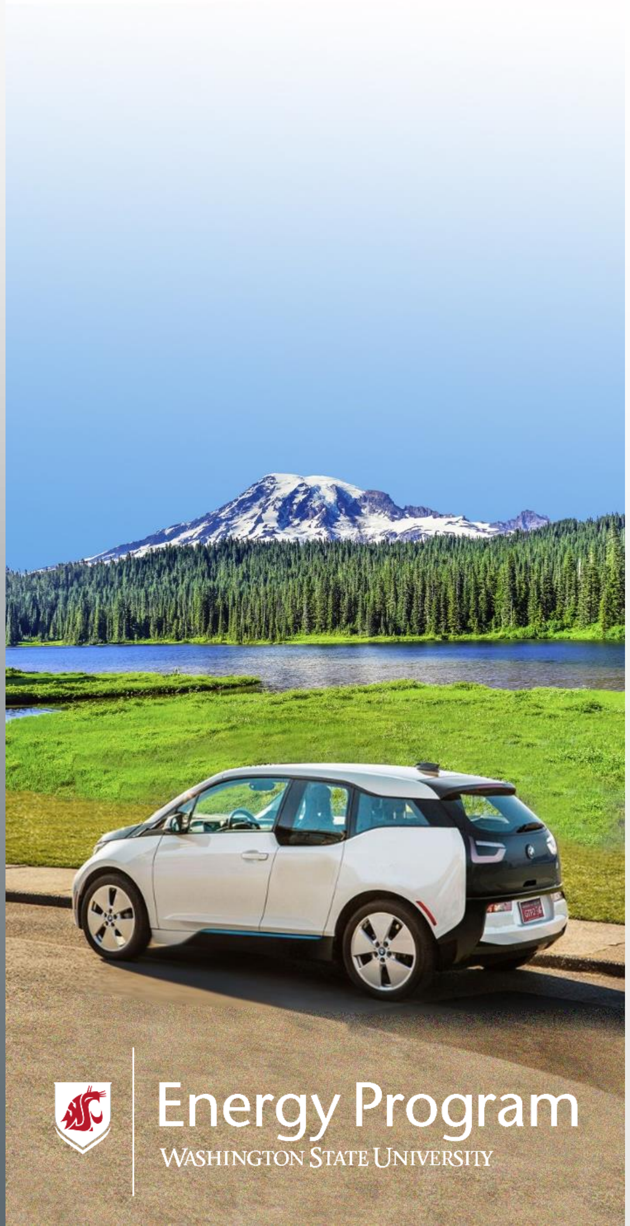
Washington
Green Transportation Program
Moving forward with Washington's public fleets



