dedicated home charging, as well as numerous public and retail deployments, offering moderate speed at moderate cost. Level 2 EVSE require either 240V or 208V AC power, and are offered in various power outputs, from 2.8 kW output (20 A breaker) to 19.2 kW output (100 A breaker). By far the most common, offered by all major manufacturers, are Level 2 chargers supplied by a 40 A circuit and outputting 6.2-7.7 kW (6.6 typical). This is the standard L2 charger output because it is what most North American BEVs have been designed to accept. Such a unit supplies approximately 20-25 miles of range per hour. Non-networked units simply start charging when plugged into a vehicle and collect no data, while networked chargers provide a suite of capabilities described in more detail below. As such, cost varies substantially within this category, and it is important to evaluate options carefully to ensure an apples-to-apples comparison of products and associated services. Level 2 charging is most appropriate for locations where a vehicle will remain parked for several hours. Along corridors, the best application for Level 2 charging is lodging where vehicles will be parked overnight.

DC Fast Charging enables much more rapid EV charging, in minutes rather than hours, thus extending effective range for longer trips or heavy usage. Many EV and auto industry insiders, as well as policy makers, view robust public DC charging infrastructure as one of the primary enablers of large-scale EV adoption. In conjunction with longer range EVs powered by bigger batteries, fast charging will enable EVs to serve as primary vehicles for more and more user groups. Due to the faster charging speeds and higher installation and operation costs, DC fast chargers are best for locations with short dwell times and high vehicle turnover. Examples include grocery stores, convenience stores, fueling stations, restaurants, retail centers, valet services, and more.

> *A note on nomenclature: DC fast chargers have been referred to by many names, including "DC quick chargers (DCQC)," "high-speed chargers," "super-fast," "Supercharging" (Tesla's marketing term), "Level 3," and more. In popular use, Level 3 has become very common, although technically, SAE (Society of Automotive Engineers, where the AC Level 1 and 2 designations come from, and which holds space for a future AC Level 3 designation) categorizes DC chargers separately with its own levels based on power output. For example, 50 kW chargers fall under DC Level 2. For purposes of this discussion we will use the general term "DC fast charger" to avoid confusion.*

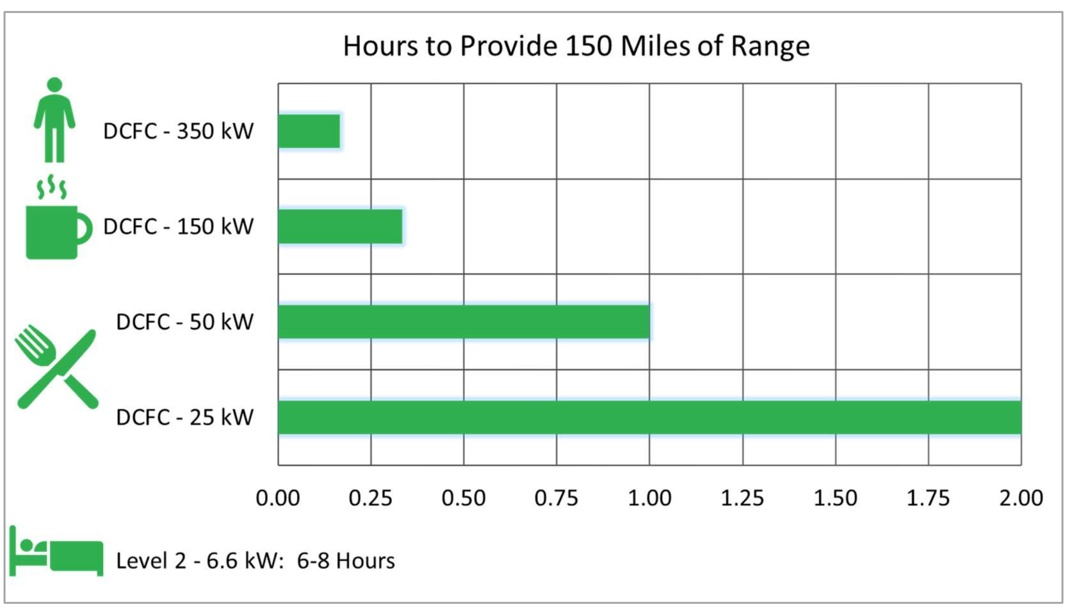
DC fast chargers work by taking an AC power supply, typically 480V but sometimes 208V, converting it to DC inside the EVSE, and supplying DC power directly to the vehicle's battery. Due to the power electronics and cooling equipment involved, DC chargers are much larger than the bollard or wall mounted Level 2 units, often around the size of a refrigerator. Higher output units often feature a modular design with separate power electronics cabinets and "dispensers" which house the connectors and user interface. DC units are available in a wide range of outputs with 25 kW, 50 kW, 150 kW, and 350 kW as common tiers. Each has cases where it is most applicable, but for highway corridors where short dwell times and high vehicle turnover are expected, the trend is toward higher power and faster speeds. While early corridor efforts utilized then-state-of-the-art 25 and 50 kW units to establish initial coverage, 150-350 kW has become the new norm for corridor charging led by large owner-operator networks such as Electrify America, Tesla, and EVgo. Fast chargers are usually deployed in a networked configuration to facilitate monitoring and maintenance but can be operated in non-networked mode if desired.

Internet speed is a helpful analogy for charging types: Level 1 is dial-up, Level 2 is DSL, 50 kW DC is cable, and 100+ kW DC is fiber. The table below summarizes power input required and kW output to the vehicle, as well as estimated miles of range provided per hour of charging per port (note this may represent aggregate miles provided sequentially to multiple cars for higher power chargers). This can be used for conceptual guidance regarding what type of user experience is desired or acceptable in terms of dwell time, and order of magnitude estimates of the type of utility connection necessary. Manufacturer specifications should always be referenced for actual design.

Charger Type	Output to Vehicle (up to)	Input Voltage (Typ.)	Circuit Breaker Required (Typ.)	Miles of Range per Hour (Est.)
Level 1 AC	1.4 kW	120 VAC	15 A	4.6
Level 2 AC	3.3 kW	208/240 VAC	20 A	10
	6.6 kW	208/240 VAC	40 A	20
DC Fast	25 kW	480 VAC*	40 A	75
	50 kW	480 VAC*	100 A	150
	100 kW	480 VAC	200 A	300
	150 kW	480 VAC	300 A	450
	350 kW	480 VAC	600 A (2x300 A)	1000

Note: The vehicle determines the actual charging speed within the capabilities of the charger. *Some 25 kW DC chargers are offered in 208/240 VAC and some 50 kW DC chargers are offered in 208 VAC.

Each type of charger has its place. To put charge speed in context it is helpful to think in terms of dwell time: how long will the driver want to be where the charger is located. In the context of road trips, Level 2 is most applicable for hotels and lodging, where vehicles will be parked overnight. DC output less than 100 kW may be great for places where drivers want to spend an hour or more, such as sit-down restaurants. Higher speeds, greater than 100 kW, are more in line with dwell time for fast food, coffee, and bathroom breaks. Of course, many lodging and dining locations have chosen to provide higher levels of speed to boost throughput and service.



Connectors and Vehicle Compatibility

Multiple types of EV plugs and ports are used in the U.S. (even more globally) to serve different types of charging and vehicles.

SAE J1772 – All mass market production EVs sold in the U.S. can use SAE J1772 connectors for both Level 1 and Level 2 AC charging (Tesla with adapter). This includes plug-in hybrid vehicles (PHEVs) which typically only charge with this standard, and full battery electric vehicles (BEVs) which are typically also be equipped with DC fast charging capability.

Three different connector types are used for light duty vehicle DC charging in the United States. Other standards are in use globally. Those in the U.S. market include:

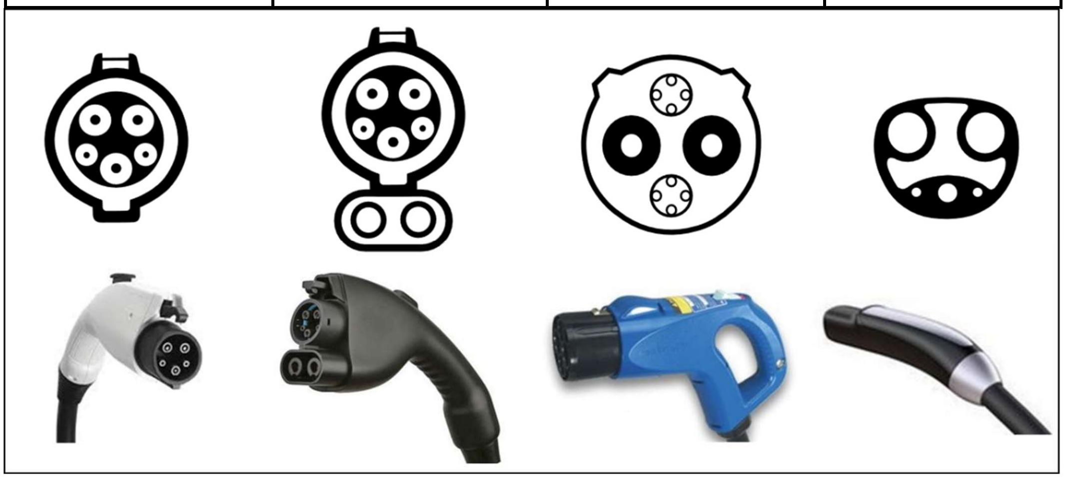
CHAdeMO – This standard was developed by Japanese automakers in partnership Japanese utility TEPCO, and was the first to see commercial deployment in the U.S. CHAdeMO was initially used by most of the Asian manufacturers, including Nissan (which has invested heavily in U.S. CHAdeMO infrastructure projects), Kia, Honda, Mitsubishi, and Toyota. Over the past several years OEM support for CHAdeMO in the US has waned in favor of the CCS standard, and now even Kia and Nissan have announced that their future vehicles offered in this market will use CCS instead of CHAdeMO. Tesla vehicles can also use CHAdeMO-equipped stations via a Tesla-supplied adapter. Vehicles equipped with CHAdeMO have two separate charging ports: one for AC and one for DC charging.

CCS Type 1 / "Combined Charging System" / "SAE Combo" – The Society of Automotive Engineers developed the CCS standard by adding DC contactors to the standard AC J1772 port and plug. This enables automakers to provide a single port capable both AC and DC charging. CCS quickly became the standard for American and European manufacturers active in the EV space including GM, Ford, Volkswagen, Audi, Porsche, Daimler, BMW, Volvo, and others. More recently as noted above, CCS has gained momentum as Asian OEMs have switched from CHAdeMO. CCS currently serves the most makes and models for sale in the US.

Tesla – In the U.S., Tesla uses its own proprietary connector for both Level 1 and 2 AC as well as DC fast charging, AKA "Tesla Supercharging." In Europe and China, regulators have required Tesla to equip its vehicles with the prevailing regional standard connectors. Tesla sells its own proprietary Level 2 EVSE for home and public destination use. Tesla continues to expand its DC Supercharger network, enabling Tesla drivers to fast charge along freeways and in cities nationwide at speeds of up to 72, 150, or 250 kW depending on configuration. Tesla drivers can charge at non-Tesla public stations by using Tesla-supplied adapters. The Tesla-to-J1772 adapter is supplied with each vehicle. The Tesla-to-CHAdeMO adapter is sold as an accessory.

EV Plugs and Ports in the U.S.

SAE J1772	SAE CCS Combo (Type 1)	CHAdeMO	Tesla
AC Level 1 & 2	DC Fast (AC L1&2 same port)	DC Fast	AC Level 1 & 2 DC Fast
Universal (Tesla w/ adapter)	US, European, now Asian OEMs	Orig. Asian OEMs, shifting to CCS (Tesla w/ adapter)	Tesla



Universal public DC fast charge stations, the focus of this study, will use CCS and CHAdeMO. Note that many DC charging stations can be equipped with dual connectors to serve both CCS and CHAdeMO vehicles (typically one at a time, some simultaneously). It is usually possible to change from a CHAdeMO cable to a CCS cable with a service call if necessary.

Networking

EVSE of all types (L1, L2, DC) can be non-networked or networked, sometimes colloquially referred to as “dumb chargers” and “smart chargers.” Networked smart chargers provide an ever-growing array of features and functions to optimize charger operations and management and enhance the driver experience. In many applications, networking is required to facilitate management and access of shared infrastructure. Still, there are some situations where a dumb charger might be a smart choice. Most Level 1 EVSE are non-networked, most DC units are networked, and Level 2 is widely deployed in both configurations.

Non-networked EVSE are very simple and easy to use. Drivers do not need any radio-frequency identification (RFID) cards, apps, memberships, or other access credentials. The driver plugs in, and the charging session begins. Most units use LEDs to visually indicate status such as power available, charging status, and errors. Non-networked hardware is less expensive and requires no software. Its simplicity can reduce maintenance issues and replacement cost. On the downside, no data is collected or shared with station operators or drivers. This may be fine for home use, or some commercial applications, but is not ideal for shared public infrastructure.

Networked EVSE connect to cloud-based management systems, and frequently mobile driver apps. This Internet of Things (IoT) functionality augments charging with an array of advanced features. For operators, this functionality can involve proactive monitoring and remote troubleshooting to support maintenance efforts and uptime, payment collection, energy management such as demand response, driver account management, environmental and incentive reporting, and much more. For drivers planning trips and even on the road, smart chargers can provide current pricing, performance capabilities, and above all locating stations and operational status (which units are available, in use, out of service, etc.). Many systems also now display real-time charging session status including elapsed time, cost, energy dispensed, vehicle state-of-charge, plus alerts for completion and errors. Network connections can be provided via cellular modem, hardwired ethernet, or Wi-Fi. Many operators choose cellular modems, which carry an ongoing cost, but can offer better reliability and reduced IT security risk through isolation from host IT systems.

With this grounding in the basic EVSE segments, the focus for purposes of this highway corridor study is:

- DC Fast Charging, 50 kW or greater, 150 kW or greater preferred
- Brand-agnostic public plug standards CCS Type 1 and CHAdeMO
- Networked "Smart" EVSE

3.2 CONCEPTUAL STATION SPECIFICATIONS

An ideal charging station design includes not only equipment, but also optimizes accessibility, reliability, and the driver experience. FHWA Alt Fuels outlines basic requirements, and REV West developed a broader set of "Voluntary Minimum Station Standards."[15] As a signatory of the REV West MOU, these form the foundation of Wyoming's station specifications. Beyond these Alt Fuels and REV West targets, additional features are suggested to improve upon the baseline where possible and anticipate future needs. Setting minimum as well as reach standards for station characteristics is important because it informs and guides identification of potential host sites (real estate requirements) and encourages station developers to provide a consistent user experience even if individual stations are owned by separate parties.

While the FHWA Alt Fuels standards are exacting when it comes to spacing between stations, they are less so regarding station performance. "Corridor-pending" simply requires "Public DC Fast Charging" without reference to plug type, kW output (speed), or number of vehicles served. "Corridor-Ready" requires each site to provide both CCS and CHAdeMO connectors[16], but does not specify output/speed and number of vehicles. There are designated corridors where segments are served by stations that provide a single plug, single standard, and a maximum charging speed as low as 25 kW. While this level of service makes EV road trips technically possible, it does not provide enough speed and convenience to inspire mass market adoption (see example in section 4.2).

REV West, while voluntary, encourages deployment with a more holistic approach, touching on the user experience and an element of future planning. REV West wisely recognizes, "Across the Intermountain West, conditions may exist at some potential locations that limit application of all minimum standards or lack the amenities found in more populated areas." It suggests that when such conditions exist, a deployment strive to meet as many of the recommended elements as possible. The REV West standards represent a good baseline from which to optimize. The following table synthesizes the REV West minimum and stretch standards

[15] https://www.naseo.org/Data/Sites/1/revwest_volminimumstandards.pdf

[16] Note rounds 1-3 of Alt Fuels designation accepted "Corridor-Ready" proposals where a single plug standard was served. Round 4 added the requirement to provide both, but did not revoke status previously granted.

(paraphrased or quoted), and augments them with additional recommendations and commentary.

