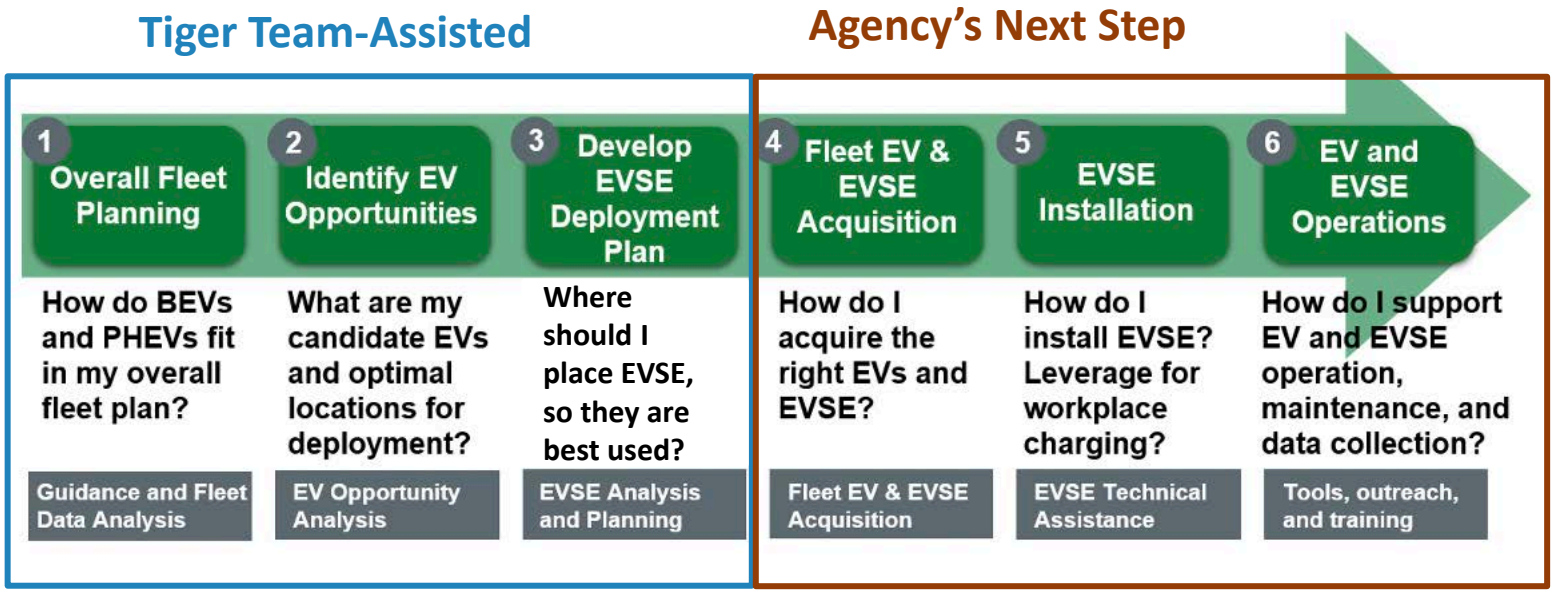
Yellowstone National Park
Federal Fleet Tiger Team EVSE Site Assessment

Leidy Boyce, Jesse Bennett, and Ranjit Desai

August 31, 2022

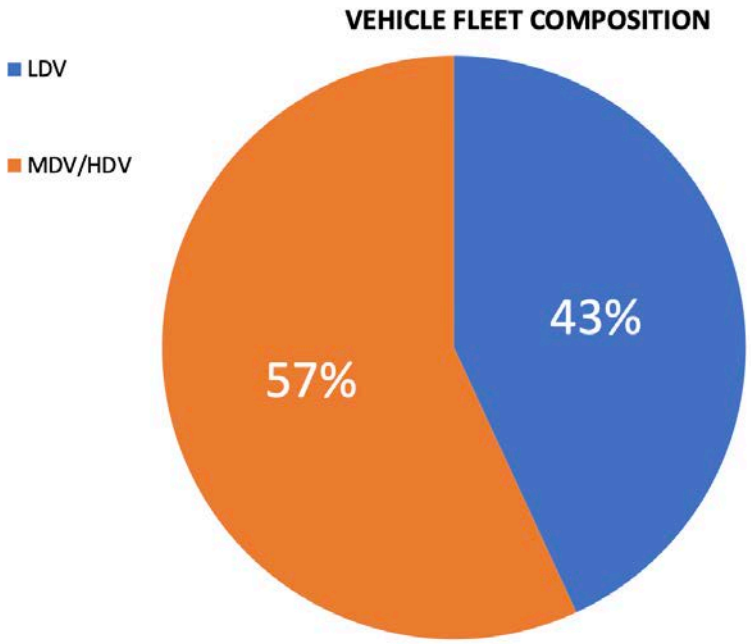
Contents

Process for Fleet Electrification

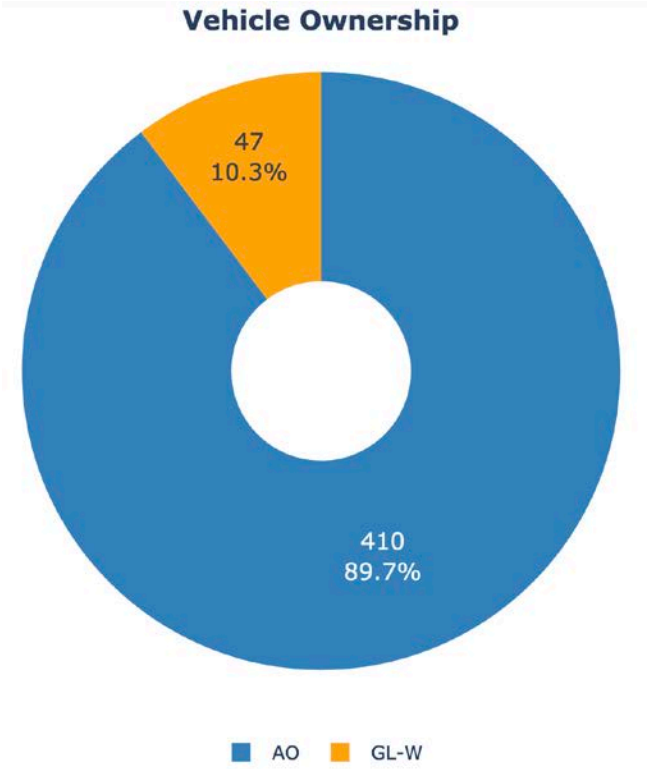


BEV = battery electric vehicle
EV = electric vehicle
EVSE = electric vehicle supply equipment
PHEV = plug-in hybrid electric vehicle

Yellowstone National Park Vehicle Fleet Composition

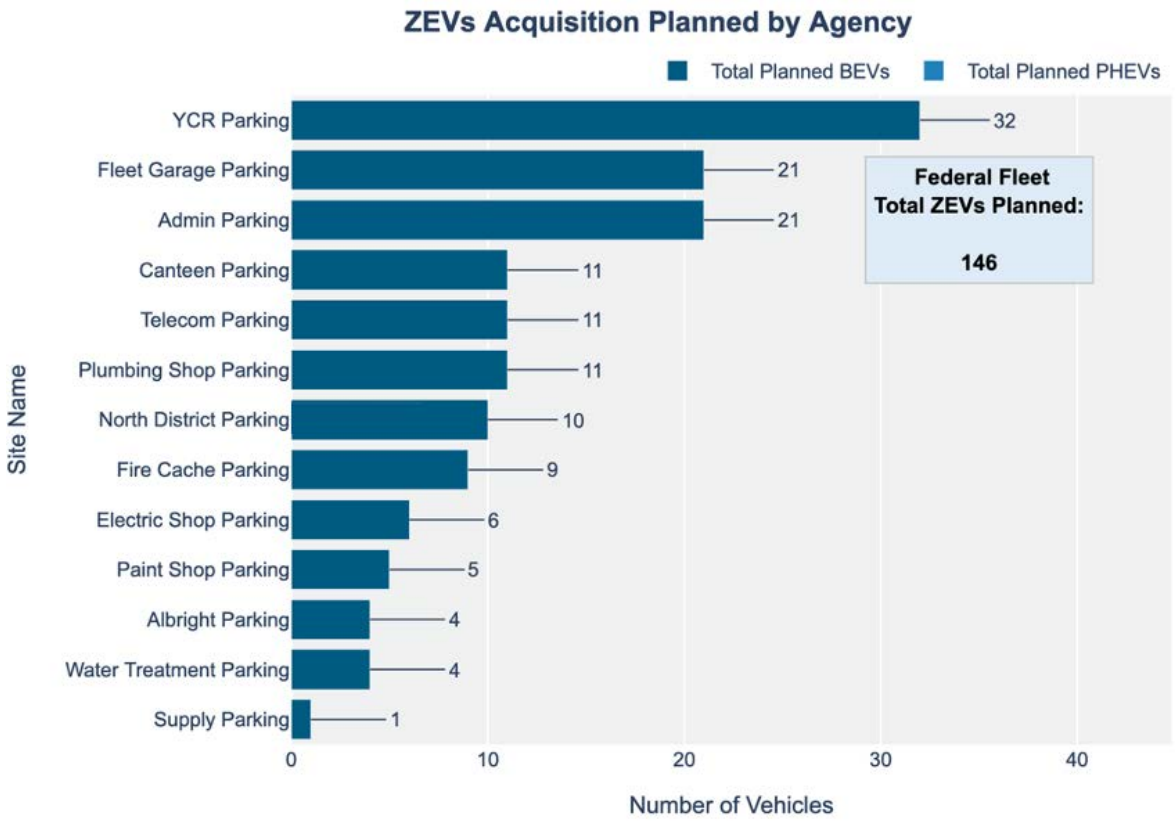


LDV = light-duty vehicle
MD = medium-duty vehicle
HDV = heavy-duty vehicle



AO = agency-owned
GL-W = GSA wet lease

ZPAC Results: Planned ZEV Acquisitions



Source: [ZEV Planning and Charging (ZPAC) tool]