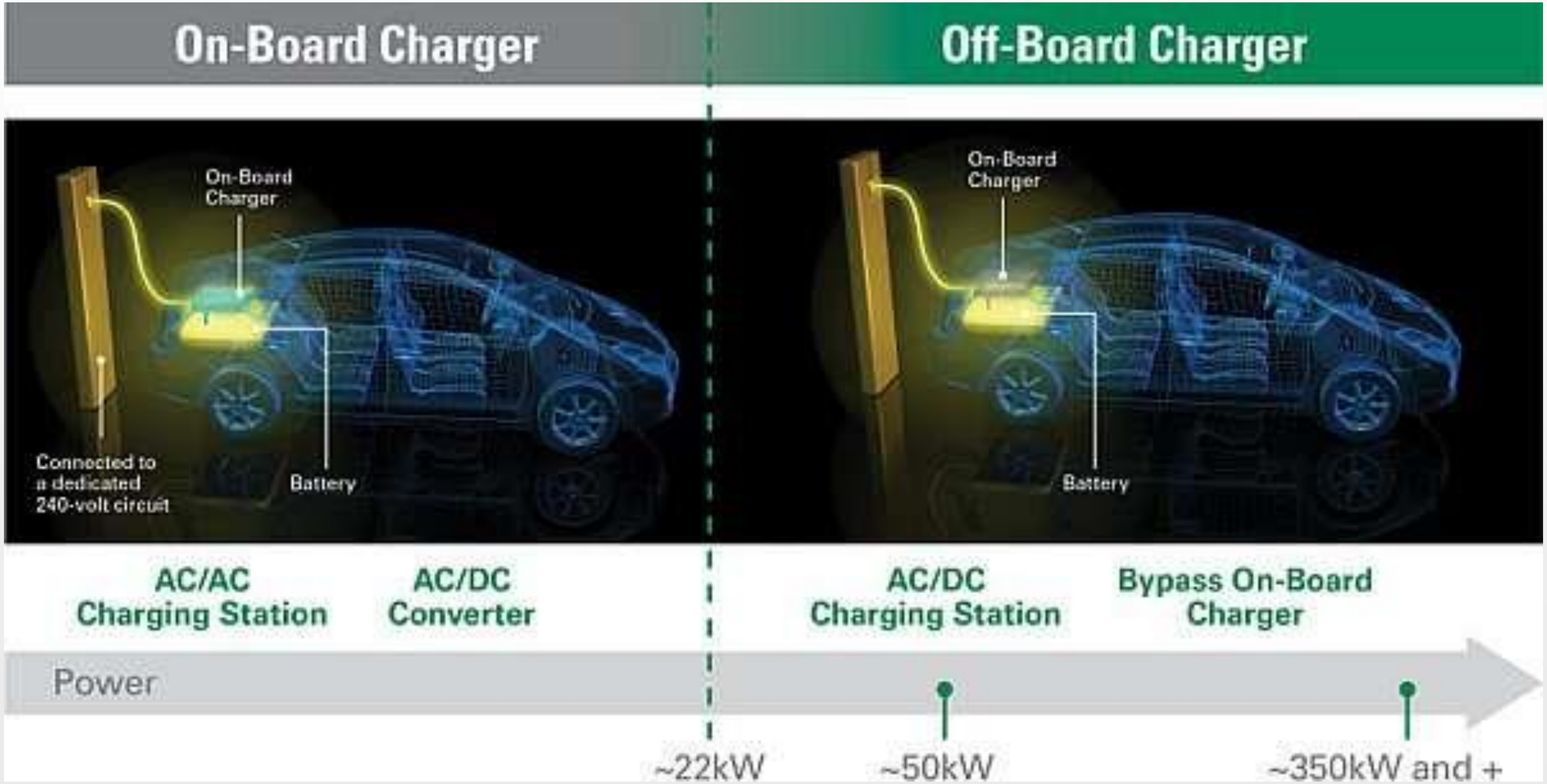
Public Fleet Electrification Planning

EV Charging Considerations
DCFC vs. AC Level 2
How to Work With Utilities

Jon Jantz

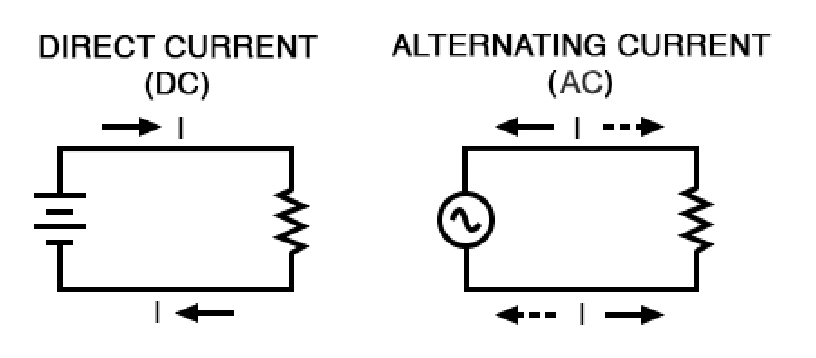
May 2022

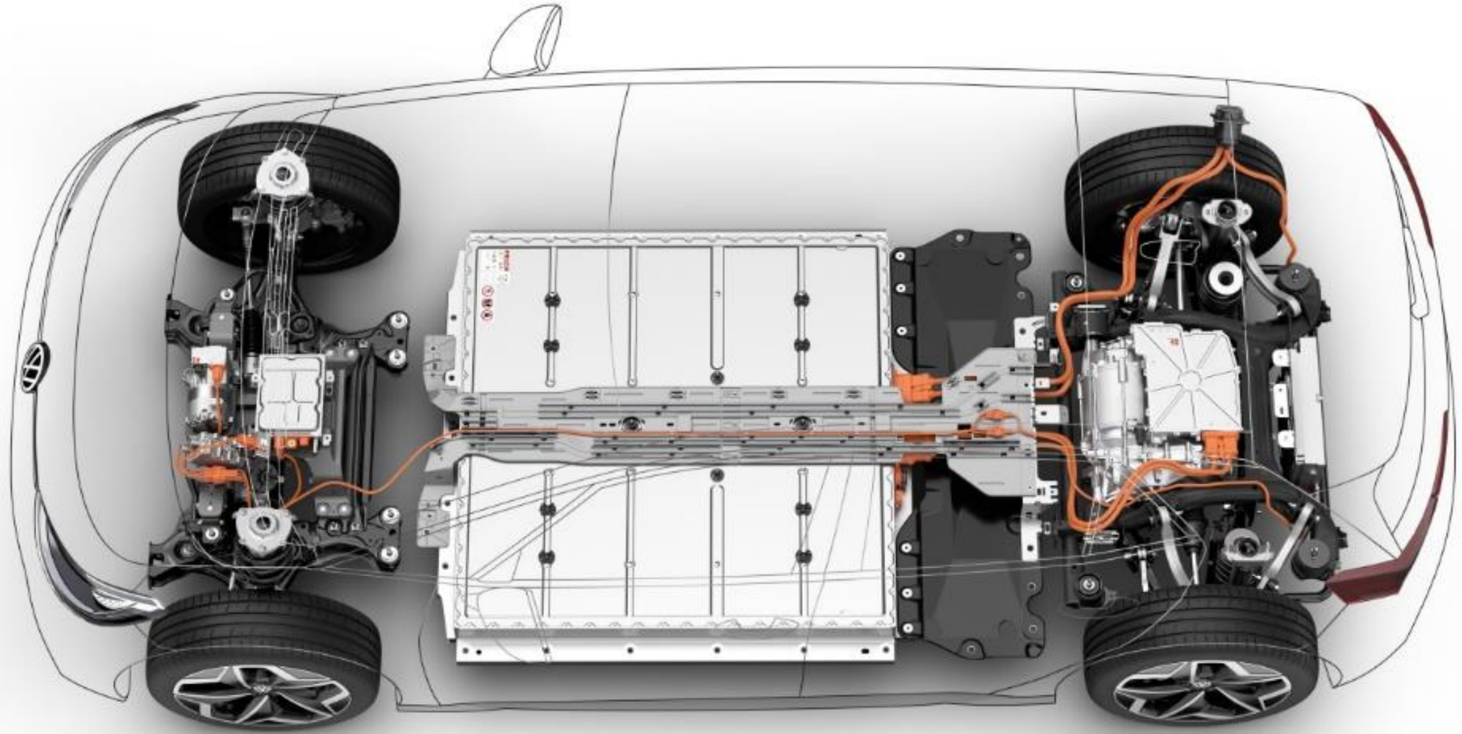
DC Fast Charging (DCFC) vs AC Level 2 (L2)