Proposed Station Specifications

RWM: REV West Min, RWS: REV West Stretch, WYS: Wyoming EV Study Stretch

Accessibility • RWM: ADA-compliance with wheelchair accessibility • WYS: Provide at least 1 van-accessible charging stall with equipment design and placement, parking stall, and loading zone meeting current ADA standards. Where possible it is advisable to provide a path of travel nearby amenities. Note in most states thus far the norm has been to provide a stall built to accessible standards, but not to designate or sign it "ADA only" because charging resources are limited. Suggested best practice is for the ADA-capable stall to be signed to the effect, "Accessible stall, please use last" to encourage keeping it open for those who need it as much as possible while maximizing available EV infrastructure.
Charger Power Output • RWM: 50 kW • RWS: 150 kW • WYS: 150 kW is the functional minimum to facilitate general public road trips and should be standard. Higher power e.g. 350 kW (or a planned upgrade path) is desirable to meet the needs of future vehicles, especially including larger models such as pickup trucks and vans.
Charger Plug Type • RWM: Dual Protocol, at least one CHAdeMO and one SAE CCS plug • RWS: Two or more of each • WYS: CCS for all chargers, CHAdeMO option for at least one. Despite CHAdeMO's early lead among US fast charging standards, automaker support has rapidly shifted to the SAE CCS standard. Recently only Nissan and Kia were still producing CHAdeMO-

equipped vehicles. Since the REV West Standards were released, Nissan[17] and Kia[18] both announced that their upcoming US EVs would use CCS. Recent deployments of CCS fast chargers in the US have also outpaced CHAdeMO. Most CHAdeMO vehicles on the road are shorter range legacy models, not ideal for road trips. Support should still be provided at each station, but is not necessary on every charger.
Number of Chargers / Vehicles Served Simultaneously • RWM: One fast charger • RWS: Two or more fast chargers • WYS: For corridor reliability, two should be considered the minimum. Most commercial developers are deploying 4-8 along rural corridors[19], and more along higher traffic routes. Either providing more than two initially (especially on interstates and at junctions) or building with a planned expansion path is strongly recommended. In addition, it is worth recognizing that equipment architecture allows some "single chargers" to serve multiple vehicles simultaneously, but this is not the norm.
Charger Design • RWM: Designed for safety, durability, and all anticipated operating conditions. Third-party certified by Underwriters Laboratories, National Electrical Manufacturers Association, etc. • WYS: In addition to UL and NEMA certification, given Wyoming's extreme weather conditions, specific attention should be paid to rated operating temperature and altitude limits. Utilizing equipment with a proven track record in cold snowy climates is recommended.   ○ Temperature: The high side should not be an issue, as most Level 2 and DC EVSE are rated to 122° F (although there are outliers). On the low end, ratings typically vary between 14° F and -31° F (sometimes stock, sometimes as a special factory option). -22° F and -31° F are common design points that could be selected. Consider site historical temperatures. Note: certain units achieve

[17] https://www.greencarreports.com/news/1128891_nissan-s-move-to-ccs-fast-charging-makes-chademo-a-legacy-standard
[18] https://electrek.co/2018/11/29/kia-2020-soul-ev-battery-pack-range/
[19] Note Tesla's stations in Wyoming typically provide 8 chargers along interstates, 4 on secondary routes.

temperature rating via deration, i.e. reducing power output to the vehicle; confirm details with each prospective vendor.

- Altitude: For DC fast chargers, altitude is significant due to cooling requirements. As altitude increases, air density, and its heat capacity, decreases. This causes electrical components to operate at a higher temperature, while also reducing the effective capacity of an air source cooling system. A DC charger installed above its altitude rating may exhibit symptoms such as nuisance shutdowns, electrical component failures, and shortened service life. It is paramount to select equipment designed to operate at the proper altitude. DC fast chargers on the market can generally be divided into the following altitude classes: under 3280 feet (inappropriate in Wyoming), under 6000-6500 feet (useful in many Wyoming locations), and under 9000+ feet (suitable for any foreseeable installation in the state). Note: certain units achieve altitude rating via deration, i.e. reducing power output to the vehicle; confirm details with each prospective vendor.

- NEMA: The National Electrical Manufacturers Association provides standards for electrical enclosures in the U.S. EV charging equipment to be installed outdoors should carry at least a NEMA 3R rating, which indicates a degree of protection against access to hazardous parts, falling dirt or debris, ingress of falling water (rain, snow, or sleet), and damage due to the formation of ice on the exterior of the enclosure. NEMA 4 adds protection against sprayed water, though is somewhat rare for EV chargers. NEMA 3, 3X, 3S, or 4X enclosures would also be acceptable, but in practice are not commonly available.

Networking

- RWM: Connected to a network. Networking protocol should be open and non-proprietary.
- RWS: Capable of collecting and reporting on data related to station usage.
- WYS: Data capabilities should go beyond reporting usage and also include: real-time station status (available, in-use, out of service, etc.) broadcast to apps and in-car navigation systems, monitoring for maintenance, payment processing, etc.

Customer Communications • RWM: Cell service or free Wi-Fi available to customers • WYS: Note this is critical for customers using mobile app payment/activation functions, reporting outages, and safety.
Payment • RWM: Support multiple payment options, including but not limited to credit card, app-based mobile payment, subscription services, chip and pin, or vehicle-based payments. • WYS: Note stand-alone chargers, not part of a large national owner-operator network, may not offer subscription services which should be considered optional. Vehicle-based payments should conform to the ISO 15118 “plug and charge” standard or emerging wireless charging and communication standards.
Signage • RWM: Highway signs indicating station location, and parking spaces signed “EV Charging Only.” • WYS: In addition to station location, long gaps will persist in Wyoming’s network so it would be helpful to provide signage indicating the distance to the next station. This applies to both the highway (similar to the “no gas next 60 miles” style signs, and also at the station where the user would be informed “95 miles east to next charging station, 65 miles west to next charging station.”
Uptime • RWS: Uptime requirement for station owners/hosts of at least 97%. • WYS: Uptime can be determined based on connectivity (i.e. is the charger communicating to the network) or ability to charge (i.e. is the charger working). A charger can have one without the other. Often when networks report uptime the number quoted relates connectivity. This should be understood to encompass both.

Customer Support • RWS: 24/7 customer support either on-site or via toll-free telephone number clearly posted near charging equipment. Support should be capable of providing or dispatching service to address customer concerns at the station including rebooting if necessary. • WYS: 24/7 customer support should be a minimum for all stations for both convenience and safety. Key support includes the ability to initiate a charging session remotely in the event of component failures such as touch screens or credit card readers in order to avoid stranded drivers. In addition to a support phone number, all EVSE should be labeled with a unique identifier visible when powered off to facilitate issue reporting.
Maintenance • RWS: Proactive station monitoring which enables charging station service providers to repair faulty equipment before a customer submits a complaint. • WYS: Charging stations are vital for EV drivers. Proactive monitoring and dispatch service should be standard. Station owner-operators should have a maintenance contract in place providing for timely preventative and corrective maintenance.
Future Proofing • RWS: 1) Include larger or additional concrete pads, transformers and other utility-related equipment, and larger and/or additional conduit to avoid having additional construction and conduit costs in the future. 2) Sufficient real estate for the addition of future DC fast-charging stations, ideally enough space to double the initial installed capacity. 3) Placed in locations where they can be expanded to accommodate increasing demand in the future. • WYS: While no station is ever "future proof," future planning can ensure that early investments have long-term value. Appropriate future planning steps will be site-specific but are encouraged whenever possible. Future planning breaks down into two areas:

- Upgrade planning can incorporate reserved utility and switchgear capacity, larger conduit, etc. to facilitate increasing peak charger speeds through equipment swaps or component enhancements.

- Expansion planning facilitates adding chargers to increase the number of vehicles served at a time. Expansion also benefits from reserved electrical capacity plus parking stalls and equipment areas, and also from well-placed additional conduits, pull boxes, and possibly equipment pads. In a perfect scenario it is possible to expand a station with a simple service call, requiring no new construction work, or at minimum significantly reduce cost.

Snow & Weather

- WYS: Snow, ice, and wind will be a concern across Wyoming. Charging equipment and associated parking stalls must be cleared of snow promptly to keep them open to drivers. Care should be taken to avoid damaging charging cables and other hardware. Cable management systems (such as retractors) are strongly recommended to keep cables off the parking surface, reducing risk of damage or trip hazard. It may be advisable to consider windbreaks, canopies, or other structures to shield chargers from snow buildup.

Equipment Protection

- WYS: Charging equipment should be protected from vehicle impact. Bollards and or wheel stops are often used for this purpose. In snowy climates wheel stops can become a trip hazard, so bollards are preferred in Wyoming. Care must be taken with placement to avoid impacting ADA accessibility.

Equipment Layout

- WYS: Charging equipment should be laid out to serve the full range of EVs on the market, including placement and cable reach. Different manufacturers, and even different models from the same OEM, place the charge port at different points on the vehicle. Two common layouts that facilitate cable reach without damaging paint:
    - 1) Placing dispensers at the head of the parking area centered on the stripe between two stalls.

○ 2) Placing dispensers in the parking field between two parking stalls ("island configuration"). ○ In addition, parking stalls greater than the typical nine-foot width provide easier access to ports located on the sides of vehicles, especially for larger SUVs and trucks. ○ Many existing charging stations are not capable of serving vehicles towing a trailer, which will become more important with the emerging EV truck market. Another reach goal would be designing for pull-through trailer use, although this requires much more space.
Energy Impact and Storage • WYS: higher power multi-disperser charging stations can be significant power users with a spikey load profile. On-site energy storage (such as batteries) and or generation (such as solar) can help offset this impact to the grid. Implementation of or future planning for addition of these tools should be considered a beneficial stretch goal.

These minimum and stretch site specification and design elements strive to provide a consistent and reliable driver experience, as well as long-term value. For corridors, charging speed is an important factor, as are vehicle throughput and redundancy. Once stations are built, they must be well maintained and supported. Stations must serve the needs and capabilities of today's vehicles, but also be built to accommodate the many new models and types launching in the next several years. An ideal design prepares for rapid growth in EV ownership with a planned pathway for future upgrade and expansion.

3.3 SITE SELECTION CRITERIA

Well defined EV charging station specifications and scope inform site selection, which involves not just choosing a location but also determining feasibility and optimizing cost and user experience. Like station design, it involves many factors which can sometimes be at odds. The REV West Minimum Standards address several basic site selection topics, indicating their criteria should be met "wherever possible." As done for station design elements in the previous section, the list below starts with REV West minimums and recommends additional areas that should be considered when identifying and qualifying potential locations. Some of these can be regarded as functional minimums, while others are recommendations for a smooth development process or positive user experience. In some parts of Wyoming with extensive retail development there will be many viable options for successful sites. In other areas – for instance one identified fill-in zone has only a single retail establishment without 480V power – compromises will inevitably be made in order to fill the gap. Site selection considerations include the following:

Proposed Site Selection Criteria

RWM: REV West Min, RWS: REV West Stretch, WYS: Wyoming EV Study Stretch

Access • RWM: Public access 24/7.
Safety • RWM: Security cameras, adequate lighting, and an emergency shelter. • WYS: It is advisable to consider neighborhood crime statistics. Stations should be visible from public areas.
Amenities • RWM: Access to drinking fountains, bathrooms, and food or vending. • RWS: Within walking distance of full-service amenities such as local restaurants, retail shopping, or tourist attractions. • WYS: Special consideration may be given to placement in a downtown core where increased visitation may have a positive economic development impact on multiple businesses.
Access to Power • WYS: Access to the necessary class and capacity of electrical service is vital. Most often for DC fast charging this means 480 V 3 phase service, although some options for 208 V 3 phase chargers do exist, as well as medium voltage connection. Capacity and timeline should always be confirmed with the utility provider.

Utility Rates • WYS: In most cases the utility provider is determined by geography, but in some instances at service territory boundaries there may be an operational expense impact to siting in one or another. In addition, at some sites it may be possible to connect via existing host power supply or an aggregate meter. This can reduce demand charges, but becomes less likely with larger higher power stations.
Buildability • WYS: Construction feasibility and potential cost must be considered. Cost can vary substantially between two sites next door to each other due to any of the following: distance to utility point of connection, slope, existing condition of parking, utility conflicts and easements, soil and excavation conditions, and many other factors.
Zoning & Permitting • WYS: Local permitting, planning, and zoning requirements may impact charger siting. Typically, public charging is deployed in areas zoned for commercial use. Special considerations such as environmental or cultural review may apply at certain sites. Timing for any of these approvals can vary widely between jurisdictions and have a major impact on deployment schedule.
Visibility • WYS: Visibility is important for three reasons: 1) placing stations within the public view promotes safety, and 2) stations, or at least hosts, being visible from the primary route or major access road assists drivers in locating the station[20], 3) highly visible public charging promotes range confidence and EV adoption among drivers who have not yet gone electric.
Cellular Data Signal • WYS: Sufficient cellular data signal for charger and support operations and safety.

[20] Note typically drivers are guided to charging locations via mobile apps or in-vehicle navigation systems.

Real Estate Commitment

- WYS: Investment in chargers and supporting electrical and civil infrastructure is substantial, therefore it is desirable to make a long-term commitment to hosting a station. This is especially imperative when public funding support is involved. A host removing a station or failing to maintain it could have a hindering effect on an otherwise continuous corridor.

Corridor fast charge station design is a multivariable optimization exercise in which it is necessary to balance sometimes competing goals. As the REV West Minimum Standards sensibly recognize, there are places in the Intermountain West where insistence on inflexible rules may prohibit establishing an initial EV charging network. To paraphrase the adage, do not let the quest for perfection become a barrier to good solutions. Wyoming should take an adaptable approach utilizing the REV West Minimum Standards to ensure a consistent basic level of service EV drivers in the region can expect, while striving to provide an optimized user experience and room for growth of the market via the REV West Stretch goals augmented with the additional recommendations of this study. Wyoming could accomplish this by approving and publishing a state-specific set of standards and reach goals and recommendations that could aid those interested in developing stations. These reach goals could also be incorporated as scoring criteria if a competitive funding or incentive source were made available, and bonus funding could be allocated for sites meeting reach goals.

3.4 ALTERNATIVES FOR CHALLENGING SITES

The sparsely developed nature of large parts of rural Wyoming poses challenges for station design and site selection. It is worth exploring creative strategies for covering especially difficult zones. These solutions involve making compromises with stretch, and in some cases, minimum standards discussed above, resulting in a less than ideal user experience. The alternative, however, might be no coverage at all. As such, the following should be considered in specific geographic locations where there are significant barriers to meeting the standards as a method to provide basic range extension and back up. Such barriers and potential solutions may include:

- Lack of access to 480V 3-phase power, 208V 3-phase available
    - 208V 3-phase DC fast chargers are available from multiple manufacturers. 20-25 kW units (approx. 70-90 miles of range per hour of charging[21]) are widely available, and 50 kW units (approx. 175 miles of range per hour) are offered by several manufacturers.
    - A customer side of the meter step-up transformer may be used to convert 208V supply to 480V to power 50 kW or higher chargers. This may be acceptable for smaller installations, but there is potential to trigger a "reactive power[22]" charge depending on the utility rate structure.
- Lack of access to any 3-phase power, only single phase available
    - Level 2 chargers can be deployed in locations where only single-phase power is available, or very low capacity 208V. The downside is that they usually provide approximately 20-25 miles of range per hour of charging. This may be sufficient for emergency coverage between fast charge stations with a large gap, but is an inconvenient solution for corridor charging. The most applicable corridor use for Level 2 is overnight charging at hotels – broad availability of Level 2 at lodging would augment DC fast charger network throughput.
    - Battery-supported fast charging would be a more effective, if costlier, solution for locations where only single phase is available. The basic premise is using a single-phase supply to continually charge a battery array, which then powers a high-output DC fast charger. Such a system could offer short charging session times similar to standard high speed chargers, but would be limited in continuous peak throughput once the battery array was depleted. This disadvantage may not be significant in the early phase of adoption when overall station utilization is still low, but could eventually pose challenges. For instance, when a steady stream of EVs wants to charge back-to-back coming home from a holiday weekend. A battery-supported system like this could be implemented with separate components and custom controls, but an elegantly integrated all-in-one solution has come to market this year from FreeWire. Their new "Boost

[21] In this section miles of range per hour of charging estimates are at peak power assuming a large battery fast charging car that can take the full available input.
[22] Reactive power (expressed in kVAr on some commercial power bills) in this context is induced by powering the transformer's coils. It can be an added operational expense associated with this technical approach.

Charger” can charge one vehicle at up to 120 kW, or two vehicles simultaneously at up to 60 kW each[23], providing approximately 100 miles of range each to 6 EVs back-to-back before depleting its battery and reverting to low power output backup while it recharges. This and other innovations could be helpful in connecting difficult gaps by providing much higher levels of service and driver experience on underlying infrastructure similar to Level 2 requirements.