ZEV = zero-emission vehicle

Not All Potential EV Candidates Have a ZEV Counterpart Available Today

Vehicle Ownership	Existing				Potential ZEV Replacement			
	Vehicle Class	Vehicle SIN	Vehicle Type	Count	BEV SIN	PHEV SIN	Make/Model	Range (Electric miles)
GSA-LEASE	LD	46	LD Pickup 4x4	4	55E		Ford F150 Lightning	350 miles
		55	LD Pickup 4x4	3	55E		Ford F150 Lightning	350 miles
		66	LD Pickup 4x4	3	55E		Ford F150 Lightning	350 miles
		96	LD SUV 4x4	1	96E		Ford Mustang Mach-E / Tesla Model Y	270 miles / 326 miles
		99	LD SUV 4x4	1	96E		Ford Mustang Mach-E / Tesla Model Y	270 miles / 326 miles
		105	LD SUV 4x4	2	96E	96P	Ford Mustang Mach-E / Tesla Model Y	270 miles / 326 miles
		106	LD SUV 4x4	1	96E	96P	Ford Mustang Mach-E / Tesla Model Y	270 miles / 326 miles
		UK	LD Minivan 4x2 (Passenger)	1		20P	Pacifica	32 miles
	MD/HD	49	MD Pickup	1	NA			
		57	MD Pickup	1	NA			
		82	MD Pickup	1	NA			
		87	MD Pickup	4	NA			
		128	MD Pickup	1	NA			
		129	MD Other	1	NA			
AO	LD	UK	LD Pickup 4x2	4	55E		Ford F150 Lightning	350 miles
		UK	LD Pickup 4x4	9	55E		Ford F150 Lightning	350 miles
		UK	LD SUV 4x2	7	91E		Ford Mustang Mach-E	300 miles
		UK	LD SUV 4x4	31	96E		Ford Mustang Mach-E / Telsa Model Y	270 miles / 326 miles
		UK	Sedan/St Wgn Compact	1	8E, 9E		Nissan Leaf / Chevrolet Bolt / Tesla Model 3	226 miles/247 miles/ 262 miles
		UK	Sedan/St Wgn Midsize	1	8E, 9E		Nissan Leaf / Chevrolet Bolt / Tesla Model 3	226 miles/247 miles/ 262 miles
		UK	Sedan/St Wgn Subcompact	5	8E, 9E		Nissan Leaf / Chevrolet Bolt / Tesla Model 3	226 miles/247 miles/ 262 miles
	MD/HD	UK	MD Other	14	NA			
		UK	MD Pickup	44	NA			
		UK	MD SUV	2	NA			
		UK	MD Van (Cargo)	3	NA			

SIN = standard item number

Buildings and Parking Areas Visited

Stop	Buildings
A	Jail/Outdoor Patio
B	YCR and Canteen
C	Admin. Building
D	Post Office
E	YCC/Fleet Maintenance Shop

YCC = Youth Conservation Corps
YCR = Yellowstone Center for Resources

Image from © Google Earth

Buildings and Parking Areas Visited

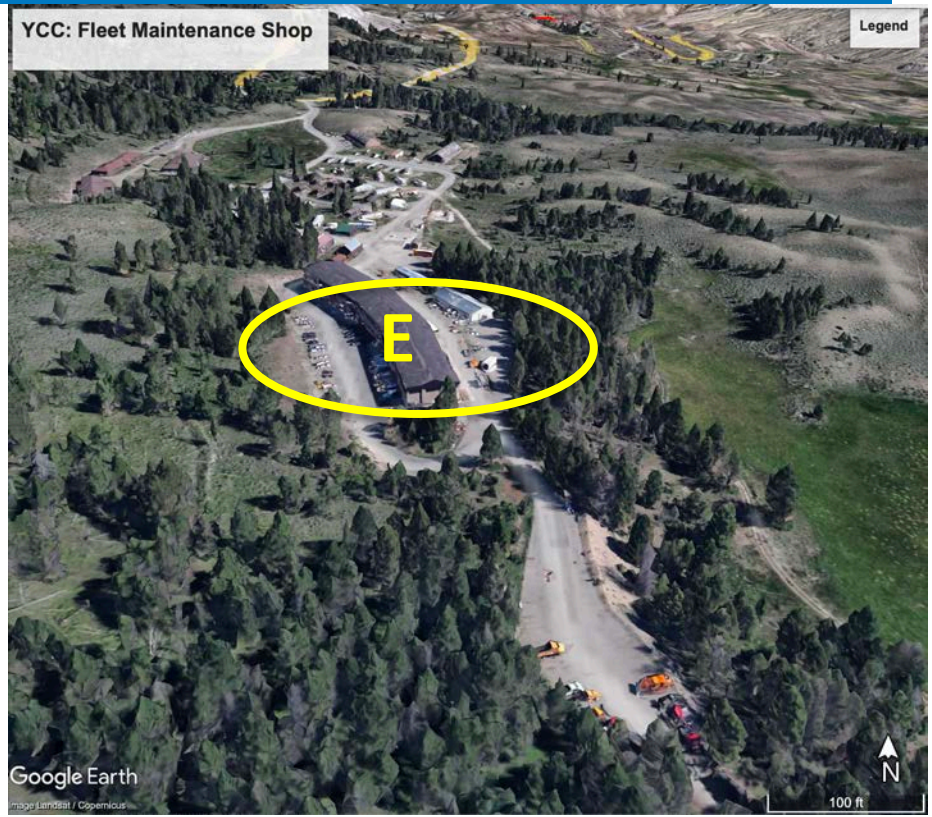
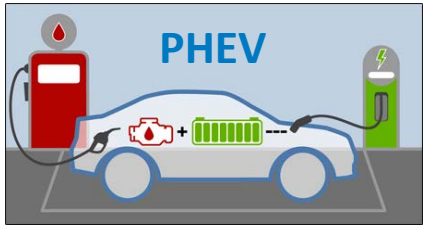


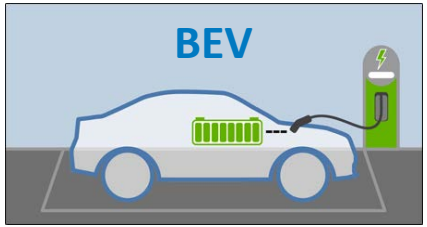
Image from © Google Earth

Contents

ZEV and EVSE Overview

- **Zero-Emission Vehicle (ZEVs)**
  - ZEVs include both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).
  - Acquisition requirements are set to 100% annually for LDVs by 2027 and MDVs/HDVs by 2035 per E.O. 14057.
  - Acquisition decisions are informed by fleet usage data and the ZEV Planning and Charging (ZPAC) tool.
- **Electric Vehicle Supply Equipment (EVSE)**
  - EVSE provides the charging power needed to deliver the energy an EV needs.
  - Level 1 AC chargers (typically portable) deliver approximately 5 miles of range per hour of charge.
  - Level 2 AC chargers (typically dual-port pedestal) deliver approximately 25 miles per hour of charge.





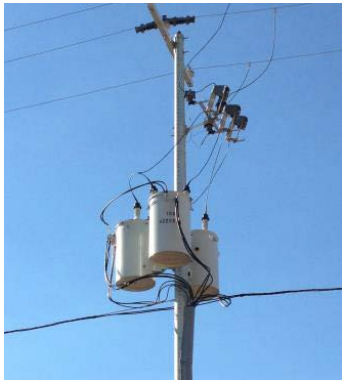
EVSE Installation Requirements

Site Equipment

- Circuit Breaker
  - NEC (National Electrical Code) 625.41: Overcurrent to be rated for 125% of maximum EVSE load.
- Panel Capacity
  - Spare breaker positions must be available.
- Main Breaker
  - It must be sized to supply *peak coincident demand* from all branch circuits.
- Transformer Capacity
  - The distribution transformer must be large enough to supply peak demand.