DC: direct current used for DC Fast Charging

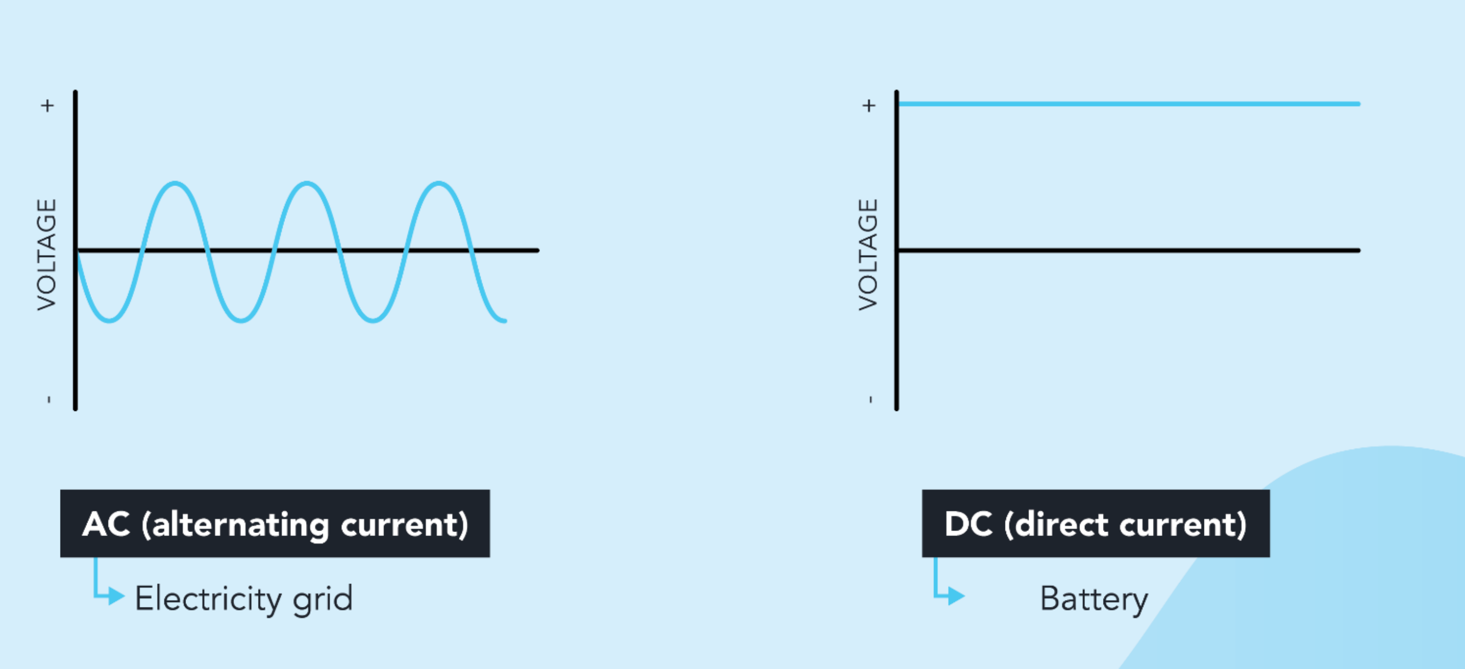
- Electric current flows 1 direction in a loop to complete a circuit
- Most EV systems are DC
  - high voltage circuits: battery, some motors
  - low voltage systems: accessories