- Insufficient power capacity
    - Power sharing fast chargers are available from multiple manufacturers. Such equipment shares the power supply to provide high peak power output from each charging plug, while also providing a higher number of plugs than otherwise possible. For a simple example, consider a system where 200 kW was shared between two ports. It could charge a single vehicle at up to 200 kW, or possibly two vehicles either at 100 kW each or 150 kW to one and 50 kW to the other. Such a system works in part because 1) not all vehicles can take the same peak power, and 2) the fast charging speed a vehicle does take is not linear, it tapers off as the battery reaches full capacity. Power sharing attempts to make full use of the station’s available power across whatever vehicles need it at that moment. It does not provide the same consistent user experience as unitary chargers used by networks such as Electrify America and recently adopted by Tesla’s V3 Superchargers, but it does provide high speeds to the vehicles capable of using them while maximizing the number of vehicles served simultaneously from a limited power supply.
    - If supply is insufficient for standard power sharing, a battery-integrated power sharing system such as FreeWire, described above, or even a Level 2 backup, could be considered.
    - Solar plus battery systems could be deployed in instances where no power is available, but the size and cost of such a system capable of high outputs required for DC Fast Charging can be substantial. Solar Level 2 systems may be a more reasonable option for gaps requiring a backup for safety. One innovator integrating solar-powered charging is Beam Global, formerly Envision Solar, now

[23] https://freewiretech.com/products/dc-boost-charger/

offering both Level 2[24], and DC Fast Charging systems[25]. These packages have the added advantage of being rapidly deployable with limited or no construction required. Beam's fast charging system is being implemented in a pilot with Caltrans this year at a California rest area without grid connection. Of course, solar off grid solutions like this will have a limited throughput before reverting to slower charging speeds, but could provide a viable backup or network extension for challenging low-utilization zones.

  - On-site generators, powered by natural gas for instance, could be utilized to provide high maximum output and power a large number of chargers in locations with otherwise limited power availability. To maximize performance, batteries would also likely be incorporated.

- Emergency Roadside Assistance
  - SparkCharge has developed the Roadie, a portable modular DC fast charger meant for emergencies[26]. This product is basically a jerrycan for electric vehicles, providing a boost for empty batteries. Roadside service providers equipped with a product like this could assist drivers who made a mistake or encountered unusual conditions.

The Electric Vehicle Supply Equipment category is rapidly developing solutions tailored to specific installation challenges, and some of the approaches described above, along with emerging and new innovations will be helpful as Wyoming connects its more remote corridors. The best solutions will be site-specific and should be considered in terms of providing the best user experience possible given the infrastructure access available.

4 ROUTE PLANNING

4.1 DESIGNATION OF PRIMARY AND SECONDARY CORRIDORS

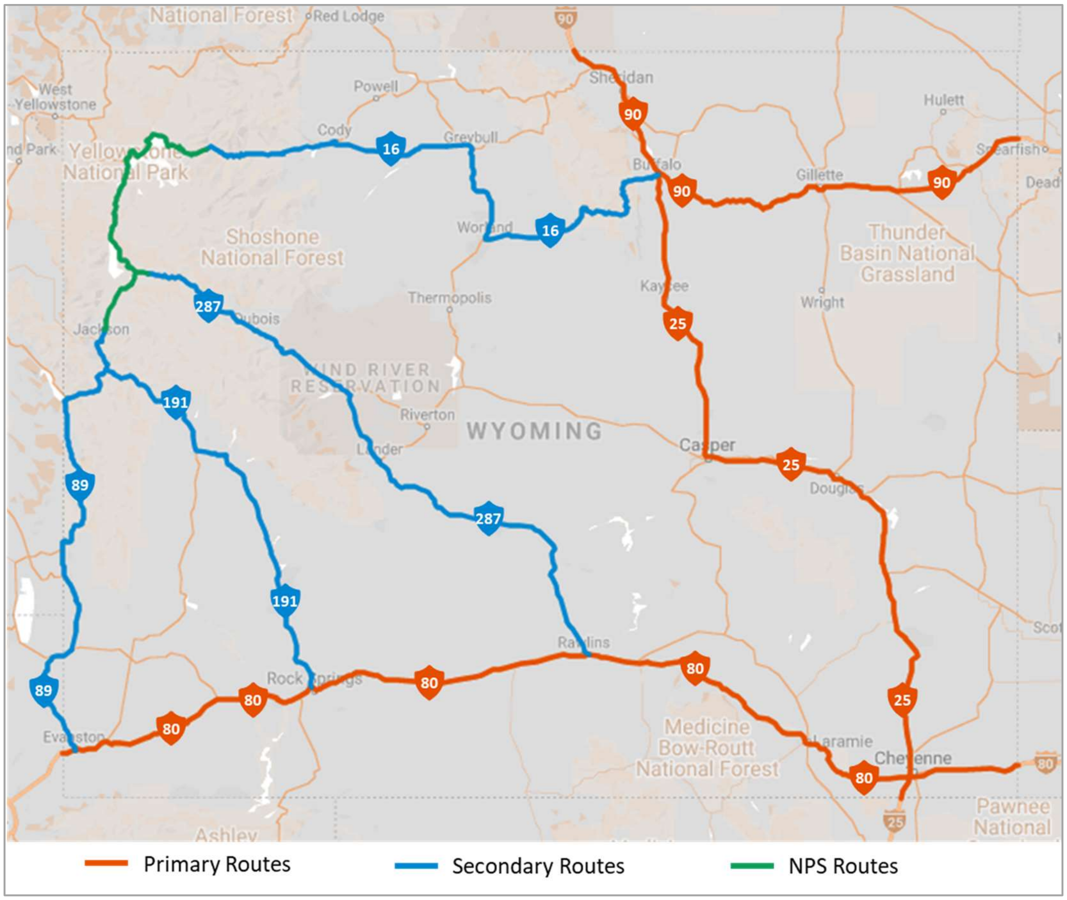
This plan builds toward coverage of Wyoming's major corridors via a phased approach consisting of Primary and Secondary corridors. In 2017 Wyoming prioritized its three interstate

[24] https://beamforall.com/product/ev-arc-2020/
[25] https://www.envisionsolar.com/envision-solar-deploys-solar-powered-ev-dc-fast-charging-for-shandon-california-rest-area-on-u-s-highway-46-east/
[26] https://sparkcharge.io/portable-chargers/?v=7516fd43adaa

corridors for electrification via both the Regional Electric Vehicle Plan for the West, also known as the REV West MOU, and application for “EV Corridor Pending” under the Federal Highway Administration’s Alternative Fuel Corridors Program. These interstates are the “Primary Corridors.” “Secondary Corridors” connecting the interstates to recreation destinations in the northwest part of the state were outlined as an additional goal for WYDOT’s 2019 RFP for this study and refined through discussions with the project team. Even if built at a later date, their inclusion informs the placement of Primary corridor stations. In addition, there are segments within Yellowstone and Grand Teton National Parks that are critical to connecting the Secondary Corridors, but outside of WYDOT’s direct scope. These will depend on coordination with the National Park Service and its concessionaires. The Corridors, totaling approximately 1850 miles within Wyoming, are as follows and shown on the included map.

- **Primary Corridors** – approximately 911 miles
    - I-80: Utah State Line to Nebraska State Line
    - I-25: Colorado State Line to termination at I-90 in Buffalo, WY
    - I-90: South Dakota State Line to Montana State Line
- **Secondary Corridors** – approximately 840 miles
    - US-16: Buffalo to National Parks
    - US-287: Rawlins to National Parks
    - US-191: Rock Springs to National Parks
    - US-89: Evanston to National Parks (32 miles of route passes through Utah)
- **NPS Corridors** – approximately 127 miles
    - US-191/89/287 & Yellowstone National Park South Entrance Road: Jackson through Grand Teton National Park to Grant Village
    - US-14/16 & Yellowstone National Park East Entrance Road and Grand Loop Road: East Entrance to Grant Village
    - Note: additional routes within Yellowstone National Park will be necessary for circulation within the park and connection to Montana and Idaho. The segments

identified above are only those necessary to connect to Wyoming's designated Secondary Routes.



Wyoming EV Network Study Designated Routes

4.2 STATION SPACING

EV corridor station spacing is a challenging topic requiring a balance of cost and user experience overlaid on specific geographic constraints. On the one hand, it would be ideal to have charging available in every town and at every exit with services. As EVs reach mass adoption, Wyoming may well get there. On the other hand, this approach is prohibitively expensive at this early phase of the EV market, and even if funding were available, it would still leave large gaps between services across the western US where there simply are no towns or service providers. To converge on a workable compromise between what is ideal and what is practicable for Wyoming it is illustrative to consider input from both the policy and EV charging network developer perspectives, as well as the user experience associated with different range vehicles and charging speeds.

Under the FHWA Alternative Fuel Corridor Program the following definitions are used[27]:

> *EV Corridor Pending:*
>
> *Public DC Fast Charging separated by more than 50 miles. Location of station/site no greater than 5 miles off the highway.*
>
> *EV Corridor Ready:*
>
> *Public DC Fast Charging, no greater than 50 miles between one station and the next on the corridor, and no greater than 5 miles off the highway. Additionally, each DC Fast Charging site should have both J1772 combo (CCS) and CHAdeMO connectors. Because Tesla stations are proprietary, we are unable to include them.*

Essentially, "Corridor Pending" is an intermediate status meant to indicate a corridor is in the planning and development stage, while "Corridor Ready" is meant to ensure continuous universal coverage, worthy of coordinated EV-specific signage. It is worth noting that the 50-mile maximum spacing for "Corridor Ready" was determined in 2016, a time when non-Tesla EVs were not typically capable of more than 100 miles of range. The same "Corridor Ready" designation for other alternative fuel types applies when stations are no greater than 100-200 miles apart depending on the fuel. Wyoming's designation of the interstates (Primary Corridors) as "Corridor Pending" is consistent with these definitions, and as shown later, achievable. WYDOT's project scope expressed the aspiration of reducing gaps to less than 50 miles in order to reach "Corridor Ready" status if possible. This study has found the 50-mile maximum spacing goal to be infeasible for Wyoming.

The REV West working group developed a set of Voluntary Minimum Station Standards to guide corridor development among signatory states. This document includes guidance that stations be located:

- *Within 50-100 miles of the next station in either direction. For distances above 50 miles, consider elevation changes or driving conditions under extreme weather to ensure standard EV batteries can make the trip on a single charge.*
- *Within one mile of a highway interchange or exit. Within 0.5 miles from a highway interchange or exit to maximize driver convenience.*[28]

[27] https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/resources/faq/
[28] REV West: Voluntary Minimum Station Standards, https://www.naseo.org/Data/Sites/1/revwest_volminimumstandards.pdf

This standard recognizes the difficulty achieving the sub-50 mile spacing suggested by FHWA in the western US where towns with services are often farther apart. It also wisely suggests placing charging closer to the primary route of travel. This is convenient and minimizes the range lost getting to and from the station. It requires a subjective judgement regarding what constitutes a "standard EV battery." This continues to be a moving target. EPA-rated ranges for BEVs on the road today vary from around 60 miles to 400 miles, and fast charging speeds from less than 50 kW to nearly 300 kW. Generally, the larger the car's battery, the faster it is possible to charge; short range EVs charge slower, long range EVs charge faster. To illustrate this variability, it is worth considering the user experience of a road trip.

Consider a hypothetical Cannonball Run-style race along I-80 from Pine Bluffs to Evanston, just under 400 miles. This does not take into consideration where it is possible to place chargers, just the minimum needs based on vehicle capabilities. There are three contestants:

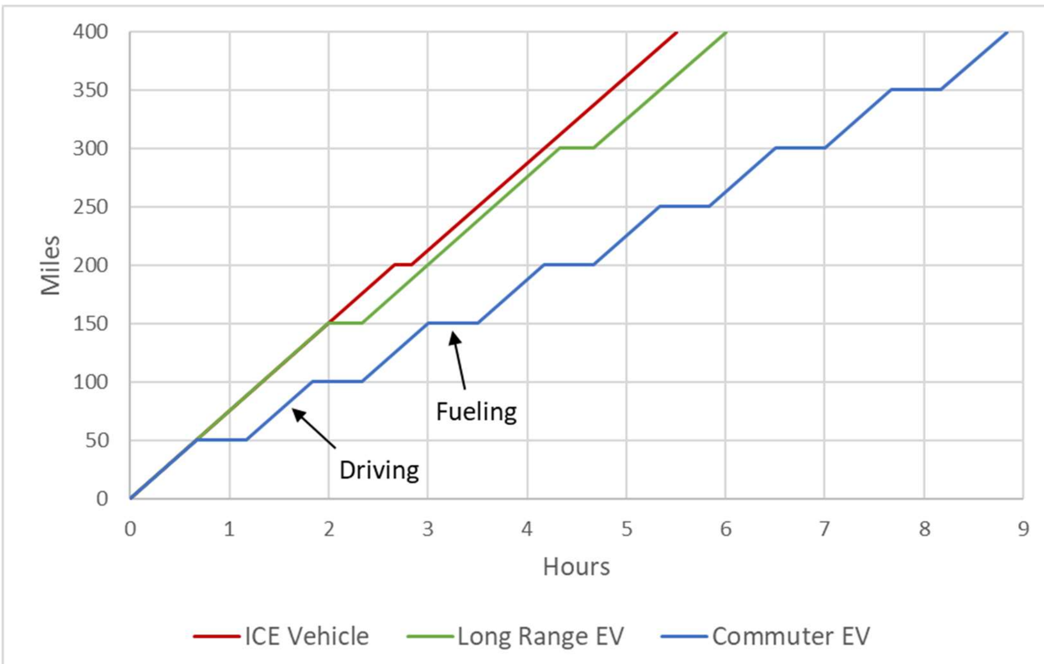
- ICE Vehicle: a typical gas-powered car (Internal Combustion Engine). For this example, consider a 300-mile range and a 10-minute fill up time.
- Legacy Commuter EV: a short range, 84-mile BEV, representative of older models still on the road. In addition to its short range, this vehicle is limited to 50 kW peak fast charging.
- New Long-Range EV: typical of those selling now and being released in the next few years. For this example, consider a 250-mile EPA-rated range and 150 kW peak fast charging.

For this highway driving comparison, all three vehicles' rated ranges have been discounted by 20% to approximate the impact of freeway speeds averaging 75 MPH, and another 20% buffer to represent the fact that drivers want to fuel well before they reach empty and EVs generally don't fast charge to 100%.[29]

[29] This example is simplistic and illustrative. Detailed modeling would take into account more variables and be calculated for specific vehicles.

This results in the following range and charging/fueling characteristics:

- ICE Vehicle: 10-minute fill up every 200 miles (2:40 hours) of driving
- Commuter EV: 30-minute charge every 50 miles (40 minutes) of driving
- Long Range EV: 20-minute charge every 150 miles (2 hours) of driving



Idealized comparison, driving and fueling time from Pine Bluffs to Evanston

The ICE vehicle is the fastest to complete the route at 5-1/2 hours with just one mandatory stop, and the modern Long Range EV isn't far behind at 6 hours and two short stops. Meanwhile, the commuter EV stops seven times and takes nearly 9 hours, spending 40% of its time charging. While some early EV enthusiasts may choose to make this compromise, most drivers will not. This example clearly shows why it does not make sense to design corridor charging for yesterday's vehicles.

In reality, these times and stops are a minimum: two factors would make the ICE and Long Range EV stop more frequently than the minimum this idealized example shows. First, the available locations of fueling infrastructure. Wyoming has long stretches of highway without any gas stations, and drivers must plan accordingly. EV charging will be the same way, and the locations of towns will to a great extent dictate where it is possible and practical to place charging stations. For the Long Range EV example, three stops of a similar total duration would be required based on the geography of Wyoming: towns just don't line up perfectly to make 2 stops possible. Second – the great equalizer – human needs. Drivers and passengers need to stop for food, beverage, stretching the legs, and of course restrooms, regardless of their vehicle's fuel type. It is likely a real-world ICE driver would have stopped more than once and for longer than ten minutes in 5-1/2 hours for food or restrooms, leveling the time. Individual habits vary, but it is reasonable that drivers would appreciate a brief break every two hours or less, lining up well with the charging schedule for the Long Range EV. This is the tipping point for the practicality of EV road trips – when the humans need to stop as often or more often than the vehicle.

Electrify America and Tesla are the two EV charging network developers who have deployed the most extensive corridors to date in the United States, and as shown by their coverage maps, they have both recognized the challenges above. In its initial Cycle 1 public plan, Electrify America stated, "Sites will be, on average, about 66 miles apart, with no more than 120 miles between stations"[30]. In their Cycle 2 plan, which both expanded geographic coverage and filled gaps in Cycle 1 corridors, Electrify America reiterated the 120-mile maximum spacing, but noted that exceptions will persist: "On rare occasions, Electrify America must extend the distance slightly beyond 120 miles to account for significant siting constraints including available real estate, utility connections, etc."[31]. Tesla is a bit harder to define as they have not published a public plan for their Supercharger network. Tesla's approach in rural regions has been to expand as quickly as possible with wide spacing, often 100-120 miles, then fill in between as utilization grows, providing backup and additional carrying capacity. At present in Wyoming the average distance between Tesla Superchargers along the interstates is 100 miles, with a minimum of 57 and a maximum of 154 miles. Non-interstate routes, such as to the parks, are longer, between 120 and 200 miles. Both Electrify America and Tesla have converged on a maximum spacing of around 120 miles, and ideally as utilization justifies, significantly less for redundancy and capacity – say 50-75 miles.