EVSE Requirements

- J1772 AC Level 1
  - Uses a single 20 A Breaker
    - 1.9 kW (120 V x 16 A)
- J1772 AC Level 2
  - Uses a double pole 40 A breaker
    - 7.7 kW (240 V x 32 A)
    - 6.7 kW (208 V x 32 A)



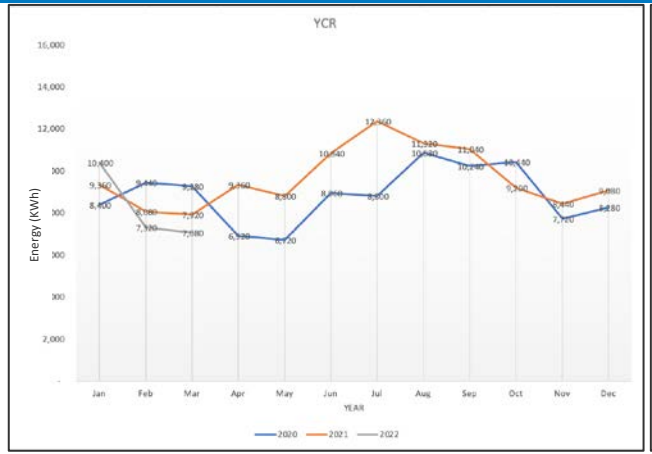
Energy versus Power

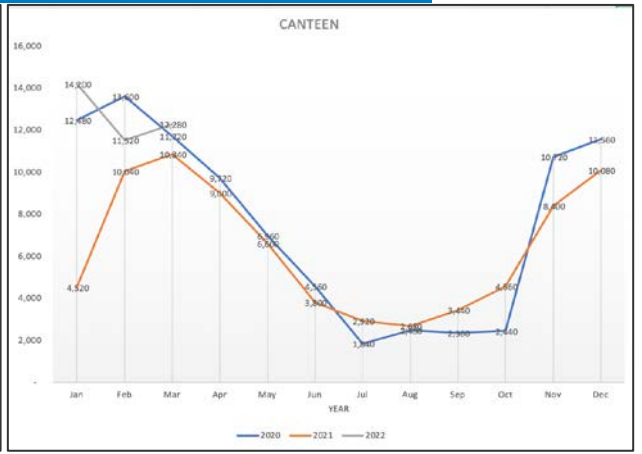
Peak demand for a given building consists of two factors:

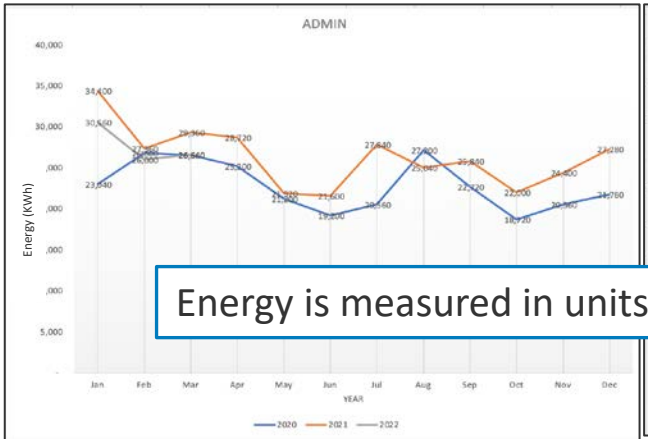
1. Quantity
2. Timing.

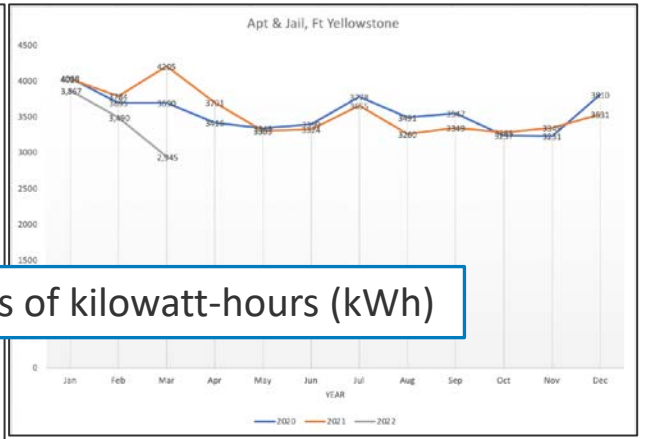
Utility companies typically measure power as the average demand over 15 minutes.

Power is measured in kilowatts (kW).









Energy is measured in units of kilowatt-hours (kWh)

Charging Station Considerations

1. Portability
2. Wi-Fi enabled
3. Maintenance and warranty
4. Hardwired or plugged in
5. Indoor versus outdoor
6. Outlet location and cord length
7. Dual charging and power sharing
8. Future-proofing

Available space in the electrical panel can indicate—but does not necessarily guarantee—whether capacity with the current electrical service is sufficient to add charging stations without an upgrade from the utility.

Three Fundamental EVSE Electrical Needs

1.Sufficient *electrical capacity from the utility connection to the electrical panel*
2. *Sufficient electrical capacity at the panel*
3. *Dedicated circuit for each EVSE unit on the electrical panel*

EVSE Electrical Considerations

Hardwired Installations

EVSE	Typical Charging Power	Typical Service Type	Typical Installation Requirements
AC Level 2	6.7 kW (32 A @ 208 V) 7.7 kW (32 A @ 240 V)	208Y/120 V 3Φ 120/240 V 1Φ	Hardwired EVSE, 40 A double-pole circuit breaker

Power of Station and Acceptance Rate

If the EVSE offers less power than the vehicle's maximum acceptance rate, the EVSE is the limiting factor in charge time. If the vehicle's acceptance rate is lower than the EVSE's maximum output rate, the vehicle is the limiting factor.

EVSE Power Specifications

ClipperCreek HCS-D40

- **Type:** Dual-port, Level 2, pedestal-style EVSE unit
- **Power:** 32 A, single-phase, 208 V (6.7 kW) or 240 V (7.7 kW)
- **Connection:** Hardwired, 40 A, double-pole circuit breaker
- **Options:** Ruggedized, ENERGY STAR, power sharing
    - NEMA (National Electrical Manufacturer Association) 4 enclosure with impact and crush-resistant charge couplers
    - Energy savings in standby mode and fully certified for safe operation
    - With one vehicle present, 32 amperes are available for charging. When two vehicles are present, 16 amperes are available to each vehicle for charging.

Assumptions for Cost Estimates

- EVSE costs are sourced from the U.S. General Services Administration (GSA).
- The electrical components are designed as per the National Electrical Code (NEC).
- The costs are estimated using the RSMeans costs.
- Project costs are assumed as fixed percentages as per the RSMeans.

Component	Assumed Fixed Percentage
Contingency Costs	20%
Taxes (Sales, State, Average)	7%
Overhead	15%
Profit	10%
Bond	2.50%
Permits	2.00%

Existing Yellowstone EVSE: Two Ports at Admin. Building

Building	Stop	Type	Rating (A)	Port Count
Jail/Outdoor Patio	A	n/a	n/a	n/a
YCR and Canteen	B	Clipper Creek	32	2
Admin. Building	C	n/a	n/a	n/a
Post Office	D	n/a	n/a	n/a
Fleet Maintenance Shop	E	n/a	n/a	n/a

Contents

Jail and Outdoor Patio: Stop A

Photos by Leidy Boyce, NREL

Current

Transformer Size	Building	Service Panel Amperage	Total Max Connected Amperage	EVSE Units
75 kVA 208Y 120 V	None	200 A	160 A	0
	None	200 A	160 A	0
	Jail	200 A	Unknown	0
	Outdoor Patio	200 A	Unknown	0

Proposed

*Using Existing Transformer

Transformer Spec	Building	Additional Service Panel	EVSE Units
75 kVA 208Y 120 V	Dedicated for EVSE	200 A	5
	Dedicated for EVSE	200 A	