AC: alternating current used for L2 Charging

- How electricity is transferred to homes & businesses through wires (AC electricity grid)
- Voltage or current oscillate, 60 times/second in the US
  - Wall plugs = AC



Electrical Energy: kWh (kilowatt hours)

- 1 kWh is defined as the **ENERGY** consumed at a power level of 1 kW for 1 hour
- Energy is measure of how much fuel is contained within something
  - Unit used to measure electricity consumed on electric meter
  - PNW rates vary from $0.03-0.15 /kWh typically 10-12 cents/ kWh

Electrical Energy: kWh (kilowatt hours)

- Measure of a battery's **ENERGY** capacity
  - For example a 75 kWh battery in a crossover SUV
  - 115-200 kWh battery in a pickup
  - 125- 220 kWh battery in a school bus

Electrical Power: kW (kilowatts)

- Power is the **RATE** at which energy is generated or used. Similar to Horsepower https://www.energylens.com/articles/kw-and-kwh
  - Rate at which chargers supply power, ie 350kW DCFC or 6kW L2
  - L2 AC charging @10 kW power level for 5 hours adds 50 kWh to battery
  - DC Fast Charging @50kW power level could add 50kWh in 1hour (ignoring taper)

AC Level 2 Charging

DCFC

Chevy Copa Camaro EV putting power to the ground

Energy Consumption: kWh/mile

- Similar to MPG, sometimes MPGe or mi/kWh is used
- Fuel economy varies based on speed driver, behavior, weather, temperature or hills like ICE
  - Electric crossover SUVs consume roughly 250Wh/mi
  - Electric pickups consume roughly 500Wh/mi or 1kWh/mi when towing
  - School buses can consume 1.7 kWh/mi

Examples

Pickups

Back

	EV	ICE
Energy Use	500 Watt-hrs/mile	16 MPG
Miles/yr	15,000	15,000
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$900	$2,812
EV Savings/yr	**$1,913**	
Load Growth/yr	**7.5 MWh**	

Bucket Truck

Back

	EV	ICE
Energy Use	1,900 Watt-hrs/mile	5 MPG
Miles/yr	9,300	9,300
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$2,120	$5,385
EV Savings/yr	**$3,460**	
Load Growth/yr	**17.7 MWh**	

School Bus

Back

	EV	ICE
Energy Use	1,700 Watt-hrs/mile	6 MPG
Miles/yr	13,140	13,140
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$2,681	$6,570
EV Savings/yr	**$3,889**	
Load Growth/yr	**22.3 MWh**	