Rules are hard to enforce on specific geography, but drawing concrete examples from the two the largest corridor deployments in the U.S to date, the following goals are suggested for planning Wyoming's corridor charging locations:

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[30] Electrify America National ZEV Investment Plan: Cycle 1.
https://www.electrifyamerica.com/assets/pdf/National%20ZEV%20Investment%20Plan.3100e374.pdf
[31] Electrify America National ZEV Investment Plan: Cycle 2.
https://www.electrifyamerica.com/assets/pdf/Cycle%202%20National%20ZEV%20Investment%20Plan%20-%20Public%20Version%20vF.50bb1fe0.pdf

- **Critical buildout**: Ideally less than 100 miles between stations, exceptions up to 125 miles where necessary. This is intended to provide initial minimum corridor-enabling coverage.

- **Fill-in buildout**: reduce gaps between initial critical locations. Gaps of less than 50 miles would be ideal, but may not be possible in many locations. Fill-in should focus on the longest gaps, areas of highest utilization, and greatest topographic or weather impacts to vehicle range.

- **Distance from route**: Within one mile of a highway interchange or exit. Within 0.5 miles from a highway interchange or exit to maximize driver convenience. If one mile is not possible, consider exceptions up to five miles from route.

These principals are fundamentally in line with the REV West Minimum Standards and FHWA "Corridor Pending," but also incorporate learnings from Electrify America and Tesla's practical experience regarding the geographic, funding, and utilization challenges especially prevalent during the early phase of development, as well as the aspirational goals of FHWA "Corridor Ready." They provide a set of ideals flexible enough to adapt to real world conditions in order to deploy a functional network and improve it over time.

4.3 SUGGESTED TARGET ZONES

Application of the spacing principles proposed in section 4.2 to the designated Primary and Secondary corridors reveals a functional plan covering each route. This process consisted of three basic parts: 1) identify "Junctions" where two or more routes come together, 2) from these junctions strive to meet "Critical" spacing goals along primary and secondary corridors, 3) evaluate opportunities to reduce spacing with "Fill-in" locations. In addition to spacing goals, the following factors were considered:

- Focused site identification beings with a geographically defined "target zone." Within this search area, hopefully including many potential site hosts, one meeting established site criteria will be recruited to host a specific charging station. For example, Evanston is identified as a Critical target zone. It has three exits that meet spacing criteria and have multiple potential hosts including retail, thus would be considered in the target zone. Proposed deviations from target zones as laid out may be possible and desirable, for instance if an enthusiastic site partner becomes available outside a designated zone, but the impact on the corridor as a whole must be specifically analyzed. Moving a target zone may create a larger gap elsewhere that requires backfilling in order to maintain corridor integrity.

- Maintaining spacing to connections in neighboring states per REV West goals. Some connecting locations are operational, and others planned. In cases where no plan has been announced, logical connection locations have been assumed.

- Strive for placement in larger population centers with a variety of host candidates, especially for Junction and Critical zones. This increases the chances of finding an optimal partner and local utilization volume.

- Efficient use of resources to cover the routes. This will be important to realizing the vision whether funding is public, private, or from a partnership.

- Above all, for a corridor to be effective it must be continuous.

The result of this analysis is a suggested set of target zones where building high speed charging stations would enable the basic REV West goal of continuous EV travel along the corridors. These locations are not meant to be exclusive, set in stone, nor sufficient for the ultimate needs of a fully developed electric vehicle ecosystem. Rather they are the starting point necessary to enable EV drivers in Wyoming, as well as their neighbors in adjoining states, to make long distance trips across the state and encourage others to go electric.

A total of 31 target zones were included in the plan for building out geographic coverage of designated Primary and Secondary corridors. A full list of target zones by type, and distance tables detailing the gaps between target zones by route, are provided in the appendix. Target zones were categorized as follows:

Junctions (6) – There are six Junctions connecting WYDOT-designated Primary and Secondary corridors: Cheyenne, Rawlins, Rock Springs, Evanston, Buffalo, and Jackson. These should be regarded as mandatory zones because moving to the next town along either route results in unacceptably long distances on the other, and possibly on the opposite side of the same route. These are also the largest cities for some distance, and each has a relatively large number of host candidates, which should help facilitate siting. The junctions are the basis for building out both the primary and secondary routes.

Primary Critical (4) – Four more Critical zones, along with the Junctions, would provide initial coverage along the Primary interstate routes: I-80, I-25, and I-90. These locations also have a reasonable number of potential hosts. These zones would result in an average spacing along

Primary routes of approximately 83 miles, with a maximum gap of 119 miles from Buffalo to Hardin, MT (anticipated logical connector, no plans announced). The longest gap in Wyoming would be approximately 114 miles from Casper to Buffalo, and two other segments would exceed 100 miles.

Note that only one Critical station is needed, in addition to the Junctions, to provide basic coverage along I-80. This route has been identified as a focus for early efforts due to relatively high traffic volume and enabling effect for the Secondary routes. It also connects to existing operational corridors in Colorado, Nebraska, and Utah.

Secondary Critical (6) – The four secondary routes, Highways 16, 287, 191, and 89, require six additional zones for basic coverage. Each of these zones also has multiple potential hosts. The suggested zones would result in an average spacing of 89 miles along Secondary routes with a maximum gap of 125 miles from Rawlins to Lander, followed by 121 from Afton to Evanston. One to two other segments may slightly exceed 100 miles based upon final placement.

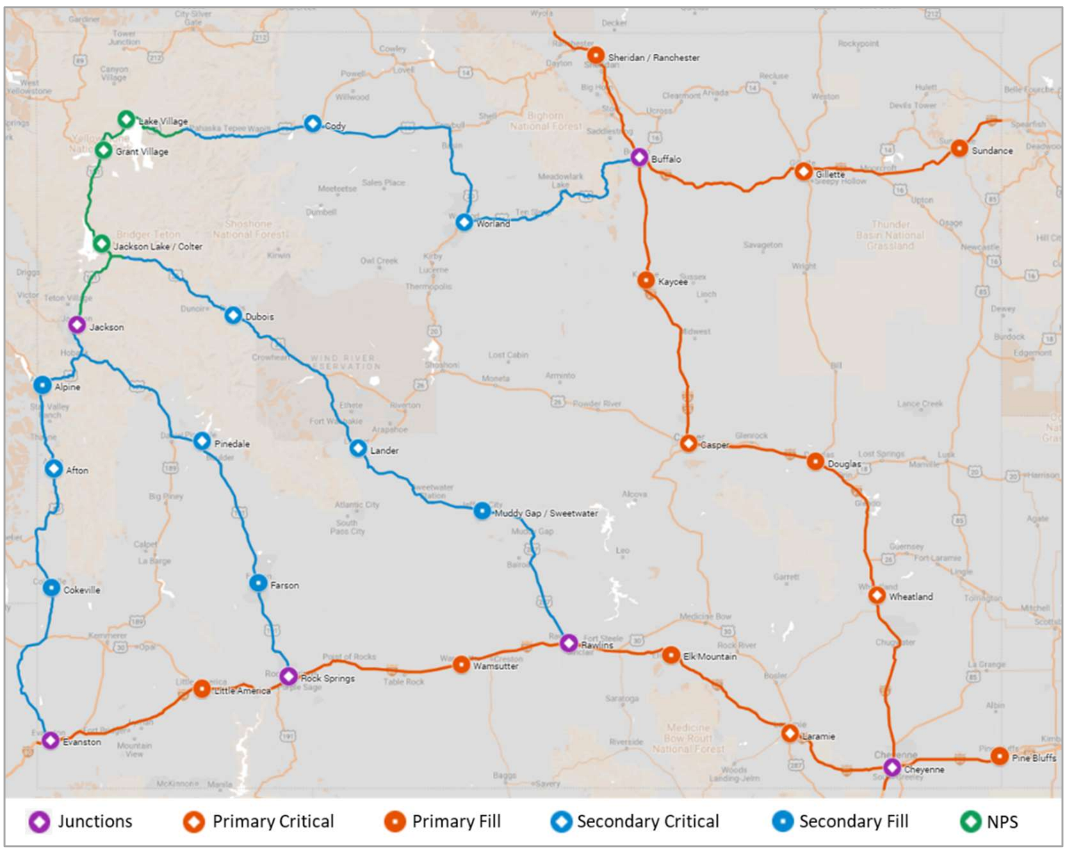
Primary Fill-in (8) – Eight zones are suggested to reduce gaps along the Primary interstate routes. Several of these are in smaller communities where host availability may be an issue: Kaycee, Pine Bluffs, Wamsutter, and especially Little America and Elk Mountain. Little America has great driver amenities but only one owner. Elk Mountain is the most challenging, as it has only one retail establishment: a gas station with single phase power. Provided all zones could be successfully filled, it would reduce the average gap across Primary routes to 52 miles, and the maximum to 84 miles.

Secondary Fill-in (4) – Four additional zones are suggested to reduce gaps along Secondary routes. Three of these are small communities with few retail options and could present challenges. Farson and Cokeville both have good but very limited site host options. The very sparse section of 287 between Muddy Gap and Sweetwater Station, including Jeffrey City, has been identified as a single zone to expand the search area. It would be ideal to add a station here, as this gap is the largest between any critical sites, but it will likely prove difficult. If the suggested Fill-in zones were added, the Secondary route average drops to 62-mile spacing, with a maximum of 91 miles.

Note: Kemmerer may be considered as an alternate to Cokeville should host acquisition prove difficult. While not on Highway 89, Kemmerer also connects Afton to Evanston, adding 26 miles to the route. It also connects Evanston to Pinedale via 189.

NPS (3) – Three additional zones within the National Parks have been identified: one in Grand Teton at either Jackson Lake Lodge or Colter Village, and two more in Yellowstone at Grant Village and Lake Village. Each of these locations has existing retail and conventional fueling. Based on distance alone, one in Yellowstone would suffice, but doing both would facilitate the type of out-and-back daytrips common for those staying in Jackson and Cody, as well as help improve capacity for peak visitation.

Note that these locations are under the direction of the National Park Service and approved concessionaires. These suggested locations are not sufficient to cover the total charging needs of the park and should be incorporated as part of a park-specific planning effort including other park destinations. They are shown here as key links connecting the WYDOT-designated corridors.



Wyoming EV Network Study Suggested Target Zones

The Junctions plus Critical zones for all corridors would produce an average gap of 86 miles range, and but with several of the longest gaps in the 114-125-mile range. Such a layout would provide initial functional coverage similar to that deployed across many rural corridors by Tesla, Electrify America, and others, and already enabling many EV drivers to make long range journeys. It would not, however, meet programmatic distance goals.

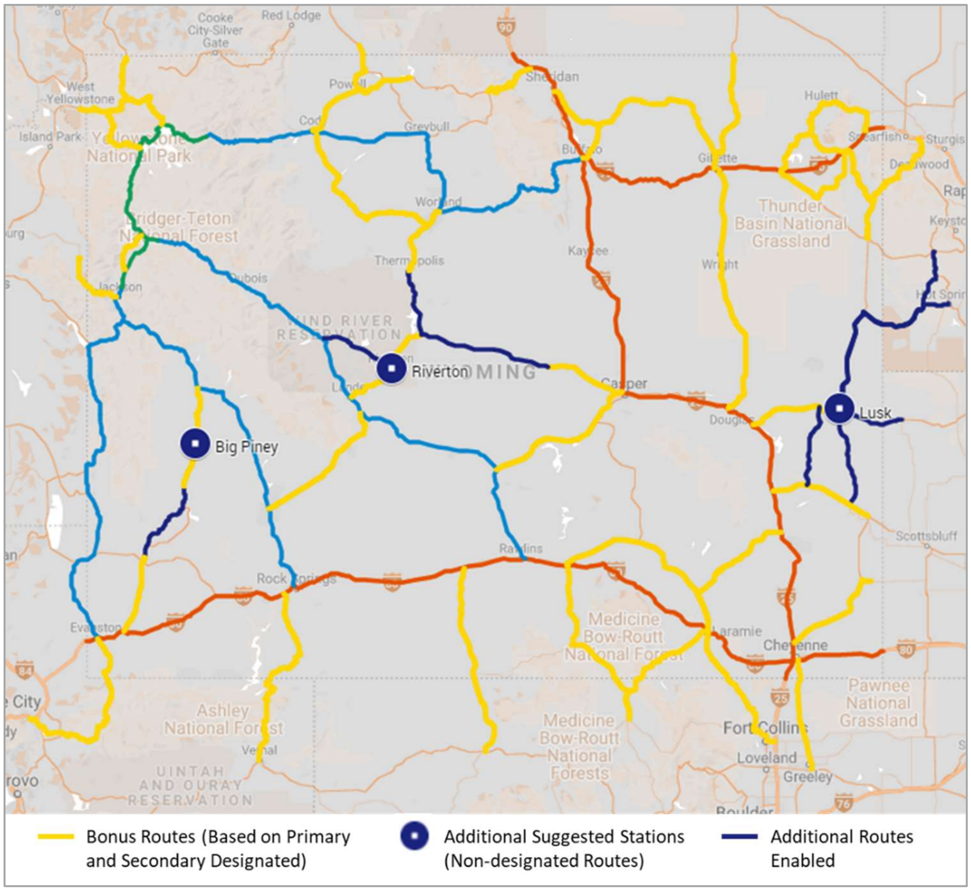
The full set of 31 Target Zones would result in an average spacing of 56 miles and a maximum gap of 91 miles. This spacing meets the criteria established for FHWA “EV Corridor-Pending” and the REV West Minimum Standards. Geographic factors make achieving the stricter 50-mile maximum spacing required for FHWA “EV Corridor-Ready” elusive. Indeed, there are segments in Wyoming and across the intermountain west where gasoline is not available for more than 50 miles.

A phased build out would be a pragmatic approach. Encouraging development of the Critical zones first, starting with I-80, would provide maximum geographic coverage for minimal investment and support early adopters as they begin to explore the state in electric vehicles. Fill-in stations could then be added, prioritizing the routes with the highest utilization, along with those with the most challenging gaps. Local governments, utilities, and host partners may also drive the process faster in some zones than in others, as in the case of Jackson where they have already taken the first step. This approach allows WYDOT to focus effort where it will have the highest impact first and ensures progress contributes to a cohesive system.

4.4 BONUS COVERAGE

The suggested stations serving primary and secondary routes would have the ancillary benefit of enabling travel on numerous adjacent routes. The map below, and accompanying table in the Appendix, identify some of the more prominent additional routes, shown in yellow. This assumes a maximum gap of 120 miles, and some segments are functional only as round trips to and from a station. Additional less prominent routes in these areas would also be enabled. These bonus routes add value to the corridor investment by connecting local communities and helping travelers reach destinations in Yellowstone, Grand Teton, Devil’s Tower, the Black Hills, and National Forests.

Bonus coverage analysis reveals three remaining major gaps along US Highways: Big Piney on 189, Riverton / Shoshoni on 26, and Lusk at the 85/18/20 junction. Routes connected by these zones are shown in dark blue. Lusk specifically enables travel between the Black Hills and points south including Cheyenne, Casper, and Colorado. Tesla has already built a Supercharger in Lusk, the only one in Wyoming besides Jackson located off the interstates. These three zones could be considered for future investment to work towards comprehensive coverage, but have not been included in program estimates as they are not necessary for the designated routes.



Bonus Coverage and Potential Expansion

5 IMPLEMENTATION RECOMMENDATIONS

5.1 CONCEPTUAL DEPLOYMENT BUDGETS

Estimating costs to deploy and operate EVSE can be very difficult. The short answer: it depends. There is no such thing as a "typical" site. Average costs do not fully represent the reality that cost distribution can be bimodal with groupings of relatively less expensive sites and more expensive sites. Conceptual station specifications provide a baseline, then each location's unique set of conditions contributes to the variability, along with factors introduced by operator and vendor selection. Still, for planning purposes it is necessary to establish expected budgetary ranges in order to identify the scope of funding necessary for comprehensive coverage of designated routes. Installation cost variables to consider include:

- **EVSE Hardware** – Charging equipment cost varies from one provider to another. Typically power and speed come at a higher price, however it does not scale linearly. Overall, DC fast charger prices have trended downwards in the past several years for a given speed as newer higher speed models have been introduced and more manufacturers enter the market. Some functionality such as credit card readers and cable management may be standard or optional additions. Purchase cost of the EVSE is only part of the picture, as when you buy hardware, you may also be committing to a software and maintenance ecosystem with more or less flexibility depending upon open / proprietary standards. It should be a priority to evaluate costs over time, as well as initial purchase price. For large equipment orders, volume discounts may be available.