Stop A Layout

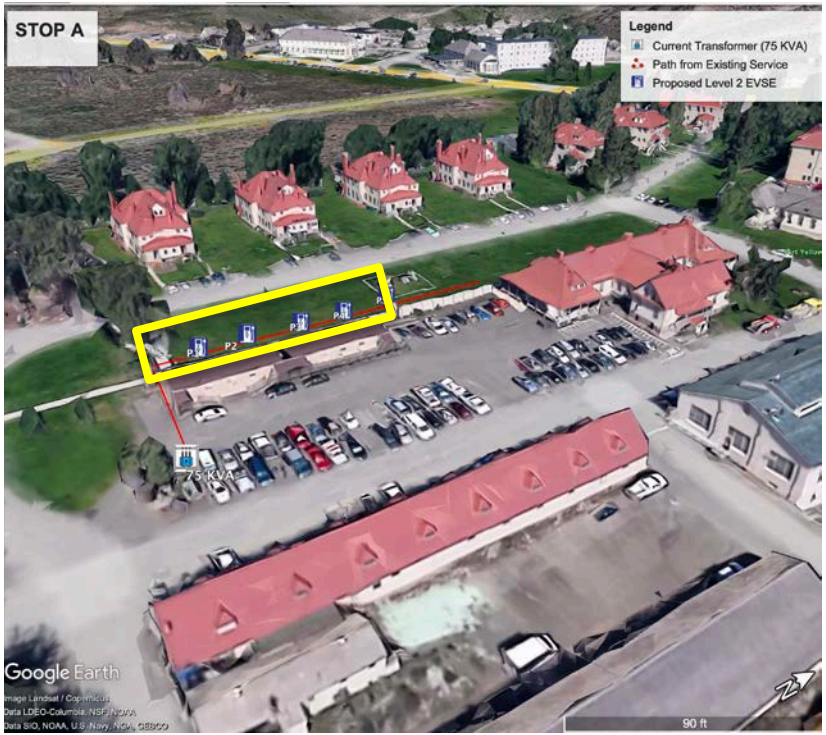


Image from © Google Earth

Dual-port Level 2 units = 10 ports

Transformer Upgrade	New Service Panel Amperage	Number of Parking Spots	EVSE Units
No	Yes (2X200 A)	21	5

Stop A Considerations

PROS

- Many parking spots are available.
- 400 A service is available.

CONS

- Installing more than five EVSE to support future privately owned vehicle (POV) charging needs would require a transformer upgrade.

RECOMMENDATIONS

- Install five dual-port pedestal units.
- Add new service panel.

Contents

Stop B: YCR and Canteen

Photos by Leidy Boyce, NREL

Current

Transformer Size	Building	Service Panel	Note
75 kVA 208Y/120 V	YCR	400A	Three-phase
	Canteen	400 A	Single-phase (10 spare breaker)

Proposed

*Using Existing Transformer

Transformer Spec	Building	Additional Service Panel	EVSE UNITS
75 kVA 208Y 120 V	YCR, Dedicated for EVSE	Yes, 200 A	2
	Canteen	No	3

Stop B: YCR and Canteen Layout

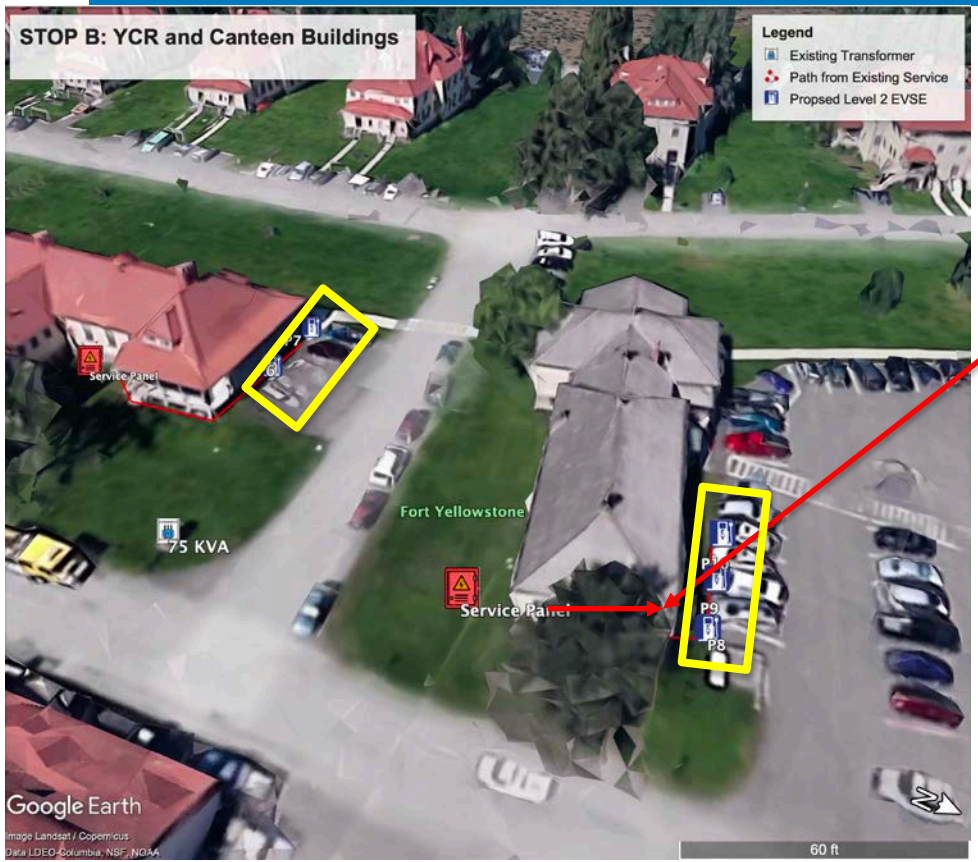


Image from © Google Earth

Photos by Leidy Boyce, NREL

5 Dual-port Level 2 units = 10 ports

Transformer Upgrade	New Service Panel Amperage	Number of Parking Spots	EVSE Units
No	Yes (at YCR building)	4	2
	No (at Canteen)	7	3

Stop B Considerations

PROS

- At YCR: No trenching through concrete needed. Conduit could be run along the porch.
- At Canteen: Spare breakers are available to accommodate three proposed EVSE.

CONS

- At YCR: Single-phase subpanel dedicated for EVSE is needed.
- Building peak demand at YCR and Canteen buildings is unknown.

RECOMMENDATIONS

- Install five dual-port pedestal units.
- Add new service panel at YCR.
- Perform load study at each building.

Contents

Stop C: Admin. Building

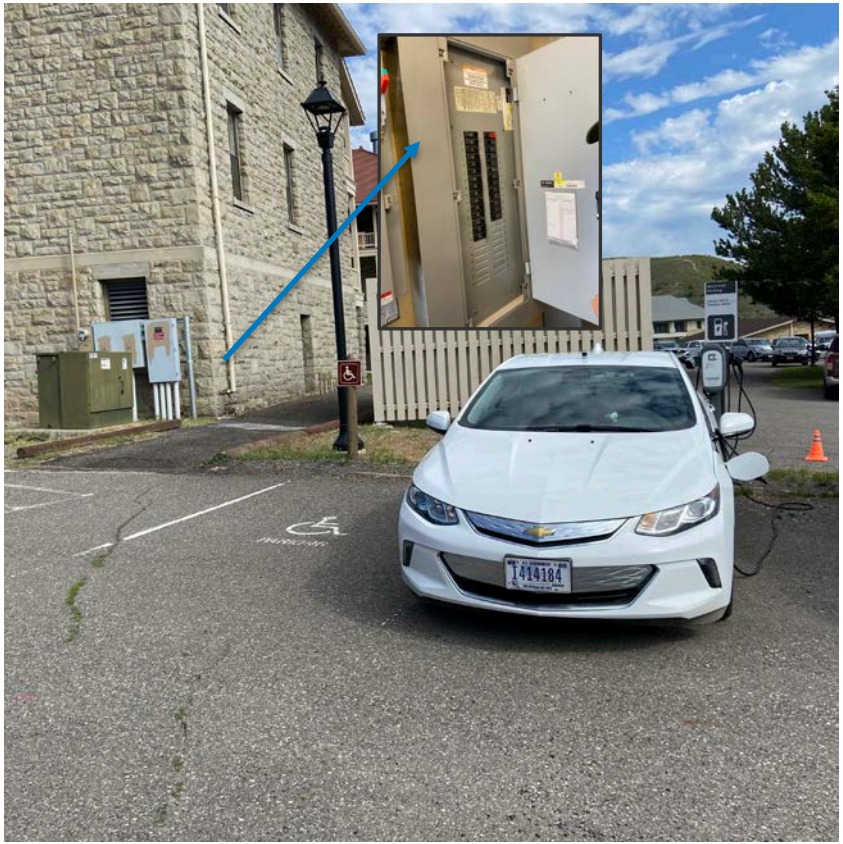


Photo by Leidy Boyce, NREL

Current

Transformer Spec	Building	Service Panel Amperage	EVSE Units
150 kVA 208Y/120 V	Admin	225 A	2

Proposed

Transformer Spec	Building	Additional Service Panel Amperage	EVSE Units
150 kVA 208Y 120 V	Admin	No	1