Police Vehicle

Back

	EV	ICE
Energy Use	500 Watt-hrs/mile	7 MPG
Miles/yr	62,050	62,050
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$3,723	$26,592
EV Savings/yr	**$22,870**	
Load Growth/yr	**31 MWh**	

https://www.betoolkit.org/applications/te/types

Examples

Garbage Truck

Back

	EV	ICE
Energy Use	1,800 Watt-hrs/mile	2.5 MPG
Miles/yr	25,550	25,550
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$5,519	$30,660
EV Savings/yr	**$25,141**	
Load Growth/yr	**46 MWh**	

Transit Bus

Back

	EV	ICE
Energy Use	1,900 Watt-hrs/mile	2.5 MPG
Miles/yr	43,800	43,800
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$9,986	$52,560
EV Savings/yr	**$42,574**	
Load Growth/yr	**83.2 MWh**	

Class 4-6 Box Van

Back

	EV	ICE
Energy Use	800 Watt-hrs/mile	6 MPG
Miles/yr	29,200	29,200
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$2,803	$14,600
EV Savings/yr	**$11,797**	
Load Growth/yr	**23.4 MWh**	

Paratransit & Shuttles

Back

	EV	ICE
Energy Use	900 Watt-hrs/mile	6.5 MPG
Miles/yr	29,000	29,000
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$3,132	$13,384
EV Savings/yr	**$10,253**	
Load Growth/yr	**26.1 MWh**	

https://www.betoolkit.org/applications/te/types

Class 8 Semi Truck

Back

	EV	ICE
Energy Use	1,900 Watt-hrs/mile	5 MPG
Miles/yr	108,750	108,750
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$24,795	$62,250
EV Savings/yr	**$40,455**	
Load Growth/yr	**206.6 MWh**	

Production is beginning from several manufacturers hoping to capitalize on this market as it goes electric. Offerings from Daimler Freightliner, Tesla, Volvo and others are on the way.

Tractor

Back

	EV	ICE
Energy Use	10 kWh/hr	3 gal/hr
Work Hours/yr	550	550
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$660	$4,950
EV Savings/yr	**$4,290**	
Load Growth/yr	**5.5 MWh**	

Motor Pool Vehicle

Back

	EV	ICE
Energy Use	300 Watt-hrs/mile	24 MPG
Miles/yr	15,000	15,000
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$540	$1,875
EV Savings/yr	**$1,335**	
Load Growth/yr	**4.5 MWh**	

Starting in the mid-$20k range, a growing number of affordable vehicles for light duty fleets promise to save taxpayers money on inexpensive electric fuel versus gas. Options include the Chevy Bolt EV/EUV, Volkswagen ID 4, Nissan Leaf, Mustang Mach E, Hyundai Ioniq 5, Kia EV 6, and the upcoming Chevy Equinox and Blazer and Ford Explorer.