- **Utility Upgrades** – Nearly all installations of multiple high-speed DC chargers will require utility service upgrades, often including an upgraded or new transformer, a new meter, switchgear, and possibly distribution line extensions. In some scenarios, chargers can be powered by spare capacity on an existing utility transformer, or even host electrical panel. This can reduce both costs and timelines, but is mostly applicable to smaller and/or lower speed installations. For the goals established by this project, new service should be assumed, and where available, existing capacity utilized.

- **Installation** – Labor and materials associated with installation are a major variable. First, site conditions impact the scope of work. Is the power source just a few feet from the EVSE location, or will it be necessary to install a long conduit run, possibly trenched or directionally bored across a parking lot? What is the existing condition of the parking area (or must new parking be built) and what level of finish is required? What other site work is required for ADA compliance (slope leveling, ramps, etc.), equipment protection, etc.? Second, contractor selection plays a role, and as with other construction work, the lowest bid does not necessarily provide the best value.

- **Miscellaneous** – Any other site-specific requirements can add cost. Locations with poor cellular service may require signal boosting equipment for the EVSE and driver app use. Sites with insufficient lighting may require provision for supplemental security lights.

- **Soft development costs** – This category includes site evaluation and (if applicable) acquisition, design, engineering, project management, and related activities. As Rocky Mountain Institute noted in its 2019 report *Reducing EV Charging Infrastructure Costs*, "These costs are poorly understood, very hard to quantify, and almost entirely undocumented in the literature."[32] Which of these activities are relevant and how they are managed will vary depending on who is deploying infrastructure and if they own the real estate or are working with third parties, plus other jurisdictional factors such as permitting and utility processes. Because of this variability these costs have NOT been included in the site or program budget summaries below, but any entity contemplating deployment should plan for them as appropriate for their approach.

Professionals experienced in fast charger deployments (a soft cost) can perform site visits to evaluate conditions and recommend layouts that minimize utility extension and ADA costs while maximizing user experience thus significantly reducing overall build cost.

Considering the recommendations in Section 3 of this report, *Station and Site Planning*, estimates have been made breaking down the deployment cost categories described above for several reference site configurations in the table below. As described at length in this study, many external factors and project team decisions can impact station development costs causing wide variability. These estimates should not be used as a budget for any specific site, but are intended to inform program-wide planning efforts.

Industry analysts have been working to document and clarify costs, and several recent studies were referenced to develop the per site estimates below. Rocky Mountain Institue's 2019 *Reducing EV Charging Infrastructure Costs*[33], a deep dive on cost drivers and levers, informed ranges for hardware and utility costs. Another 2019 paper, The International Council on Clean Transportation's *Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas*[34] provides insight into installation costs including how they vary with charger count. A third study, by charging network owner-operator EVgo, *The Costs of EV Fast Charging Infrastructure and Economic Benefits to Rapid Scale-Up*[35], provided additional support for these ranges. These high-level references correlated very well to the project team's field experience, as well as a bottom-up analysis completed for a specific reference site in Wyoming.

[32] Chris Nelder and Emily Rogers, Reducing EV Charging Infrastructure Costs, Rocky Mountain Institute, 2019, https://rmi.org/ev-charging-costs.
[33] Chris Nelder and Emily Rogers, Reducing EV Charging Infrastructure Costs, Rocky Mountain Institute, 2019, https://rmi.org/ev-charging-costs.
[34] Michael Nicholas, Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas, 2019, https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf
[35] Jonathan Levy, Isabelle Riu, Cathy Zoi, The Costs of EV Fast Charging Infrastructure and Economic Benefits to Rapid Scale-Up, 2020, https://www.evgo.com/wp-content/uploads/2020/05/2020.05.18_EVgo-Whitepaper_DCFC-cost-and-policy.pdf

Cost savings, represented by the low range, can be obtained through careful site selection and design, as well as vendor selection and management. Cost estimates do not take into account incentives or other supplemental funding sources.

Estimated Cost Ranges For Sample Site Configurations

Cost Category	Site Configuration		
	(2) 50 kW	**(2) 150 kW**	**(4) 150 kW**
EVSE Hardware: DC fast charger, well equipped	$50,000 - $70,000	$150,000 - $200,000	$300,000 - $400,000
Utility Upgrades: highly variable, may amortize via contract	$35,000 - $53,000	$44,000 - $69,000	$66,000 - $173,000
Installation: electrical, civil, labor, materials, permit	$54,000 - $90,000	$76,000 - $96,000	$112,000 - $152,000
Total Estimated Build Costs	**$139,000 - $213,000**	**$270,000 - $365,000**	**$478,000 - $725,000**

Note: project development “soft costs” not included

Site configurations shown include (2) 50 kW chargers, (2) 150 kW chargers, and (4) 150 kW chargers. In each case it has been assumed a new dedicated utility meter and new or upgraded utility transformer will be required. This doesn’t represent the full range of equipment available or site configurations, but two or four 150 kW units represents this study’s suggestion for initial Wyoming corridor coverage. It may make sense to place two in some locations and four in others initially. The 50 kW option is shown because it is commonly deployed, though as shown in section 4.2, it is no longer the best option for corridors. Note that boosting some or all of the 150 kW units in the examples shown to 350 kW units might be done for a porportionally minor increase in first cost, provided there are not utility complications – the ICCT report is a good reference for more detail.

Using the reference site budgets above, corridor build out costs were estimated based upon the number of sites in each phase. The same caveats apply – but these estimates illuminate the potential scope of investment necessay to meet Wyoming’s corridor electrification goals.

Estimated Cost Ranges For Designated Corridors

Route(s)	# Sites	Site Configuration (2) 50 kW			Site Configuration (2) 150 kW			Site Configuration (4) 150 kW		
Estimated Cost Range Per Site		**$139,000**	**-**	**$213,000**	**$270,000**	**-**	**$365,000**	**$478,000**	**-**	**$725,000**
I-80 Critical (not additive)	5	$ 0.7 M	-	$ 1.1 M	$ 1.4 M	-	$ 1.9 M	$ 2.4 M	-	$ 3.7 M
Primary Critical + Jct.	10	$ 1.4 M	-	$ 2.2 M	$ 2.7 M	-	$ 3.7 M	$ 4.8 M	-	$ 7.3 M
Secondary Critical	6	$ 0.9 M	-	$ 1.3 M	$ 1.7 M	-	$ 2.2 M	$ 2.9 M	-	$ 4.4 M
Primary Fill-in	8	$ 1.2 M	-	$ 1.8 M	$ 2.2 M	-	$ 3 M	$ 3.9 M	-	$ 5.8 M
Secondary Fill-in	4	$ 0.6 M	-	$ 0.9 M	$ 1.1 M	-	$ 1.5 M	$ 2 M	-	$ 2.9 M
NPS (corridor only)	3	$ 0.5 M	-	$ 0.7 M	$ 0.9 M	-	$ 1.1 M	$ 1.5 M	-	$ 2.2 M
Full Plan	**31**	**$ 4.4 M**	**-**	**$ 6.7 M**	**$ 8.4 M**	**-**	**$ 11.4 M**	**$ 14.9 M**	**-**	**$ 22.5 M**

As shown, electrification of all designated corridors using the preferred 150 kW or greater chargers could cost between $8-23 million. While this is a large investment, two perspectives bring it into focus. First, it isn't necessary to do it all at once. A phased plan makes sense, as corridors are only useful if continous. If funding is limited, concentrating it initially could yield the highest value. For instance, minimum enabling critical coverage along I-80 with two 150 kW units in each location could be provided for under $2 million. Providing the same basic critical coverage across both primary and secondary corridors statewide might cost between $5-6 million; corridors could be filled in, expanded, and upgraded as funding becomes available and usage increases. Second, the estimated cost range to electrify Wyoming's 1850 miles of designated corridors is in line with the cost forseen in other states pursuing highway electrification. California and New York have already allocated hundreds of millions of dollars for charging infrastructure. Closer to home, Colorado has been providing incentive support for years, including more than $10 million allocated for corridor development underway now, with more on the horizon. The utility Rocky Mountain Power just received approval to invest $50 million in electrification in Utah, most of it in infrastructure. All of this is on top of private investments totaling $2.75 billion and counting committed nationwide[36]. The estimated full

[36] Conner Smith, Investment in Public EV Charging in the United States, Atlas Public Policy, 2020, https://www.atlasevhub.com/wp-content/uploads/2020/02/Investment-in-Public-EV-Charging-in-the-United-States.pdf

plan budgetary range is a big investment, and even that will not be sufficient for forecasted market growth, but it is in line with what is committed and anticipated elsewhere to jump start the process.

5.2 OPERATIONAL COSTS

Beyond installation costs, operational costs should also be considered and budgeted. This critical component of total project lifetime costs is often forgotten in planning exercises and omitted from incentive funding. Yet, over the lifetime of a station, operation and maintenance could exceed installation cost. Indeed, some early EV charging deployments made admirable investments in installation, but did not sufficiently provide for operation and maintenance, resulting in outages, unreliable infrastructre, and frustrated drivers. Operational cost categories include but are not limited to the following.

- **Electricity** – Usage on a public station can be difficult to predict and electricity is sold according to many different rate schedules depending on the local utility and categorical characteristics of the station. There is also often seasonal and time of day variability in rates. Many commercial rate schedules, applicable to DC fast chargers, include a demand charge assessed based on peak power draw, in addition to the consumption-based energy charge. Demand charges can be burdensome for fast chargers in early market deployments because fast chargers have a high peak power (kW demand), but if lightly utilized are only dispensing a small amount of energy (kWh). Higher utilization rates (i.e. percentage of hours actively charging) can dramatically reduce operator cost per EV mile powered by amortizing the demand charge over more kWh. Demand charges can be more than half of the electrical bill, and lead to a high fixed operating cost independent of utilization, but can be managed to some extent through smart charger features, power sharing, demand limiting, and energy storage. Additional basic monthly charges may apply if a separate service meter is required. Site-specific rate analysis should be part of the planning process for a charging station deployment. This work can reveal opportunities to optimize utility bills over the life of the system.

- **Network Operations / Customer Service** – Networking and data plans, if applicable, are typically billed monthly or annually, and can be assessed separately or bundled. Data is typically provided via cellular modem connectivity and priced per modem, usually one per charger for redundancy, but sometimes per “hub” or “gateway.” Networking is usually priced per DC charger and can include software as a service, plus active management services such as usage data collection and reporting, Network Operations

Center (NOC) activities such as proactive monitoring, remote troubleshooting, dispatch, etc., and customer service functions such as call center and payment processing. Third party packages vary by provider, bundled or a-la-carte. Large owner-operator networks usually self-perform some or all of these elements. It is also possible in some cases to bundle networking and maintenance costs into the initial purchase price for a period, say 3 or 5 years, if it is desirable to shift costs from an operating budget to a capital budget.

- **Maintenance** – Some organizations have installed EV chargers without a maintenance plan or budget. This can lead to chargers being inoperable for an extended period. If the goal is to promote EV adoption and range confidence, an unmaintained charger is worse than no charger. Drivers rely on this infrastructure, and charger maintenance can require specialty knowledge, so it is not sufficient to wait until there is an issue to research and hire service providers. DC fast chargers require both scheduled (per manufacturer guidelines) and corrective maintenance. Their advanced functionality simply necessitates more components that may require attention: communications, energy metering, screens, credit card readers, and sophisticated power electronics. Manufacturers offer standard and optional extended warranties to cover parts, and in some cases, labor. Not every potential issue is a charging hardware problem, however, so provisions should be made for dealing with site issues as well, including basic cleaning of screens and chargers, as well as parking lot maintenance and snow removal.

  There are three main strategies for EVSE maintenance: 1) self-perform, 2) third party on-call, or 2) a third-party service level agreement. The first is appropriate for large owner-operator networks where economies of scale allow. The second can limit costs, but runs the risk of significant delays and downtime; in the event of a failure, time may be lost as a bid is obtained, on top of technician travel time to rural destinations. For critical infrastructure along corridors, a service level agreement is advisable. In this case, a provider is contracted to correct issues within a pre-defined time frame, ensuring station availability. Some manufacturers offer maintenance packages directly, and other electrical service contractors also provide service level agreements. For both warranty and maintenance agreements, it is important to carefully review proposals to ensure an equitable comparison.

- **Real estate** – If the station is owned by the site owner, this cost may not apply, but if access to land must be acquired there may be lease or purchase costs.

- **Miscellaneous** – Ongoing operation entails typical business expenses such as licensing, insurance, taxes, etc.

Operational costs vary so widely based on serving utility and rate structure, ownership model, network, maintenance needs, real estate and more that it is not useful to estimate them specifically here. This section is intended as a reminder that any party contemplating EV fast charger ownership must consider life cycle costs, not just deployment costs, to ensure long-term viability of a station. While it is anticipated that public fast charging stations will be capable of providing a return on investment, and some already do in high-EV adoption markets, it is likely that initial operating costs exceed expenses for early deployments in low-adoption areas. This fact may lead to difficulty recruiting partners and hosts. It may be beneficial to consider creative incentive structures to alleviate this burden. Most current incentive programs focus on grants to offset capital expenditues. A phased operating allowance incentive may do more to bridge the gap between the need for initial infrastructure build out and economic levels of EV adoption.

5.3 POTENTIAL PARTNERS AND FUNDING

As outlined above, a full buildout, or even completion of a single corridor such as I-80, is a major undertaking requiring significant resources. Comprehensive coverage will require funding and active siting and development participation from multiple parties including federal, state and local government, utility, real estate and retailers, and charging network deployment and operation companies. The following is a non-exhaustive description of potential categories and partners; this is simply meant to illustrate the range of potential participant categories and identify specific entities where objectives may align with this plan.

> *Note: while it may seem logical to place chargers at highway rest areas, federal policy prohibits most types of commercial activity at facilities supported by federal funding, including rest areas. There are ongoing legislative efforts to exempt charging from this policy in the interest of serving drivers in rural areas, but it is uncertain if they will succeed and even if they do it is likely to be a slow process. This prohibition necessitates working with partners including private land owners, retailers, and service providers in order to achieve Wyoming's highway electrification goals.*

Wyoming Volkswagen Settlement – In 2015 Volkswagen (VW) admitted to installing emissions control defeat equipment on hundreds of thousands vehicles, which allowed emissions of nitrogen oxide (NOx) up to 40 times higher than legally permitted. One important element of the 2016 Volkswagen 2.0 and 2017 3.0 Liter Diesel Consent Decrees (VW Diesel Settlement) was the establishment of a mitigation trust fund. States were required to develop plans to use VW mitigation funds to counter the impacts of non-compliant VW diesel emissions by taking specifically approved actions such as upgrading or replacing diesel-powered vehicles and equipment with lower emission alternitives and installing EV charging infrastructure. Per "Wyoming's VW Beneficiary Mitigation Plan"[37] the Wyoming Department of Environmental Quality[38] is the state's lead management agency for this purpose. Wyoming's share of mitigation funds is expected to be approximately $8 million. Of that, up to 15% or $1.2 million may be allocated to "the acquisition, installation, operation and maintenance" of light duty EV charging. Under the state's plan funding may be made available for multiple types of charging including Level 1 and Level 2 as well as DC fast charging, and installed at government, public, workplace, and multi-unit dwelling locations (different cost share requirements apply). This means that funding may not be made available exclusively for corridor development, although coordination with WYDOT and tourism corridors were specifically called out. It will clearly be necessary to leverage this funding to accellerate and inspire other investments.

Federal Funding – President-elect Biden's Climate Plan[39] [40] pledges federal collaboration with state and local governments to support the deployment of over 500,000 public chargers by 2030. It also promises to encourage EV adoption by removing the manufacturer cap on the federal electric vehicle tax credit. It is too early to tell what structure the new administration's EV policy will take and how much financial support will be available. Congress also continues to debate several proposals that would increase federal EV infracture funding. This will remain an important area to watch, and could be a source of significant additional support for Wyoming.