Stop C: Admin. Building Layout

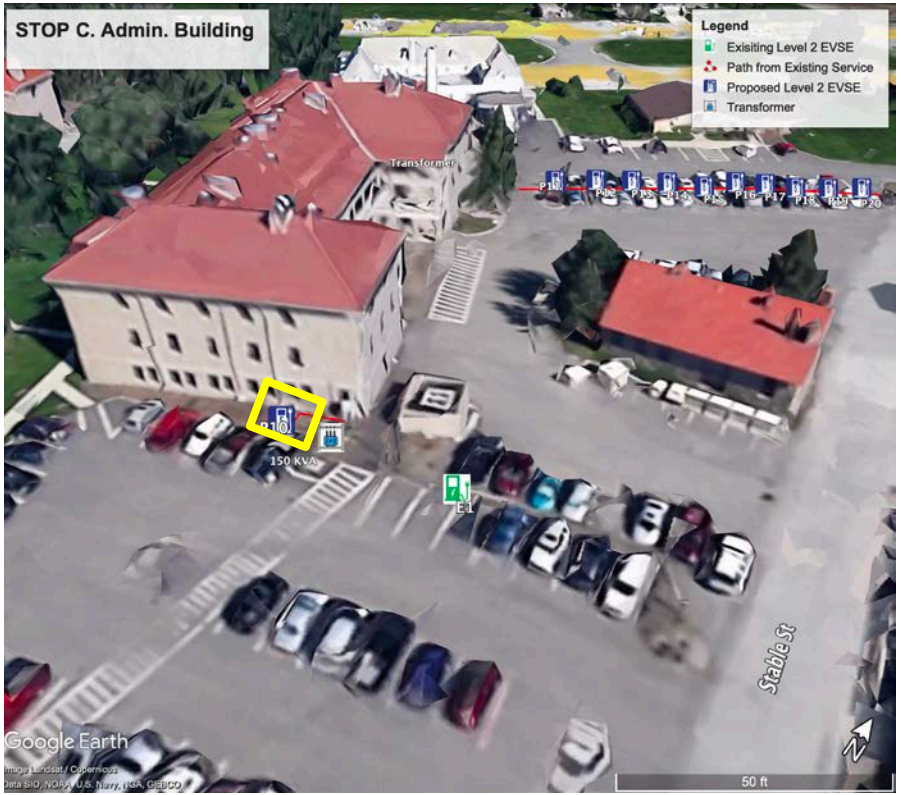


Image from © Google Earth

1 Dual-port Level 2 units = 2 ports

Transformer Upgrade	New Service Panel Amperage	Number of Parking Spots	EVSE Units
No	No	5	1

Stop C Considerations

PROS

- Dedicated 225 A service panel for EVSE.
- Short distance from service panel.

CONS

- Building loads could not be evaluated.

RECOMMENDATIONS

- Install one dual-port pedestal unit on existing 225 A service panel.

Contents

Stop D: Post Office

Photo by Leidy Boyce, NREL

Current

Transformer Spec	Building	Service Panel Amperage	EVSE Units
25 kVA	Post Office	Unknown	0

Proposed

Transformer Spec	Building	Service Panel Amperage	EVSE Units
225 kVA	Post Office	800 A	10

Stop D: Post Office Layout

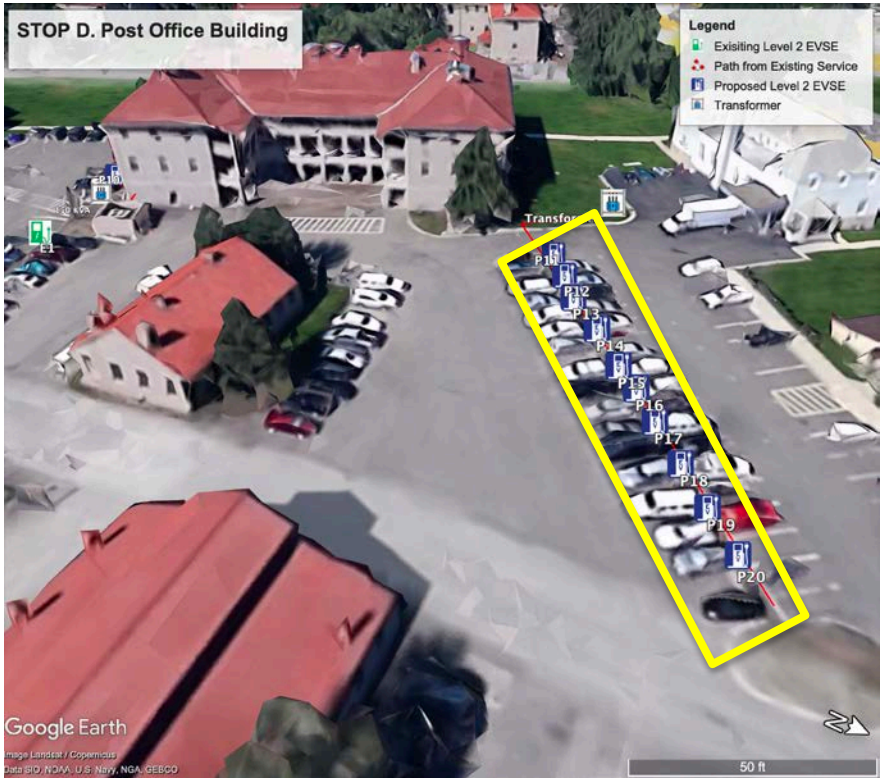


Image from © Google Earth

10 Dual-port Level 2 units = 20 ports

Transformer Upgrade	New Service Panel Amperage	Number of Parking Spots	EVSE Units
Yes	Yes	20+	10

Stop D Considerations

PROS

- Plenty of parking spaces available for EVSE.
- Most trenching is through softscape.

CONS

- Transformer upgrade from 25 kVA to 225 kVA.
- New service panel needed.

RECOMMENDATIONS

- Install 10 dual-port pedestal units.
- Talk to utility about the distribution transformers.

Contents

YCC/Fleet Maintenance Shop: Stop E

This is the maintenance location for all fleet vehicles and the storage location for most MDVs and HDVs. It is a large multi-bay garage with three-phase power.

Photos by Jesse Bennett, NREL

Recommendations

- **Near Term:** Install L2 EVSE for LDVs.
  - Provide access to charging power for vehicles undergoing maintenance or repairs.
  - Power EVSE from subpanel and step-down transformer from spare circuit on MDP (shown on the right in red).
  - 40–80 A (9.6 kW–19.2 kW), which is ideal for MDVs.
- **Long Term:** Install direct current fast charging (DCFC) for MDVs and HDVs.
  - Install DCFC to support regular charging needs of large MDVs and HDVs.
  - Power EVSE from spare three-phase breaker positions in MDP (shown on the right in blue).

Tiger Team Recommendations for EVSE Deployment

Stop	Building	Existing EVSE Ports	Planned New EVSE Ports	Recommendations	Estimated Total Installation Cost*
A	Jail and Outdoor Patio	0	10	400 A, single-phase service panel needed (20 circuit breaker)	$120K
B	YCR and Canteen	0	10	Single-phase service panel needed at YCR building	$131K
D	Post Office	0	20	Transformer upgrade from 25 kVA to 225 kVA	$256K
Total		**0**	**40**		**$507K**

*Cost includes EVSE units, materials, and labor. Labor wage estimates are from RSMeans.com. The RSMeans includes the labor wages as national average.

EVSE Deployment Recommendations

1. Daily vehicle utilization data from telematics would enable a better understanding of the number of EVSE ports required at the location.

2. Prioritize EVSE siting based on proximity to power source, service panel electrical and physical (spare breakers) availability.

3. Perform a building load study to assess existing loads and expected EVSE loads.

Thanks

National Park Service

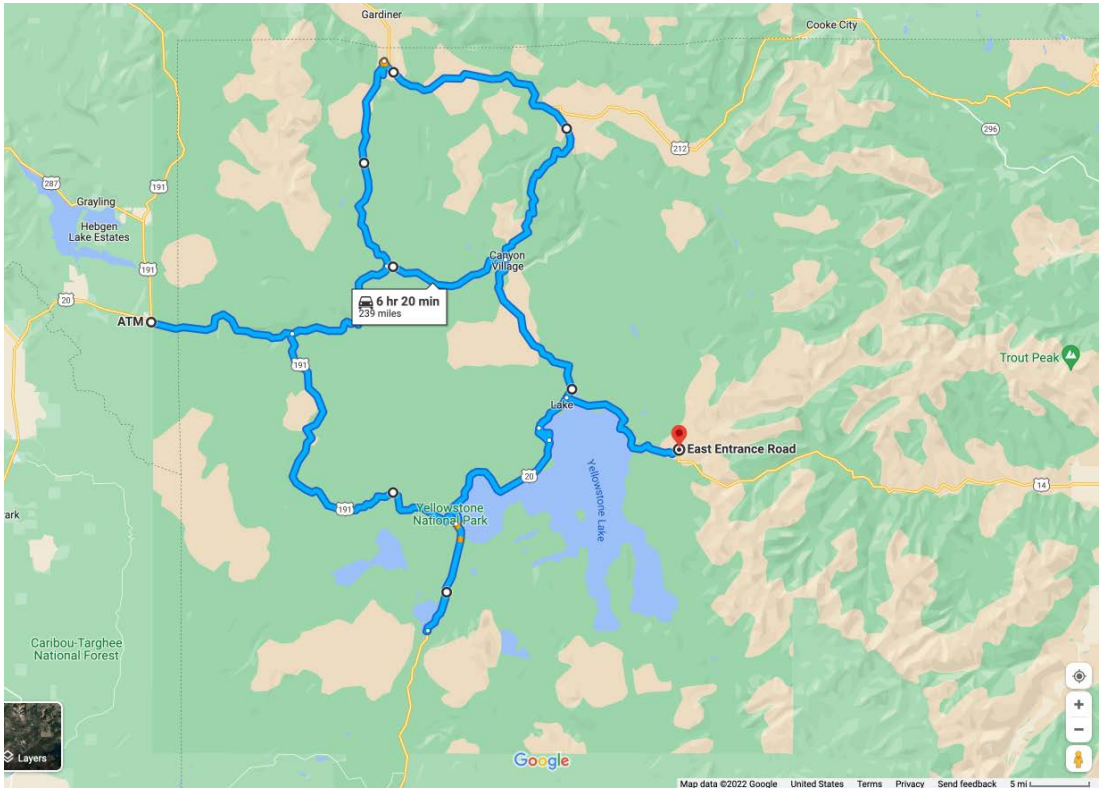
FEMP-NREL Tiger Team

Special thanks to:

- **Lynn Chan**, Landscape Architect/Project Manager, Sustainability Division of Facility Management and Operations, Yellowstone National Park
- **Rachel Dodgen,** FMSS Specialist, Yellowstone National Park
- **April D Browning,** Transportation Specialist, Yellowstone National Park
- **Chris White**, Electrician, Yellowstone National Park

Appendix: Guidelines for EV Operations and Fleet Resources

Can EVs do the job at Yellowstone National Park?



The short answer is *yes*.

Potential ZEV Replacement			
BEV SIN	PHEV SIN	Make/Model	Range (Electric miles)
55E		Ford F150 Lightning	350 miles
55E		Ford F150 Lightning	350 miles
55E		Ford F150 Lightning	350 miles
96E		Ford Mustang Mach-E / Tesla Model Y	270 miles / 326 miles
96E		Ford Mustang Mach-E / Tesla Model Y	270 miles / 326 miles
96E	96P	Ford Mustang Mach-E / Tesla Model Y	270 miles / 326 miles
96E	96P	Ford Mustang Mach-E / Tesla Model Y	270 miles / 326 miles
	20P	Pacifica	32 miles
55E		Ford F150 Lightning	350 miles
55E		Ford F150 Lightning	350 miles
91E		Ford Mustang Mach-E	300 miles
96E		Ford Mustang Mach-E / Telsa Model Y	270 miles / 326 miles
8E, 9E		Nissan Leaf / Chevrolet Bolt / Tesla Model 3	226 miles/247 miles/ 262 miles
8E, 9E		Nissan Leaf / Chevrolet Bolt / Tesla Model 3	226 miles/247 miles/ 262 miles
8E, 9E		Nissan Leaf / Chevrolet Bolt / Tesla Model 3	226 miles/247 miles/ 262 miles

Battery: Idling Misconceptions

- Electric cars do not idle.
- An EV only uses electricity to drive when it is moving.

Battery: Idling Facts

- Electricity is used to power basic electronics in the EV when it is sitting "idle."
- When an electric vehicle is *not* in motion, it consumes about 1-2 kW of power for climate control.

Range Reduction $\approx \frac{3\ miles}{1\ hr\ of\ idling} x\ 6\ hrs \approx 18\ miles$

An EV with a 40-kWh battery and Fuel Economy of $\frac{30\ KWh}{100\ miles}$

Energy Usage $\sim 18\ miles\ x \frac{30\ KWh}{100\ miles} = 5.4\ KWh$

$$\frac{32\ KWh}{5.4\ KWh} \rightarrow \frac{80\ \%}{?}$$

? = 13.5%

Range Reduction

$$\sim \frac{3\ miles}{1\ hr\ of\ idling}$$

EV Charging Infrastructure Specifications and Performance

Type	Input Power	Maximum Output Power (kW)	Driving Miles per 1-Hour Charge	Maximum Driving Miles per 6-Hour Charge	Maximum Driving Miles per 9-Hour Charge
AC Level1 Outlet	120V AC, 15-20 A	1.4	5	30	45
AC Level 2 EVSE	120V AC, 15-20 A	1.9	7	42	63
AC Level 2 EVSE (low power)	240V AC, 20 A	3.3	10-12	60-72	90-108
AC Level 2 EVSE	240V AC or 208V AC 40 A	6.6	20-25	120-150	180-225

Measuring and Reporting Electricity Use in Electric Vehicles

Federal fleet reporting *does not require measuring electricity at the EVSE*. Instead, EV energy consumption must be reported to the Federal Automotive Statistical Tool (FAST).

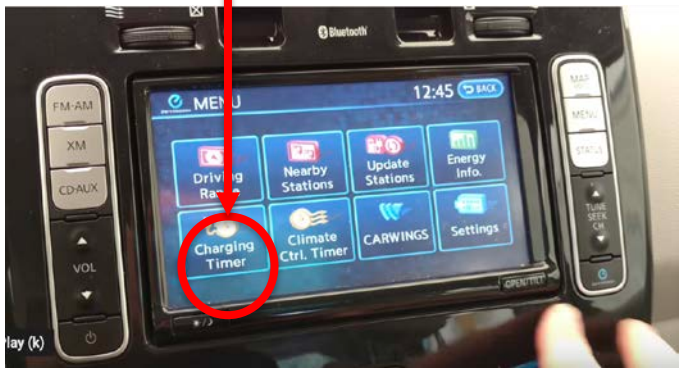
Four Different Methods

1. Meter at on-site EV charging station.
2. Use telematics to capture energy consumption in kWh from EVs.
3. Estimate using FEMP measurement and verification standards.
4. Collect transaction receipts at off-site EV charging station.

Charging Best Practices

1. Charge the battery to only 80% and discharge it to 20%.
2. Aim to use 60% of the capacity.
3. Battery temperature governs how fast a battery can be charged, for example:
   - At 40°C (104°F), a battery charges in 1.0 hour compared to 1.5 hours at 5°C (41 °F), but the packs degrades more quickly than at a moderate 25°C (77 °F).
4. Industry standards have rated Level 2 charger operation as optimal between -20°C/-4°F and 50°C/122°F and fast chargers as optimal between -5°C/-31°F and 50°C/122°F.
5. Fast charging is most effective at a state of charge of 20%–50%.

Charging Timer Settings



Source: https://www.youtube.com/watch?v=WeR0SXzQdto

POV Considerations: Network versus Non-Network EVSE

- Network costs range from $250 to $1,250 per year per port.
- Maintenance service plans range from $200 to over $1,000 per year (port/station coverage varies).
- Cellular connection plans are not available through GSA; they may be negotiated with mobile phone and internet carriers.
- Telematics subscriptions are available through GSA for *$156 per year per vehicle*.
- GSA telematics plan details can be found at GSA:
  - "Telematics: GSA Fleet's Telematics Program - Driving Innovation in Federal Fleet Management," GSA, https://www.gsa.gov/buying-selling/products-services/transportation-logistics-services/fleet-management/vehicle-leasing/telematics.

POV Considerations: Network versus Non-Network EVSE

Feature	Network	Non-Network
Purchase and installation costs	$$$	$
Maintenance and downtimes	$$$	$
Ability to set pricing of EV charging	Yes	No
EVSE usage data	Yes	No

POV Considerations: Reimbursement Is Mandatory

Alternative to New Unit Installation	Employees will need to reimburse the facility for the cost of electricity but not the cost of the unit or installation. - 42 U.S.C. §6364.
New Unit Installation	Fees must be collected for POV charging at government-owned EVSE, which may include electricity costs, unit and installation costs, network fees, and transaction fees. - Fixing America's Surface Transportation Act

POV Considerations: How To Collect Fees?

1. Agencies may work with pay.gov's implementation team at pay.gov@fiscal.treasury.gov to establish a web-based collection system using either a general form or unique bill issued for each employee.
2. Agencies can customize a payment system through this e-billing service managed by the U.S. Department of the Treasury that will send a monthly bill to employees.
3. Agencies may alternatively withdraw the fee from employee's payroll as a post-tax deduction and then deposit the money into a Treasury account.

Source: https://www.pay.gov/public/home

POV Recommendation

If using EVSE installed for government owned vehicles (GOV), consider networked EVSE to access management (payment processing is needed).

Appendix C: POV Fee Calculations in *Federal Workplace Charging Program Guide*

https://www.energy.gov/eere/femp/articles/federal-workplace-charging-program-guide

How to collect fees:

https://www.pay.gov/public/home

Battery Life and Operational Range

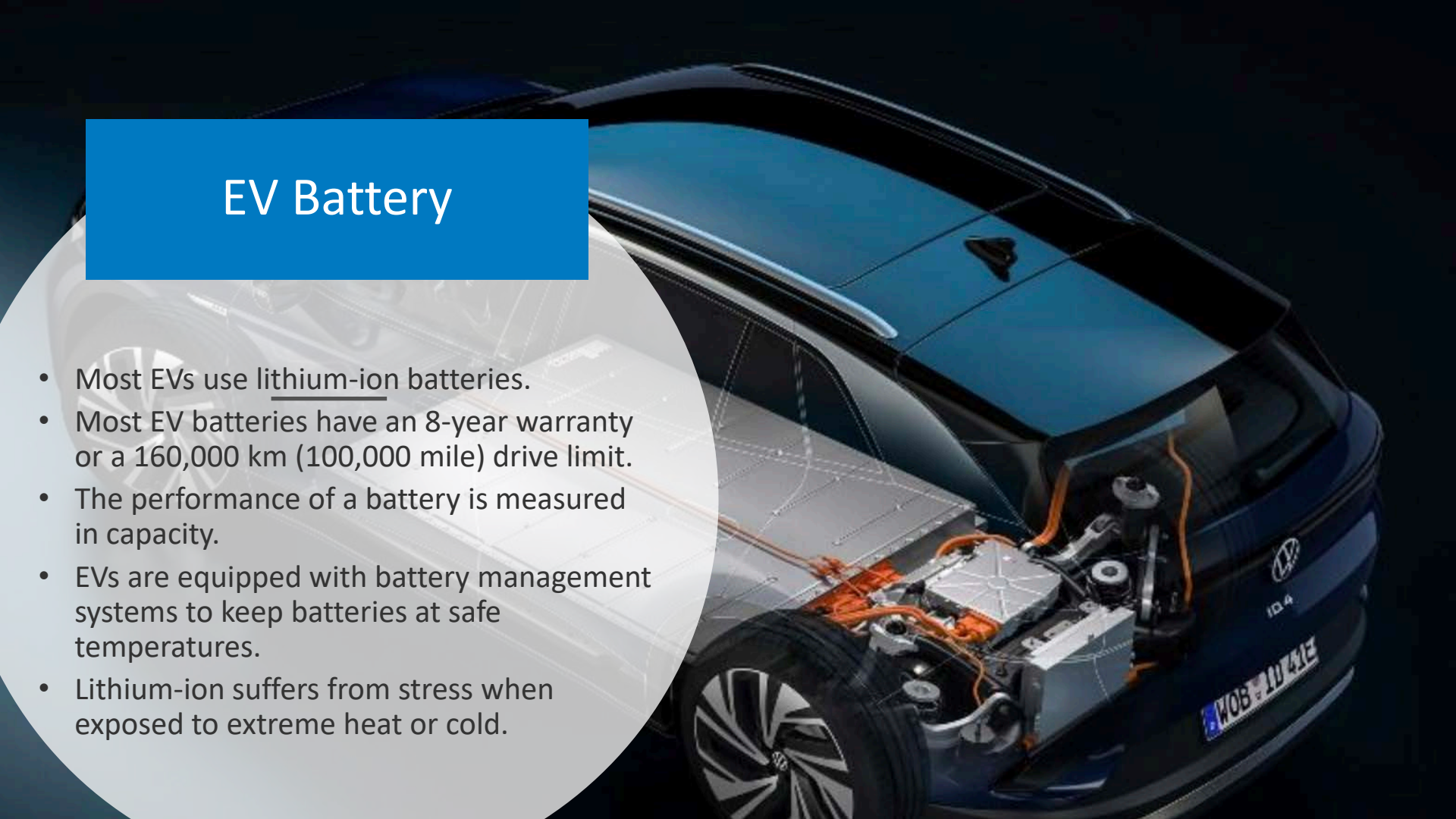
- Cold winter months
- Long idling times
- Wildlife-related traffic jams

A group of bison walk along the road towards Lamar Valley with cars following behind them

NPS / Jacob W. Frank

EV Battery

- Most EVs use lithium-ion batteries.
- Most EV batteries have an 8-year warranty or a 160,000 km (100,000 mile) drive limit.
- The performance of a battery is measured in capacity.
- EVs are equipped with battery management systems to keep batteries at safe temperatures.
- Lithium-ion suffers from stress when exposed to extreme heat or cold.



EV Battery and Temperature Relationship

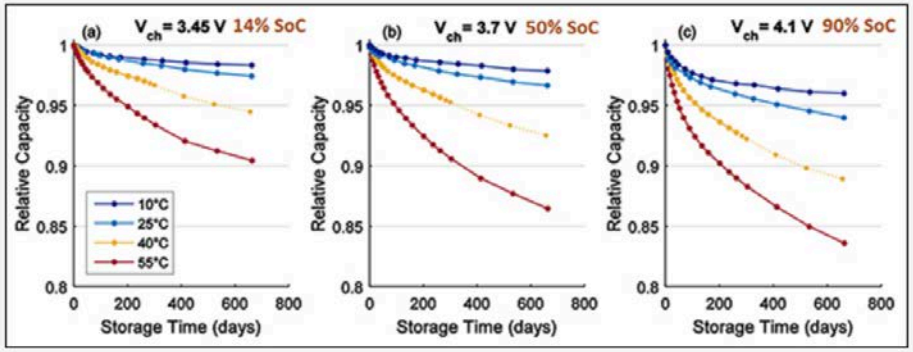


Figure 3: Capacity fade by calendar aging with different charge end voltages and temperatures [1]

Estimated Recoverable Capacity When Storing Li-ion for 1 Year at Various Temperatures

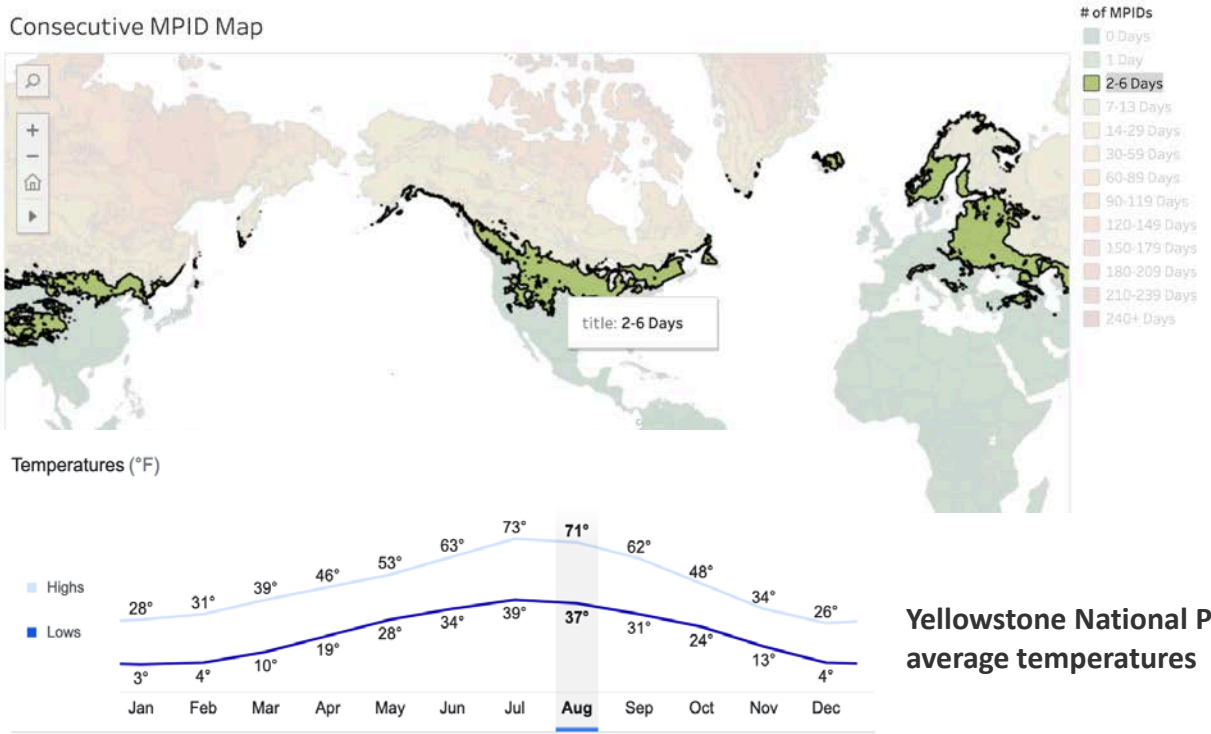
TEMPERATURE	40% CHARGE	100% CHARGE
0°C	98% (after 1 year)	94% (after 1 year)
25°C	96% (after 1 year)	80% (after 1 year)
40°C	85% (after 1 year)	65% (after 1 year)
60°C	75% (after 1 year)	60% (after 3 months)

- Historical data from Tesla show capacity degradation of about 5% after 80,000 km (50,000 miles).
- Geotab cited an average decline in battery heath of 2.3% per year.
- Reports reveal that under the right conditions *capacity fade in storage can be kept below 10% in 15 years*.
- Capacity fade only reduces the driving range while power remains strong.