Utilities – Utilities across the country have launched or are developing EV programs. The approach varies widely from rebate and grant incentives, to innovative rate schedules, to make-readies (where the utility invests in the electrical upgrades for stations owned by others), to charging stations owned directly by the utility. Wyoming utilities are actively developing their own programs and will be a critical partners for any significant fast charger deployments. Wyoming utilities already actively supporting EV development include:

> **Rocky Mountain Power (PacifiCorp)** – RMP has taken a leadership role in EV infrastructure in the region as an active participant in the REV West process and through

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[37] http://deq.wyoming.gov/media/attachments/Administration/Volkswagen%20Settlement/VW%20Mitigation%20Plan%20WDEQ.pdf
[38] http://deq.wyoming.gov/admin/volkswagen-settlement/
[39] https://insideevs.com/news/446786/trump-biden-future-electric-car-support-promises/
[40] https://joebiden.com/climate-plan/#

its own dedicated programs. To date, RMP efforts have focused in Utah including DOE-supported WestSmart / Live Electric and activities directed by state legislation such as STEP (Sustainable Transportation and Energy Plan) which funded charging infrastructure rebates and custom grants, as well as vehicle incentive programs[41]. As of early 2020, Rocky Mountain programs had supported the deployment of 50 DC fast chargers and over 1000 Level 2 chargers across Utah. The spring 2020 Utah HB 396[42] went even further, instructing the utility to invest up to $50 million in utility upgrades necessary for charging, and allowing utility ownership of charging stations in the state. The original WestSmart effort identified the need to extend fast charging infrastructure along Wyoming's corridors with a tourism focus well aligned with WYDOT goals, but deployment has not yet occurred. RMP was recently awarded another DOE grant totaling $6.6 million to support a continued effort dubbed "WestSmart EV@Scale"[43]. Detailed plans have not yet been released, but the utility has described this as a regional effort touching seven states with corridor development as a key component. This program could be a boon to fast charging development in Wyoming and early coordination is recommended. Rocky Mountain Power will play a critical role in the success of Wyoming corridors, as it serves 13 of 31 target zones identified in this study, including 8 of 16 critical zones – by far the most of any utility.

Black Hills Energy – In December 2019, Black Hills Energy, which also owns Cheyenne Light, Fuel & Power, launched an EV charger rebate program across their service territories in Wyoming, South Dakota, and Colorado. Rebates are available for both residential and commercial Level 2 chargers, as well as up to $35,000 per DC fast charger[44]. This program could assist installations in two corridor target zones, including the crucial I-80 / I-25 junction in the state's capital city.

Cooperative and Municipal Utilities – Rural electric cooperatives and municipal power providers across the state have begun planning and in some cases implementation of vehicle electrification programs. Associations such as the Wyoming Rural Electric Association (WREA)[45] and Wyoming Municipal Power Agency (WMPA)[46] could be helpful platforms for coordination and sharing of best practices as these programs evolve.

[41] https://www.liveelectric.org/incentives
[42] https://www.rockymountainpower.net/about/newsroom/news-releases/utah-expands-ev-charging.html
[43] https://www.pacificorp.com/about/newsroom/news-releases/pacificorp-westsmart-ev-scale-project-awarded-6-million-to-develop-electric-vehicle-ecosystems.html
[44] https://www.blackhillsenergy.com/efficiency-and-savings/ready-ev/electric-vehicle-charging-rebate.
[45] https://www.wyomingrea.org/
[46] http://www.wmpa.org/

Tri-State Generation & Transmission Association – This co-op power provider supplies 45 members across four states, 8 of which are in Wyoming (and members of WREA as well). Tri-State's *Responsible Energy Plan*[47] pledges nearly $2 million to help provide EV charger access, and support EV education. Each member will be allocated $45,000 to install charging stations. Tri-State's website describing their program is worth quoting at length, as their well-articulated vision applies across all of Wyoming:

"Bringing public EV chargers to rural areas is not only a service to residents who will drive EVs (including the impressive electric pickup trucks and SUVs coming onto the market soon), but it will also be an economic necessity in the not-too-distant future. When more Americans are driving EVs, rural communities cannot afford to be shut off from those travelers and tourists. Many of the public EV chargers currently installed in small towns are located in front of businesses, like restaurants or motels, that hope to get a boost from EV drivers stopping to recharge."[48]

One innovative element of Tri-State's program is the EV Experience Fleet. The co-op purchased several EVs and PHEVs and loans them out to member utilities for ride-and-drives, a proven tool to building consumer awareness and confidence in the technology. They plan to add trucks as soon as available. Tri-State members WYRULEC[49] and High West Energy[50] and possibly others are already sharing the EV Experience Fleet with customers and promoting EVs on their websites. High West has also already utilized Nebraska VW Mitigation funding to install a DC fast charging station of its own in Potter, NE[51].

Local government – Cities and counties will be important partners, possibly contributing to siting, funding, and connecting other interested parties. The town of Jackson is one such example: it has operated public Level 2 chargers since 2014[52], and this summer put Wyoming's first public DC fast charger into service.

CPOs – EV charging network owner/operators, also known as Charge Point Operators, could have a transformative impact on Wyoming corridor electrification, should they decide to or be incentivized to invest in the state. Their expertise with large-scale corridor build-outs in other markets, as well as the nuances of long-term operation, will likely make them key participants

[47] https://tristate.coop/sites/tristategt/files/PDF/Responsible-Energy-Plan/Tri-State-Responsible-Energy-Plan.pdf
[48] https://www.tristategt.org/cooperatives-bringing-electric-vehicle-chargers-rural-communities
[49] http://www.wyrulec.com/content/electric-vehicles,
[50] https://www.highwestenergy.coop/category/electric-vehicle/
[51] http://deq.ne.gov/NDEQProg.nsf/OnWeb/AirVW-4
[52] https://www.jacksonwy.gov/284/Electric-Vehicle-Charging-Stations

and potentially drivers. Thus far, none has invested in Wyoming, but there are reasons it might make sense to do so, especially for the following three (this section does not attempt to describe all of the efforts of these companies, just those directly related or adjacent to Wyoming):

Electrify America – This network was founded in late 2016 as part of the Volkswagen diesel settlement, in order to fulfill VW's commitment to invest $2 billion over ten years on EV infrastructure in the U.S., separate from and in addition to the mitigation funds allocated to states. This investment is planned in four 30-month cycles. The largest portion of this direct investment has focused on high speed charging, mostly 150 and 350 kW, in large metro markets and along major highway corridors aross America. As of December 2020, EA reports 2,268 fast chargers at 520 operational stations and 148 more coming soon[53]. This effort has provided the first coverage along numerous highway segments, including completion of the first two public coast-to-coast fast charging routes. Electify America's National ZEV Investment Plans for Cycle 1 (April 2017)[54], and Cycle 2 (February 2019)[55] both omitted Wyoming, as well as North and South Dakota and most of Montana, likely due to market conditions described in Section 2 and low participation in public comment in these states. These investments did, however, designate I-80 from San Francisco to New York, except Wyoming, and I-25 from Albuquerbue to Fort Collins, in addition to a large metro deployment in Denver. Most of this planned infrastructure is already operational. EA's planning continues, and this summer Wyoming submitted comments for Cycle 3, based in part on preliminary recommendations of this project team, requesting that Electrify America extend its existing work along the adjacent interstates to include Wyoming, which would result in a third coast-to-coast route for the network.

EVgo – EVgo was the first owner/operator to invest in public fast charging nationwide, and earlier this year completed its 800th fast charging location[56]. The focus has been metro markets, especially in California (300+ locations), but early investments in neighboring states included opening stations in Colorado and Utah starting in 2015. As of October 2020, the Utah network consists of 7 stations along the Wasatch Front, while in Colorado EVgo operates 26 locations, focused around the Denver metro area and

[53] https://www.electrifyamerica.com/locate-charger/
[54] https://www.electrifyamerica.com/assets/pdf/National%20ZEV%20Investment%20Plan.3100e374.pdf
[55] https://www.electrifyamerica.com/assets/pdf/Cycle%202%20National%20ZEV%20Investment%20Plan%20-%20Public%20Version%20vF.50bb1fe0.pdf
[56] https://www.evgo.com/about/news/evgo-announces-opening-of-800th-evgo-fast-charging-location/

extending along the I-25 corridor from Colorado Springs to Fort Collins[57]. Most of these provide one or two 50 kW chargers, plus Level 2, but the newest in Colorado offer four 100 kW chargers. It would be logical to exend Front Range coverage at least to Cheyenne and Laramie, and potentially beyond. One key benefit for EVgo could be enabling Wyoming recreation travel for their established customer base in Utah and Colorado. This July EVgo and General Motors announced a partnership to deploy 2,700 new fast chargers over the next five years in support of the auto maker's upcoming electric vehicle releases[58]. While public plans to date have not specified if corridors will be part of this effort, the announcement did state that the parties are hoping to form public-private partnerships.

ChargePoint – While ChargePoint is best known as a leading provider of bundled charging hardware, software, and support services, the company has also become an owner/operator for select corridor projects. This includes east and west coast efforts with BMW as well as the California Energy Commission program. In 2018 ChargePoint was awarded a $10.33 million grant from the Colorado Energy Office to install fast chargers at 33-34 sites along six designated routes including both interstate and secondary segments statewide[59]. Stations include either 125 kW or 62.5 kW units. This buildout supports both Colorado's state EV plan, as well as its regional commitement to REV West. The first stations opened summer 2020, and as of fall 2020, this effort is still underway but somewhat delayed by the difficulty of establishing site host partnerships amid COVID-19. The Colorado Energy Office estimates nearly 50% of stations will be open by year end. As with EVgo, it may make sense for ChargePoint to consider extending these Colorado efforts into adjacent parts of Wyoming.

Retail and Real Estate – Commercial real estate owners and retailers are critical to driver-friendly corridor charging stations. After all, roadtrip-appropriate amenities like food, beverage, shopping, and entertainment make charging stops more enjoyable. For early deployments it is often easiest to add charging alongside existing amenities. Shopping centers, grocery stores, convenience stores, hotels, restaurants and more have hosted stations for other corridor programs. By and large, the role these parties have so far played in fast charge corridor developments is as hosts, seldom as owner/operators who buy and manage their own equipment. They often see charging as another amenity that draws customers to their

[57] https://www.evgo.com/charging-locations/
[58] https://www.evgo.com/about/news/general-motors-and-evgo-aim-to-accelerate-widespread-ev-adoption-by-adding-fast-chargers-nationwide/
[59] https://energyoffice.colorado.gov/zero-emission-vehicles/electric-vehicle-fast-charging-corridors

property, and are happy to let another party (such as a CPO) make the steep investment and take responsibility for operational costs and management while they focus on their core business. This may change over time. One subsegment where some are partnering and others are beginning to do it themselves is fuel retailers.

> **Fueling Providers** – Some gas stations and convenience stores have begun supporting electric vehicles. In many ways this is a logical evolution. EV travelers need the same things on road trips as their ICE counterparts: restrooms, food, and beverage. A modern "service station" aspiring to meet the needs of all travelers should include EV charging. One early regional example is Maverik, who partnered with Rocky Mountain Power to place fast chargers at eight stores along highway corridors in Utah. Maverik operates approximately 30 locations across Wyoming. Global players such as Shell have launched pilots deploying their own chargers at select locations[60], and even invested in EV service providers. Other large operators such as Love's Travel Stops[61], and individual franchise owners, have chosen to partner with growing charging operators such as Electrify America. There seems to be increasing recognition in the fueling provider sector that EV charging adds value, but the market is still well short of large scale rollouts. Partnerships and incentives will be crucial.

Yellowstone-Teton Clean Cities and the National Park Service – A member of the DOE-funded Clean Cities program, this non-profit based in Jackson has been bringing electric and hybrid vehicles to the National Parks via multiple rounds of grant funding since 2012. Their work to date includes installation of three Level 2 chargers each[62] for Yellowstone[63] and Grand Teton[64] National Parks. As of fall 2020, they YTCC website indicates that all currently available EVSE funding has been awarded, but they will likely participate in future federal funding rounds and their experience and relationships with the parks could make them a key partner for developing the corridors through these areas. In addition to the efforts above some park lodging and services concessionaires have begun installing Level 2 chargers as well[65]. It is hoped that these efforts expand to include DC fast chargers.

There are numerous potential partners who could contribute to electrifying Wyoming's highways, each playing a vital part. Still, someone has to design, build, host, own, manage, and

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[60] https://www.cspdailynews.com/fuels/shell-installs-its-first-us-ev-charging-stations
[61] https://www.loves.com/en/news/2020/august/electrify-america-announces-collaboration-with-loves-travel-stops
[62] https://ytcleancities.org/projects/intiatives/
[63] https://cleancities.energy.gov/national-parks/yellowstone
[64] https://cleancities.energy.gov/national-parks/teton
[65] https://www.nps.gov/articles/evcharging.htm

pay for each individual station. This could theoretically be one party, or each function could be performed by separate entities. The most logical combination of roles may vary by location. A one-size-fits-all approach will not serve to accellerate deployments. Whatever programs are developed to encourage and help fund this plan should strive for inclusion and flexibility. This promotes fairness, competition, and rewards those willing to come along for the ride. Realizing this full vision is likely outside the scope of any one entity acting alone. It might take a CPO network tackling an interstate here, some service stations and utilities there, and a city revitalizing a business district elsewhere. A multi-party collaboration of this sort could effectively leverage greater resources, but coordination and standards are needed to ensure optimal functional and coverage. By bringing these partners to the table, Wyoming maximizes it's potential near-term progress and builds toward a robust electrified highway network.

6 CONCLUSION

New long-range high-performance electric cars, SUVs, and pickups are beginning to explore Wyoming's highways, communities, and destinations. Comprehensive high-speed public charging is crucial to enabling these journeys. The State of Wyoming has committed to facilitating this rollout, and in service to that effort, this study outlines practical recommendations regarding station design and features, site selection, and prioritized route buildouts, as well as program scope and budgetary estimates. Given the scale of the infrastructure necessary, success will require investment and active participation from multiple sectors, including government, utilities, charging network operators, and real estate and retail businesses. Maintaining minimum standards of service while promoting higher levels of service whenever possible will ensure that even with many parties contributing, the result is a highly-functional, comprehensive network offering consistent driver experience and seamless travel from one corner of Wyoming to the other.

The electric vehicle space is evolving so rapidly that this plan will inevitably require revision. Forward looking recommendations including reach goals (especially higher power and more dispensers), and provisions for expansion and upgrade will significantly increase the useful life of investments. As charging technology, vehicles, and the sheer volume of adoption continue to evolve, however, it is essential that Wyoming regularly review and update electric vehicle plans to keep pace with growth and change.

Next steps:

- Maintain minimum station and site standards, but emphasize and incentivize aggressive stretch goals. Wyoming deserves better than minimum.
- Focus on designated interstate routes first, then expand and upgrade coverage.
- Develop an inclusive partner outreach effort and build support and collaboration within state and local government, utilities, and private partners.
- Develop policies, programs, and incentives to implement this plan.
- Schedule reviews to periodically update this plan to keep up with EV advancements.