Sources

- "BU-1003a: Battery Aging in an Electric Vehicle (EV)," Battery University, last updated August 27, 2019, https://batteryuniversity.com/article/bu-1003a-battery-aging-in-an-electric-vehicle-ev
- "BU-808: How to Prolong Lithium-Based Batteries)," Battery University, last updated November 3, 2021, https://batteryuniversity.com/article/bu-808-how-to-prolong-lithium-based-batteries

Must-Plug-In Day (MPID) Map



Yellowstone National Park average temperatures

MPIDs are defined as the maximum number of days in the 10-year data period for a location where the average daily temperature did not exceed -20 C.

Source: ACEP EV MAP, https://public.tableau.com/app/profile/michelle1506/viz/ACEPEVMAP_16061795177860/Home?publish=yes

EV Storage Guidelines

The recommended state of charge for long-term storage is 40%–50%.

- Exposing the battery to high temperature (a battery dwelling above 30°C (86°F) is considered *elevated temperature)* and dwelling in a full state-of-charge for an extended time can be more stressful than cycling.
- The main cold weather issues impacting EVs are range decreases, slower charging speed, lower power in extreme cold, and the need to keep a vehicle plugged in or housed in a heated space, especially during extended periods below -4°F, to prevent a partial discharge; this reduces stress and prolongs battery life.
- Lower charge voltages and cooler temperatures preserve the Li-ion battery when not in use.

Source: "BU-1003a: Battery Aging in an Electric Vehicle (EV), Battery University, last updated August 27, 2019, https://batteryuniversity.com/article/bu-1003a-battery-aging-in-an-electric-vehicle-ev.

EVSE Recommendations: Site Preparation

1. EV charging for fleet vehicles with long-dwell periods should be focused on lower power AC Level 1 [1.9 kW] or low-power AC Level 2 [3.3 kW], “slower” low-cost charging infrastructure options.
2. Charging station installations should have a load analysis performed on the facility’s electrical demand to determine whether capacity is sufficient to add EV charging stations.
3. Consult with licensed electrician and notify your local utility of EVSE deployment plans. The local utility must determine whether the local distribution system is sufficient.
4. Minimize the distance between the electrical panel and EV charging station.
5. When possible, use electrical panels with additional capacity and available breaker slots.
6. Fit the design to the required electrical capacity.
7. Place EV charging stations where a single charging port cable can be accessed via multiple spaces.
8. Ensure the charging station is well integrated into the parking lot. Consider the path of the charging cord when in use so it is not a tripping hazard and evaluate your parking lot management practices.
9. Use charging station protection to prevent cars, snowplows, or sweepers from hitting the station or snagging the charging cords.
10. Consider cellular signal strength, an important factor for networked EV charging station installations.
11. Consider future-proofing by building in enough electrical capacity for EVSE expansion.
12. Install a load management system to regulate power distribution of charging stations based on demand.

EVSE Recommendations: Monitoring

1. **Measure and report electricity use in electric vehicles.**
   - Monitor electricity usage using EVSE software, which is available through network subscription.
   - Place new meters close to a power source to reduce trenching costs.
   - Use telematics to capture energy consumption in kWh from EVs.

2. **When sharing EVSE with POVs, be sure to use network subscriptions.**

3. **Take advantage of incentives offered by utilities that might reduce the cost of separate meters.**

EVSE Recommendations: Operations

1. Charge the battery to only 80% and discharge it to 20%.
2. Avoid extended dwell periods in a full state of charge and during exposure to extreme temperatures.
3. For fleet pool vehicles, consider using a parking reservation system to manage access and inform drivers of available mileages.
4. Establish an EV charging station usage policy.
5. Use visible signage and pavement markings identifying EVSE. Doing so helps EV drivers locate stations and fosters increased EV awareness.

RESOURCES

Procuring Electric Vehicle Infrastructure through GSA

- Electric Vehicle Charging Stations, GSA

Energy Savings Performance Contracts (ESPCs)

- Procuring Electric Vehicle Infrastructure, DOE

Utility Energy Service Contracts (UESCs)

- Utility Program and Utility Energy Service Contracts for Federal Agencies, DOE FEMP
- DOE Qualified Energy Service Companies, DOE FEMP

Federal Workplace Charging Program Guide
www.energy.gov/eere/femp/articles/federal-workplace-charging-program-guide

- Appendix C: POV Fee Calculations, DOE

How to Collect Fees

- See www.pay.gov.

UESC On-Demand Webinar Series: Phase 1—Acquisition Planning
"Whole Building Design Guide," National Institute of Building Sciences, education.wbdg.org

- UESC On-Demand Webinar Series: Introduction Part 1—Overview and Background
- UESC On-Demand Webinar Series: Introduction Part 2—Legislation and Contracting
- UESC On-Demand Webinar Series: Phase 1—Acquisition Planning
- UESC On-Demand Webinar Series: Phase 2—Utility Selection and Preliminary Assessment
- UESC On-Demand Webinar Series: Phase 3—Project Development
- UESC On-Demand Webinar Series: Phases 4 and 5— Project Implementation and Construction, and Post-Acceptance Performance
- UESC On-Demand Webinar Series: Advanced Topics — Performance Assurance

RESOURCES

Smart Charging Case Study

- *Integrating Electric Vehicle Charging Infrastructure into Commercial Buildings and Mixed-Use Communities: Design, Modeling, and Control Optimization Opportunities*, Shanti Pless, Amy Allen, Lissa Myers, David Goldwasser, Andrew Meintz, Ben Polly, and Stephen Frank (NREL).

Cybersecurity

- *Vehicle Cybersecurity Threats and Mitigation Approaches*, Cabell Hodge, Konrad Hauck, Shivam Gupta, and Jesse Bennett (NREL)
- "Federal Fleet Cybersecurity," DOE FEMP
- Government Fleet and Public Sector Electric Vehicle Supply Equipment (EVSE) Cybersecurity Best Practices and Procurement Language Report, U.S. Department of Transportation Volpe Center
- Vehicle Cybersecurity Threats and Mitigation Approaches, Cabell Hodge, Konrad Hauck, Shivam Gupta, and Jesse Bennett (NREL)
- DOE labs conducting research
  - "Recommended Cybersecurity Practices for EV Charging Systems," Jay Johnson et al. (Sandia National Laboratories)
  - "Review of Electric Vehicle Charger Cybersecurity Vulnerabilities, Potential Impacts, and Defenses," Jay Johnson et al. (Sandia National Laboratories)
- Joint Office of Energy and Transportation (DOT/DOE)
  - National Electric Vehicle Infrastructure Formula Program, DOT
- Industry activities
  - SAE PKI Task Force: "SAE International Performs First Test of EV Charging Public Key Infrastructure Design" (SAE, April 27, 2022)
  - SAE/ISO Vehicle Cybersecurity Engineering: "Road Vehicles - Cybersecurity Engineering ISO/SAE21434" (SAE, August 31, 2021)
  - Auto-ISAC: "Community Calls"
  - Open Charge Alliance: Improved Security for OCPP 1.6-J Edition 3 Final, February 17, 2022 (Open Charge Alliance White Papers)

EV Battery Health

- "What Can 6,000 Electric Vehicles Tell Us About EV Battery Health?" by Charlotte Argue (Geotab *Electric Vehicles* blog, July 7, 2020)
- "Overcoming EV Range Anxiety with Electric Vehicles," by Lindsey Hall (Geotab *Electric Vehicles* blog, June 21, 2022)

Acronyms and Abbreviations

A	ampere
AC	alternating current
AO	agency-owned
BEV	battery electric vehicle
DCFC	direct current fast charging
DOE	U.S. Department of Energy
ESPC	energy savings performance contract
EV	electric vehicle
EVI-LOCATE	electric vehicle infrastructure localized charging assessment tool and estimator
EVSE	electric vehicle supply equipment
FEMP	Federal Energy Management Program
GL-W	GSA wet lease
GSA	U.S. General Services Administration
HDV	heavy-duty vehicle
ISAC	Information Sharing and Analysis Center
ISO	International Organization for Standardization
LDV	light-duty vehicle
kVA	kilo-volt-ampere
kW	kilowatt
kWh	kilowatt-hours
MDP	main distribution panel
MDV	medium-duty vehicle
MPID	must-plug-in day
NEC	National Electrical Code
NEMA	National Electrical Manufacturer Association
NREL	National Renewable Energy Laboratory
OCPP	Open Charge Point Protocol
PHEV	plug-in hybrid electric vehicle
PKI	public key infrastructure
POV	privately owned vehicle
SIN	standard item number
UESC	utility energy service contract
V	volts
VAC	volts-alternating current
YCC	Youth Conservation Corps
YCR	Yellowstone Center for Resources
ZEV	zero-emission vehicle
ZPAC	ZEV Planning and Charging

www.nrel.gov

NREL/PR-5400-84084

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Federal Energy Management Program. The views expressed in the report do not necessarily represent the views of the DOE or the U.S. Government.