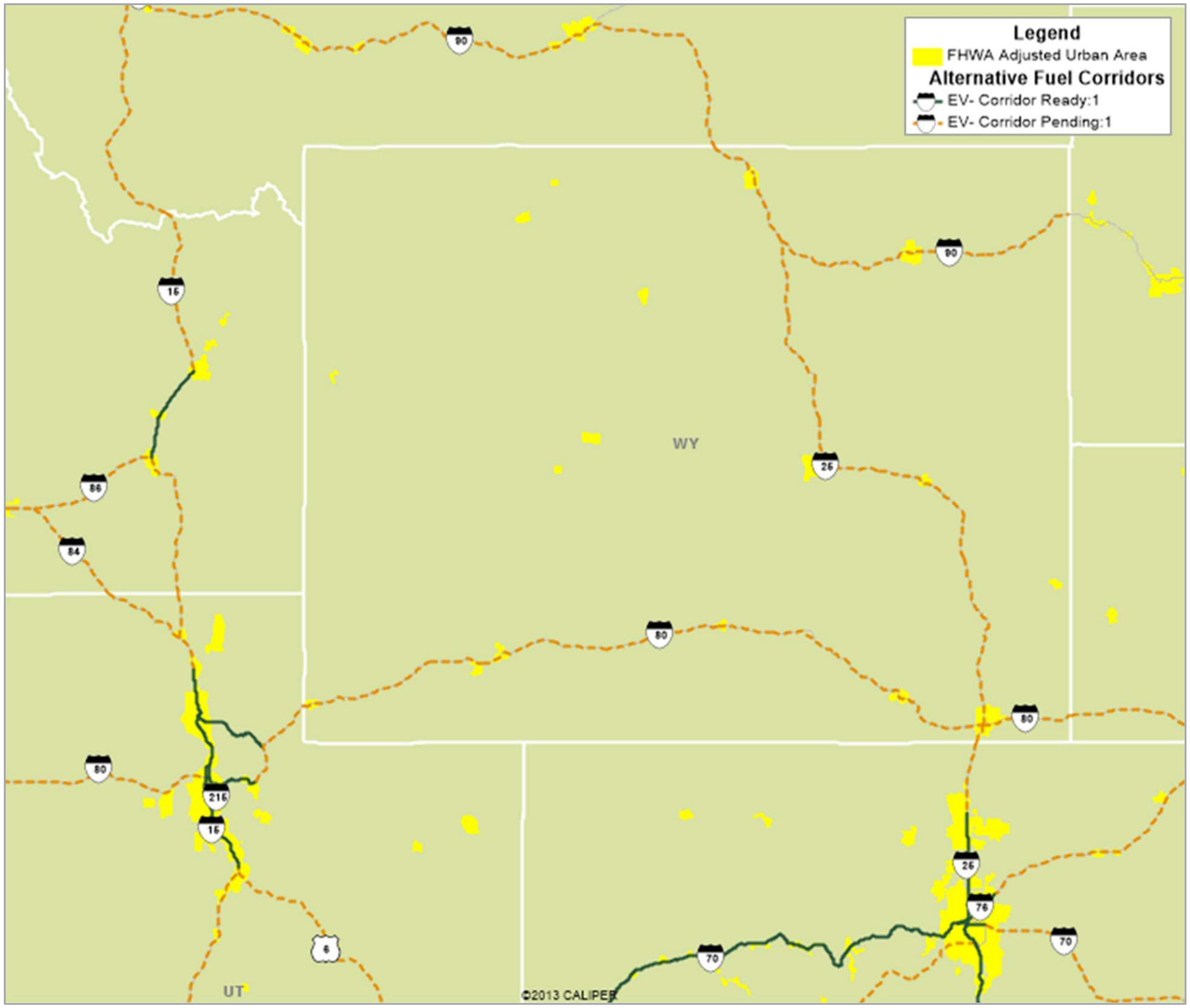
GLOSSARY

BEV	Battery Electric Vehicle. 100% electric and fully dependent on charging infrastructure – the focus of this work.
CCS	DC fast charging plug type conforming to Society of Automotive Engineers (SAE) Combined Charging System standards, AKA Combo. The United States uses SAE CCS Type 1, while Europe uses Type 2. CCS was initially adopted by European and American automakers, in increasingly now used by Asian manufacturers as well for vehicles sold in the U.S.
CHAdeMO	DC fast charging plug type conforming to CHAdeMO Association standards. This standard was developed by Japanese automakers and utility TEPCO, and initially used by Asian automakers. Support for CHAdeMO in the U.S. seems to be fading in favor of CCS.
DC Fast Charger	High speed EVSE supplying direct current to the battery. Typically used for public and fleet charging.
EV	Electric Vehicle. This is a broad term that can encompass both BEV and PHEV, and even standard hybrids and hydrogen vehicles depending on the usage. In this report it is often used in general reference to the BEV category.
EV Charger	Electrical equipment converting AC power to DC that can charge a vehicle battery. For DC fast chargers, this is inside the infrastructure. Note that in the case of Level 1 and Level 2, the physical infrastructure colloquially referred to as a "charger" is technically Electric Vehicle Supply Equipment, and the charger is actually on-board the vehicle.
EV Charging Station	Often used interchangeably with both EV charger and EV charging site, so it can refer to a single unit, or an entire location depending on context.
EV Charging Site	A charging station or group of charging stations as a whole, and their physical location.

EVSE	Electric Vehicle Supply Equipment. Infrastructure and equipment that supplies power to electric vehicles. This is the technical name for what is colloquially called an “EV charger,” “charging station,” or “charging equipment.”
ICE	Internal Combustion Engine. A vehicle powered by conventional fossil fuels.
Level 1 EVSE	Alternating current 120V EVSE, which can plug into a standard household outlet. Often supplied with the vehicle.
Level 2 EVSE	Alternating current 208-240V EVSE, available in many configurations and used widely for home, multifamily, workplace, public, and fleet charging.
Level 3 Charger	Sometimes used to refer to DC Fast Chargers, but a misnomer.
PHEV	Plug-in Hybrid Electric Vehicle. PHEVs use both electricity and fossil fuel, charging and using electricity for local trips, but using conventional fossil fuel and infrastructure for longer trips. PHEVs are typically not capable of DC fast charging.
SOC	State of Charge is an EV’s current percent of battery capacity available.

APPENDIX

FHWA EV Corridor Status, as of Oct 2020[66]



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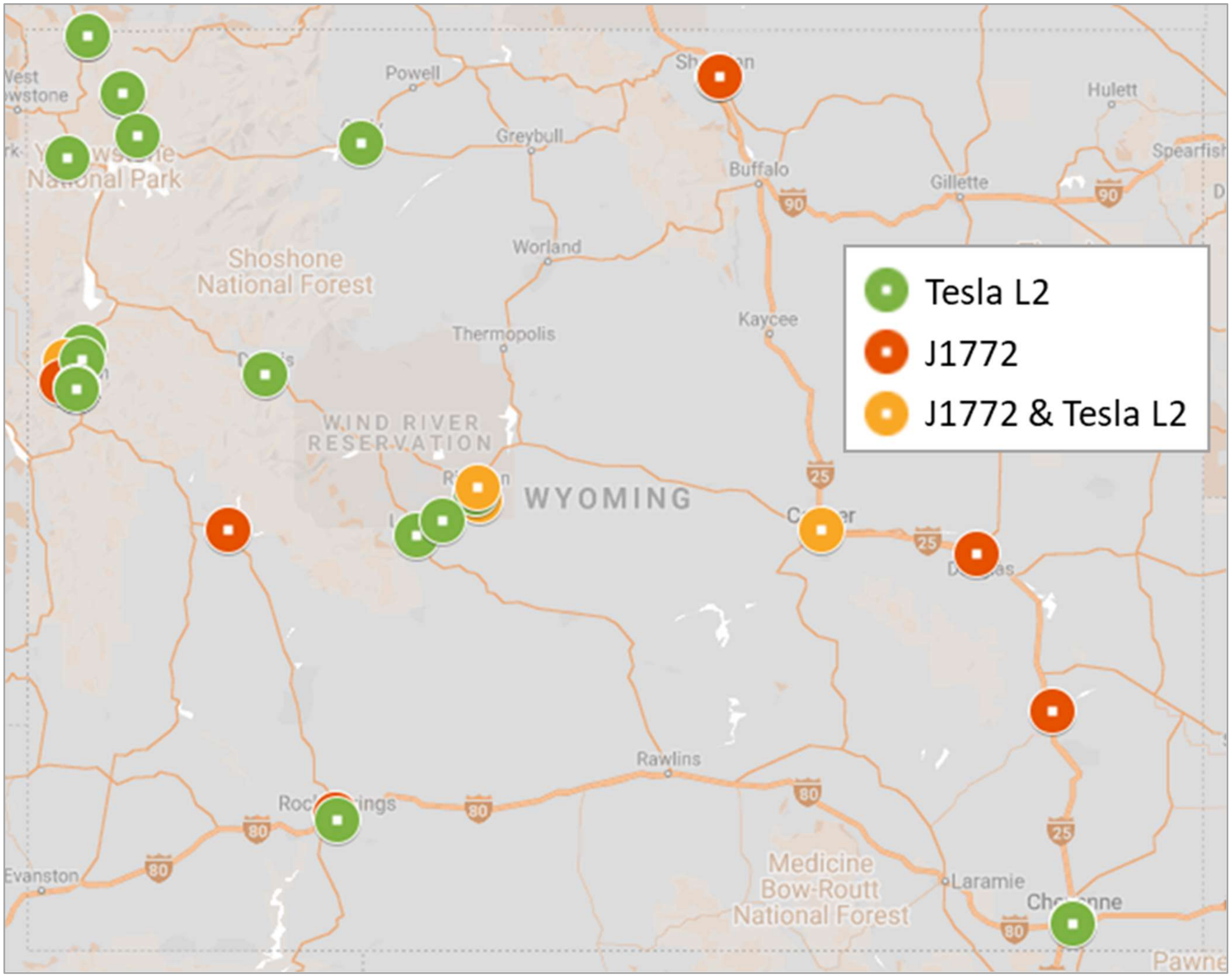
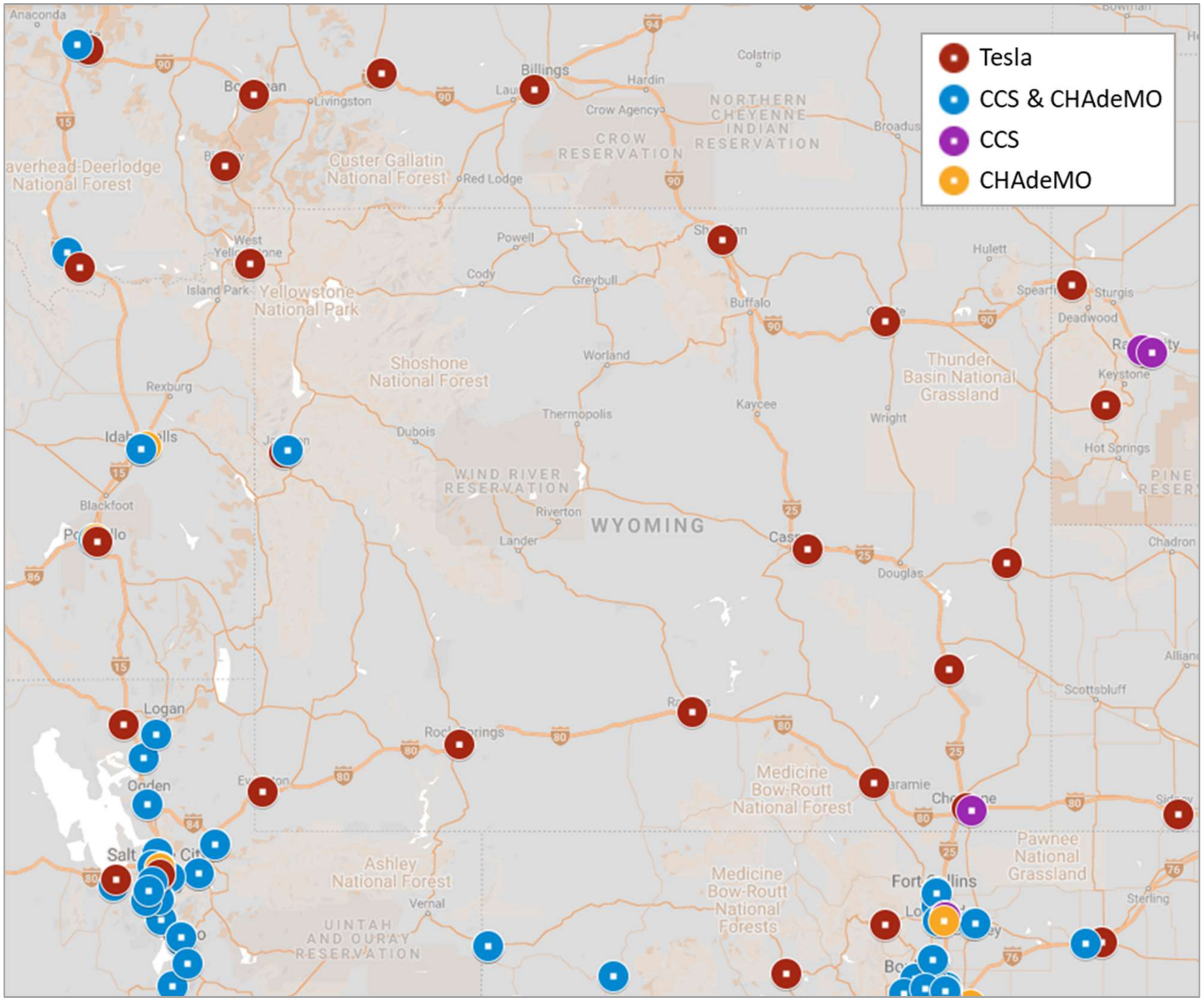
66 https://hepgis.fhwa.dot.gov/fhwagis

L2 Charging Locations in Wyoming, Oct. 2020[67]



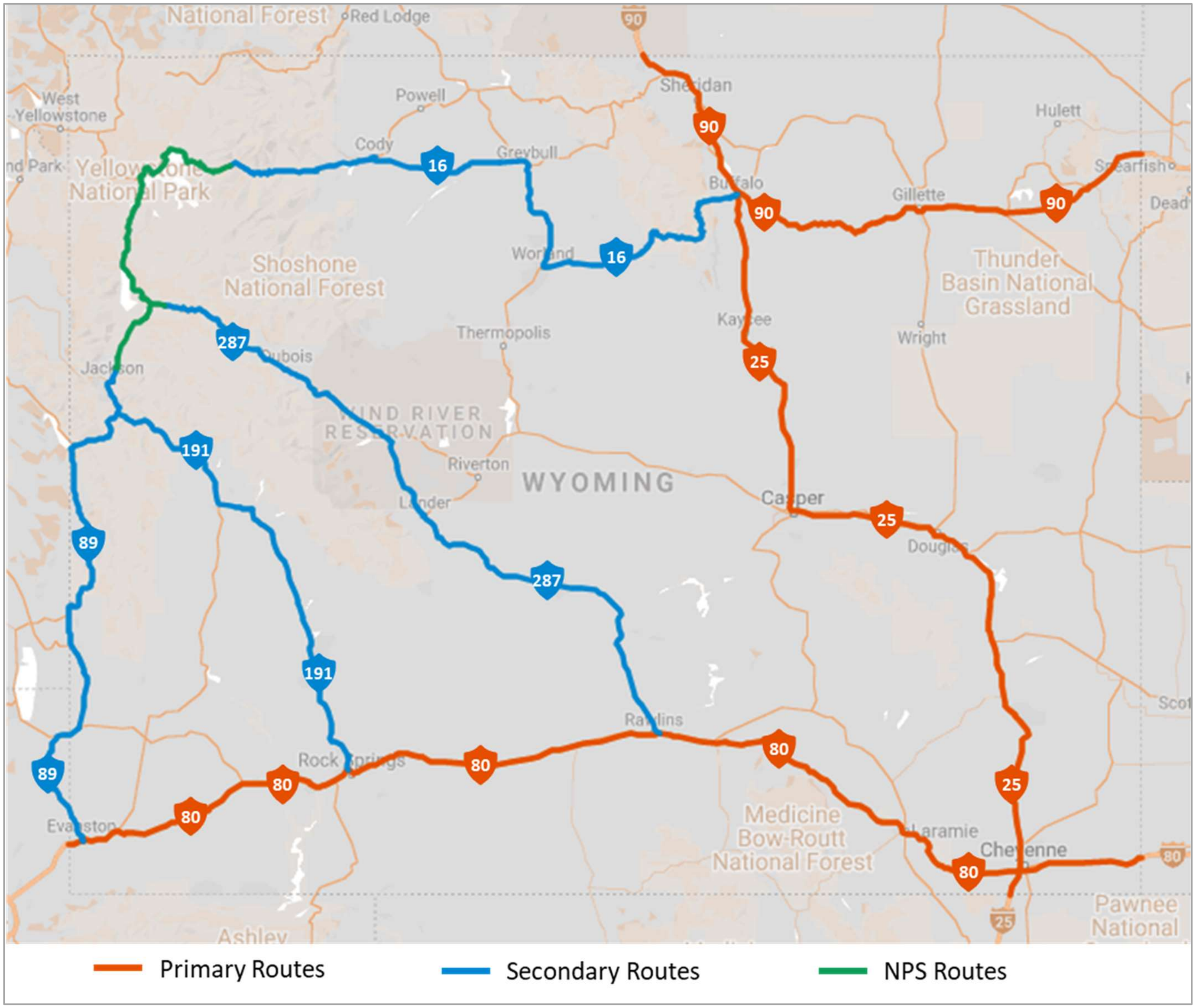
[67] Map created with source data from https://afdc.energy.gov/stations/#/find/nearest

DC Fast Charging Locations in Wyoming & Surrounding States, Oct. 2020[68]

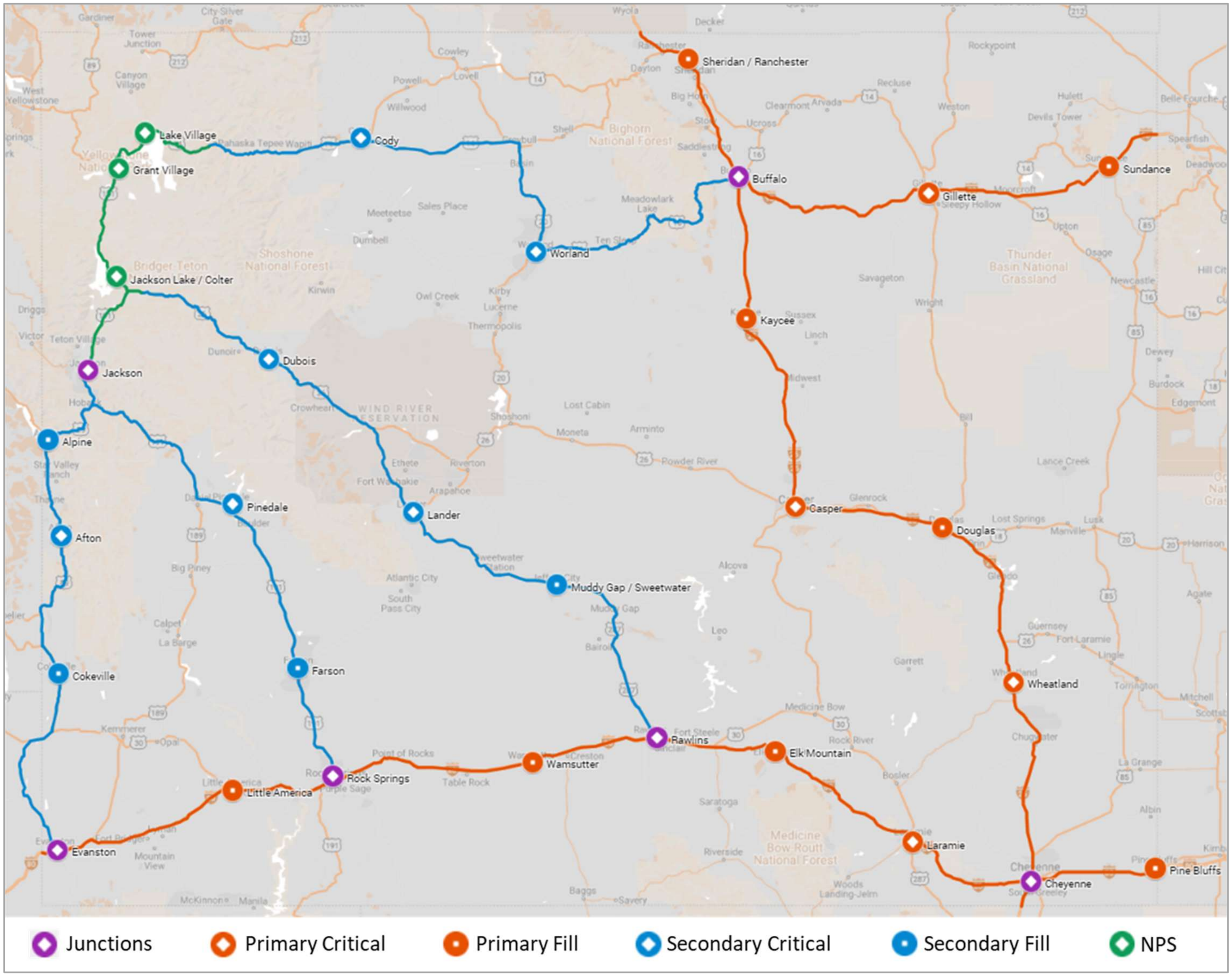


[68] Map created with source data from https://afdc.energy.gov/stations/#/find/nearest

Wyoming EV Network Study – Designated Routes



Wyoming EV Network Study – Suggested Target Zones



Wyoming EV Network Study – Suggested Target Zones

Location	Route Type	Zone Type	Primary Routes	Secondary Routes	Lat, Lon Reference	Utility*	Search Area Notes
Buffalo	Primary	1-Junction	I-25, I-90	16	44.354238, -106.686773	Powder River Energy	I-90 exits 56-58; I-25 exits 298-299; I-25 exit 299 & I-90 exit 58 preferred
Cheyenne	Primary	1-Junction	I-80, I-25	-	41.113845, -104.850888	Black Hills Power (Cheyenne Light Fuel & Power)	I-80 exits 358-364; I-25 exits 7-13; Near I-80 / I-25 jct. preferred
Evanston	Primary	1-Junction	I-80	89	41.262128, -110.954521	Rocky Mountain Power	I-80 exits 3-6; I-80 exit 5 or 6 preferred
Jackson	Secondary	1-Junction	-	191, 89, (287)	43.479635, -110.762372	Lower Valley Energy	191 in town
Rawlins	Primary	1-Junction	I-80	287	41.789113, -107.200696	Rocky Mountain Power	I-80 exits 209-215; I-80 exit 215 preferred
Rock Springs	Primary	1-Junction	I-80	191	41.607747, -109.229478	Rocky Mountain Power	I-80 exits 102-107; I-80 exit 104 preferred
Casper	Primary	2-Primary Critical	I-25	-	42.857608, -106.333695	Rocky Mountain Power	I-25 exits 182-189
Gillette	Primary	2-Primary Critical	I-90	-	44.279543, -105.494093	City of Gillette (PR Near)	I-90 exits 124-128
Laramie	Primary	2-Primary Critical	I-80	-	41.297563, -105.594683	Rocky Mountain Power	I-80 exits 310-316
Wheatland	Primary	2-Primary Critical	I-25	-	42.046639, -104.965378	Town of Wheatland (Wheatland REA near)	I-25 exits 78-80
Douglas	Primary	3-Primary Fill-in	I-25	-	42.758025, -105.410253	Rocky Mountain Power	I-25 exits 135-140
Elk Mountain	Primary	3-Primary Fill-in	I-80	-	41.724142, -106.459797	Carbon Power & Light (TS)	I-80 exits 255-267; EXCEPTIONALLY SPARSE, ONE OWNER
Kaycee	Primary	3-Primary Fill-in	I-25	-	43.715969, -106.641349	Powder River Energy	I-25 exit 254
Little America	Primary	3-Primary Fill-in	I-80	-	41.542399, -109.857419	Rocky Mountain Power	I-80 exit 68; ONE OWNER
Pine Bluffs	Primary	3-Primary Fill-in	I-80	-	41.175812, -104.075781	Town of Pine Bluffs	I-80 exit 401

Sheridan / Ranchester	Primary	3-Primary Fill-in	I-90		44.877644, -106.999895	Montana-Dakota Utilities	I-90 exits 9-25
Sundance	Primary	3-Primary Fill-in	I-90	-	44.401655, -104.366178	Powder River Energy	I-90 exits 185-189
Wamsutter	Primary	3-Primary Fill-in	I-80	-	41.674659, -107.980705	Rocky Mountain Power	I-80 exit 173, VERY SPARSE
Afton	Secondary	4-Secondary Critical	-	89	42.724368, -110.933586	Lower Valley Energy	89 in town
Cody	Secondary	4-Secondary Critical	-	16	44.526067, -109.056340	City of Cody (RMP Near)	16/14 in town, close to jct. preferred
Dubois	Secondary	4-Secondary Critical	-	287	43.533623, -109.630921	High Plains Power (TS)	287/26 in town
Lander	Secondary	4-Secondary Critical	-	287	42.831144, -108.724005	Rocky Mountain Power	287 in town, close to 789 jct. preferred
Pinedale	Secondary	4-Secondary Critical	-	191	42.866386, -109.856199	Rocky Mountain Power	191 in town, close to Fremont Lake Rd preferred
Worland	Secondary	4-Secondary Critical	-	16	44.016857, -107.955824	Rocky Mountain Power	16 in town, close to 20 jct. preferred
Alpine	Secondary	5-Secondary Fill-in	-	89	43.163614, -111.017994	Lower Valley Energy	89 in town, 26 jct. or Forest Rd 10138 preferred
Cokeville	Secondary	5-Secondary Fill-in	-	89	42.085450, -110.948452	Rocky Mountain Power	89 in town, close to 232 jct. preferred, Consider Kemmerer as alt route
Farson	Secondary	5-Secondary Fill-in	-	191	42.108641, -109.449072	Bridger Valley Elec Assn	191 in town, near 28 jct. preferred. SPARSE.
Muddy Gap / Sweetwater Station	Secondary	5-Secondary Fill-in	-	287	42.494525, -107.825757	Rocky Mountain Power / High Plains Power (TS)	Muddy Gap, Jefferson City, Sweetwater Station. EXCEPTIONALLY SPARSE
Grant Village	Secondary	6-NPS	-	16, (191)	44.390920, -110.571716	Northwestern Energy	Grant Village
Jackson Lake / Colter Village	Secondary	6-NPS	-	191, (287)	43.904425, -110.590667	Lower Valley Energy	Jackson Lake Lodge or Colter Village
Lake Village	Secondary	6-NPS	-	16, (191)	44.551721, -110.408705	Northwestern Energy	Lake Village preferred, alternates: Fishing Bridge, or Bay Bridge

*Serving utility per Energy Information Administration map https://www.eia.gov/state/maps.php (confirmed with provider/city website as needed)
Utility provider must be confirmed on site for specific station candidate locations.

Wyoming EV Network Study – Target Zone Spacing Analysis – Primary Routes

Key Junctions	
Routes	**Location**
I-80/89	**Evanston**
I-80/191	**Rock Springs**
I-80/287	**Rawlins**
I-80/I-25	**Cheyenne**
I-25/I-90/16	**Buffalo**
191/89/287	**Jackson**

LEGEND	
Connecting zone in adjacent state (status)	
## [Miles: Connecting to Critical]	
Critical Zone	
## [Miles: Critical to Critical]	*## Miles Critical-Fill*
	Fill-in Zone
	## Miles Fill-Critical
Critical Zone	

I-80	
Coalville / Park City UT (existing)	
40 / 63	
Evanston	
100	*65*
	Little America
	40
Rock Springs	
109	*68*
	Wamsutter
	42
Rawlins	
99	*42*
	Elk Mountain
	58
Laramie	
48	
Cheyenne	
83	*43*
	Pine Bluffs
	41
Potter NE (planned)	

I-25	
Wellington CO (planned)	
30	
Cheyenne	
71	
Wheatland	
106	*60*
	Douglas
	47
Casper	
114	*70*
	Kaycee
	45
Buffalo	

I-90	
Spearfish SD (anticipated)	
93	*32*
	Sundance
	62
Gillette	
71	
Buffalo	
119	*35 / 50*
	Sheridan / Ranchester
	84 / 69
Hardin MT (anticipated)	

Wyoming EV Network Study – Target Zone Spacing Analysis – Secondary Routes

LEGEND	
Connecting zone in adjacent state (status)	
## [Miles: Connecting to Critical]	
Critical Zone	
## [Miles: Critical to Critical]	*## Miles Critical-Fill*
	Fill-in Zone
	## Miles Fill-Critical
Critical Zone	

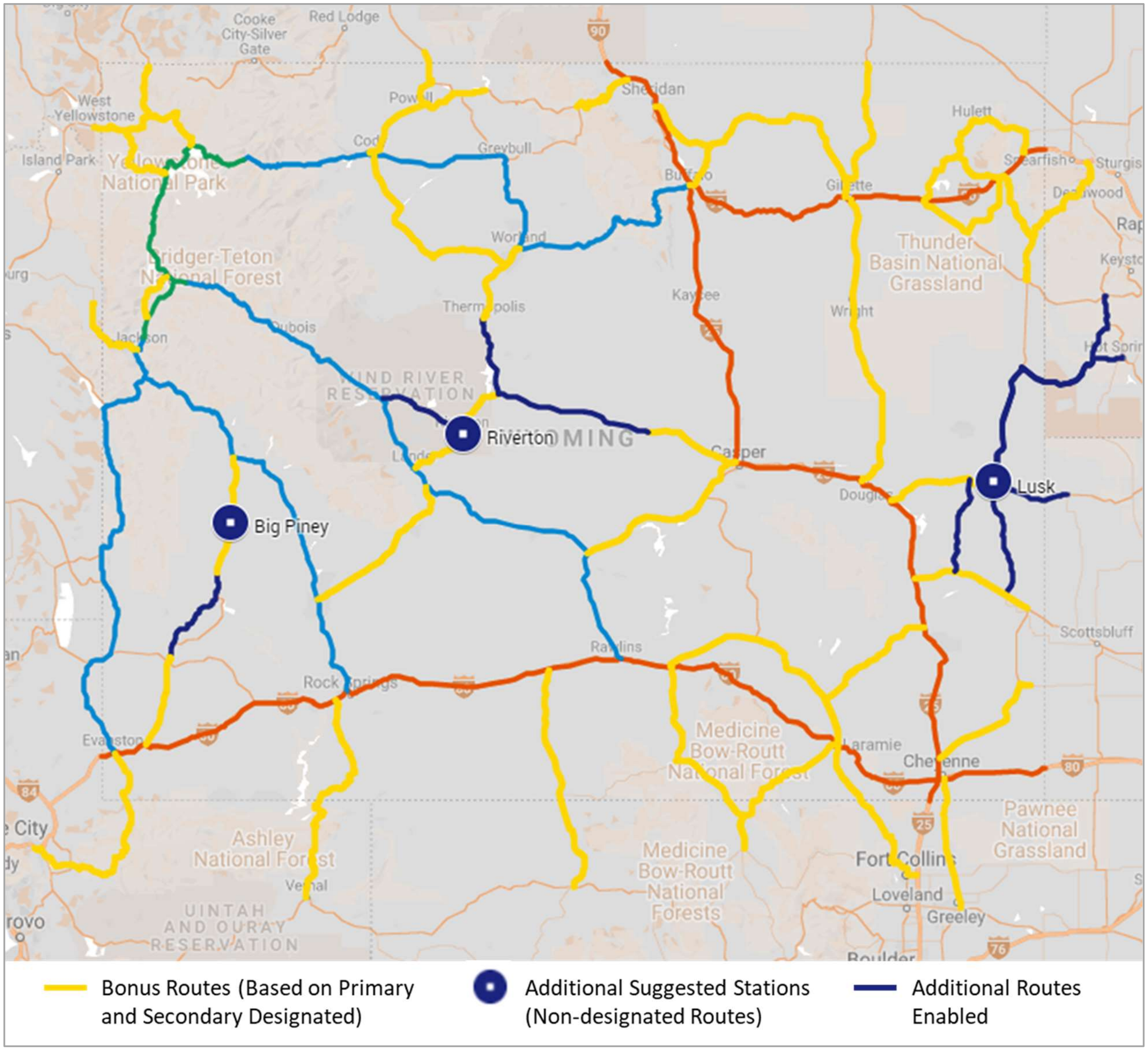
Hwy 16
Buffalo
90
Worland
91
Cody
80 / 101
Lake Village / Grant Village
57 / 51
West Yellowstone MT (anticipated)

Hwy 191	
Rock Springs	
101	*43*
	Farson
	60
Pinedale	
77	
Jackson	
98 (78)	*35 / 40*
	Jackson Lake / Colter
	63 / 58 (43 / 38)
Lake Village (Grant Village)	

Hwy 287	
Rawlins	
125	*44 / 86*
	Muddy Gap / Sweetwater Station
	81 / 39
Lander	
75	
Dubois	
86 / 62 / 66	
Jackson / Jackson Lake Lodge / Colter Bay	

Hwy 89	
Jackson	
70	*37*
	Alpine
	33
Afton	
121	*54*
	Cokeville
	69
Evanston	
Alt: Afton to Logan UT (existing) 116 mi	

Bonus Coverage Map



Bonus Coverage Table

The following route segments and round trips (RT) are enabled by the Full Plan designated charging infrastructure, assuming a max gap of 120 miles, and are shown in yellow on the Bonus Coverage Map. Additional state and county routes would also be enabled.

Route	From	To	Miles
16/14	Buffalo	Arvada (RT)	96
26	Casper	Powder River (RT)	80
85	Cheyenne	Greeley, CO	55
85	Cheyenne	La Grange (RT)	114
14 Alt	Cody	Kane (RT)	118
14 Alt/310	Cody	Warren, MT (RT)	106
18	Douglas	Lusk (RT)	110
59	Douglas	Gillette	114
189	Evanston	Kemmerer (RT)	102
150	Evanston	Park City, UT	96
14	Gillette	Arvada (RT)	110
59	Gillette	MT state line (RT)	117
90/14	Gillette	Devil's Tower (RT)	120
90/16	Gillette	Upton (RT)	95
22/33	Jackson	Driggs, ID (RT)	66
Teton Park Road	Jackson	Colter Bay	40
YNP Grand Loop	Lake Village	Lake Village	95
89	Lake Village	Mammoth (RT)	100
191	Lake Village	West Yellowstone, MT (RT)	114
789/26	Lander	Shoshoni (RT)	98
230/127/125	Laramie	Walden, CO	63

Route	From	To	Miles
287	Laramie	Fort Collins, CO	64
30/34	Laramie	Wheatland	77
189	Pinedale	La Barge (RT)	115
789/13	Rawlins	Craig, CO	118
130/230	Rawlins	Walden, CO	109
287/220	Rawlins	Casper	117
30	Rawlins	Medicine Bow, Laramie	115
28	Rock Springs	Lander	117
191	Rock Springs	Vernal, UT	110
14	Sheridan	Ucross (RT)	55
14	Sheridan	Burgess Junction	96
14/24	Sundance	Devil's Tower (RT)	54
14/24	Sundance	Hulett (RT)	72
90/24	Sundance	Hulett (RT)	90
90	Sundance	Sturgis, SD (RT)	104
90/85/585	Sundance	Deadwood, Four Corners	112
85	Sundance	Newcastle (RT)	91
116	Sundance	Upton (RT)	60
26	Wheatland	Torrington (RT)	120
20	Worland	Thermopolis (RT)	67
120	Worland	Cody	90