https://www.betoolkit.org/applications/te/types

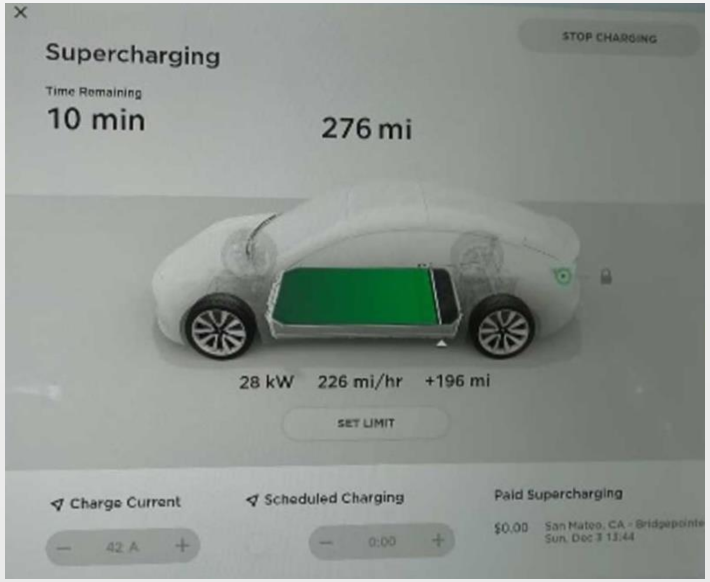
Forklift

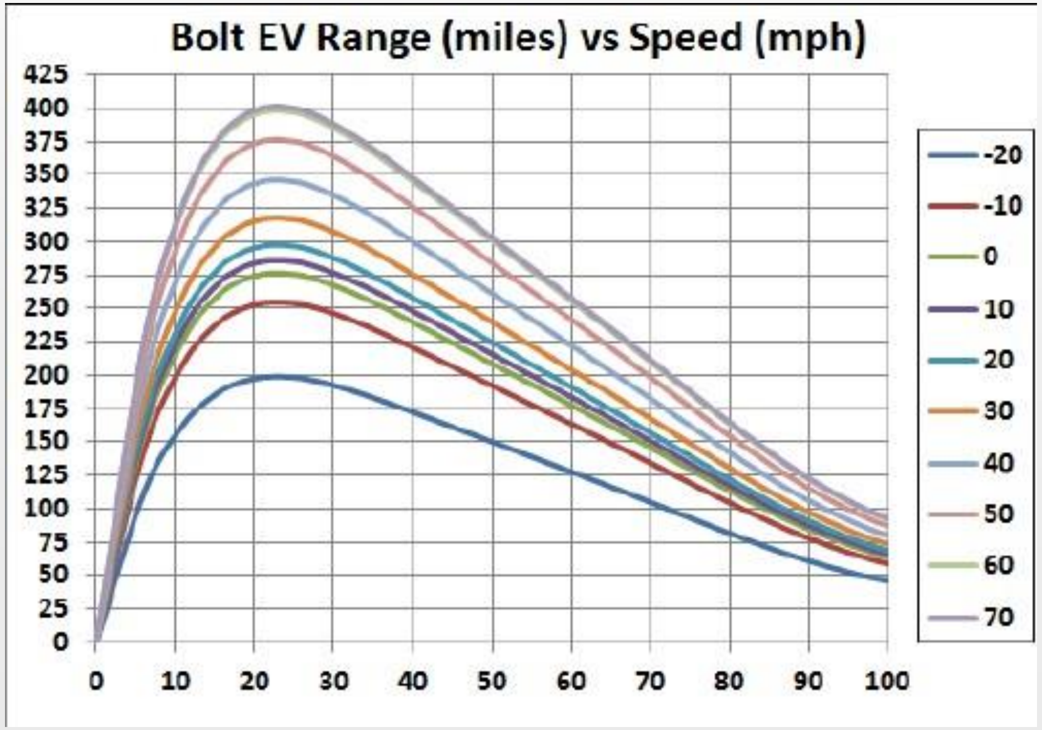
Back

	EV	ICE
Energy Use	3.5 kWh/hr	1.1 gal/hr
Hours/yr	2,920	2,920
Energy Price	$0.12/kWh	$3.00/gal
Energy Cost/yr	$1,226	$9,834
EV Savings/yr	**8,410**	
Load Growth/yr	**10.2 MWh**	

Vehicle range: in miles

- Calculated similar to using MPG & gallons of fuel
- Battery capacity (kWh) divided by Vehicle Consumption (kWh/mi) = usable range
- Can start each day at 100% or charge a couple times weekly





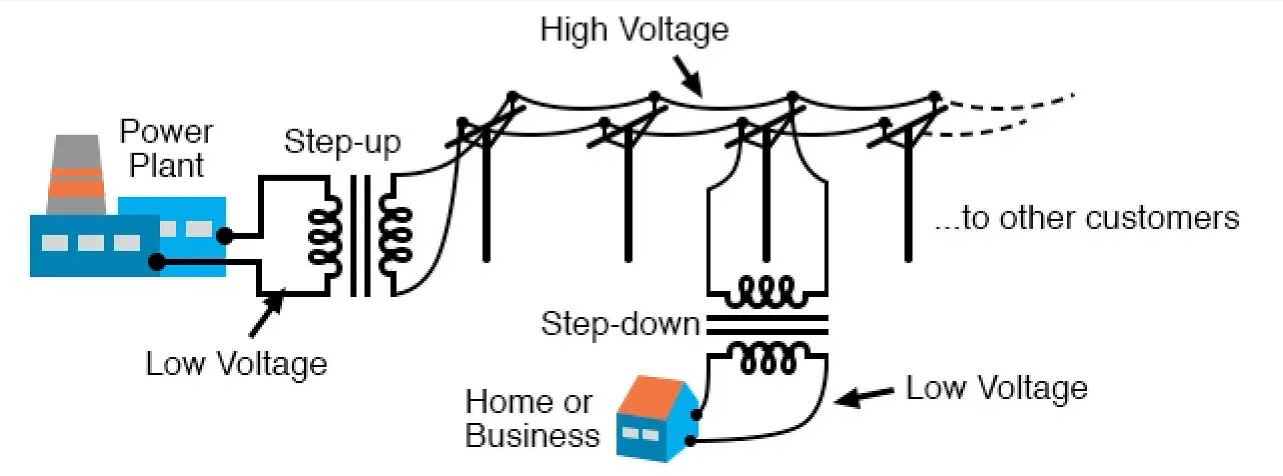
Vehicle range impacts:

- As fleet managers you get it that driver behavior & weather can have large impacts on ICE mpg
- Important to consider driving conditions & use cases when considering charging needs
- Crossover SUV with 75 kWh battery driving in town in warm conditions may consume 220 Wh/mi resulting in 340 miles of range
- Same vehicle driving at freeway speeds in cold snowy weather with an aggressive driver may consume 375 Wh/mi reducing range to 200 miles

Transformer: step downs decreases voltage

- At homes or businesses they step down voltage from AC distribution lines (~16kV) to 240V* AC
- DC fast chargers (DCFCs) use dedicated transformer to step down voltage from AC lines to ~480-1000V
  – One of largest supply chain bottlenecks to build DCFC

* Or 208V 3 phase or 480V

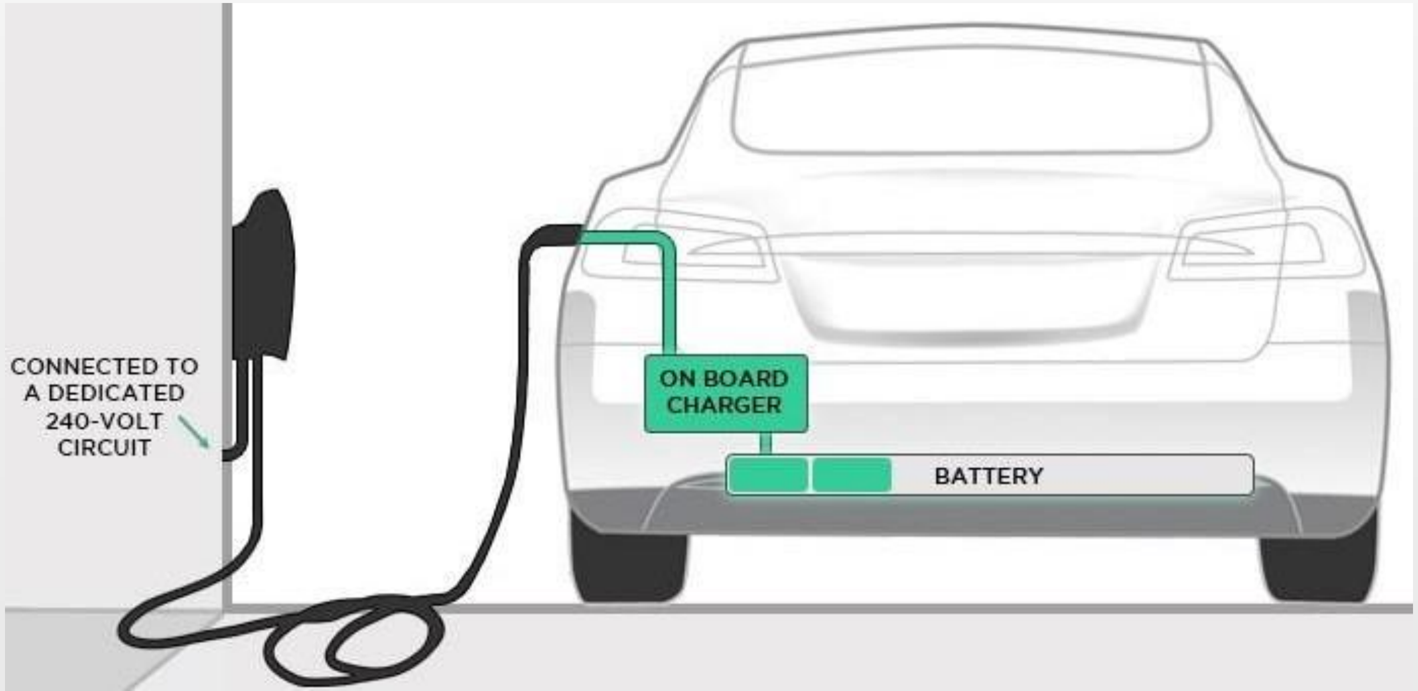


Transformer for Electrify America DCFC

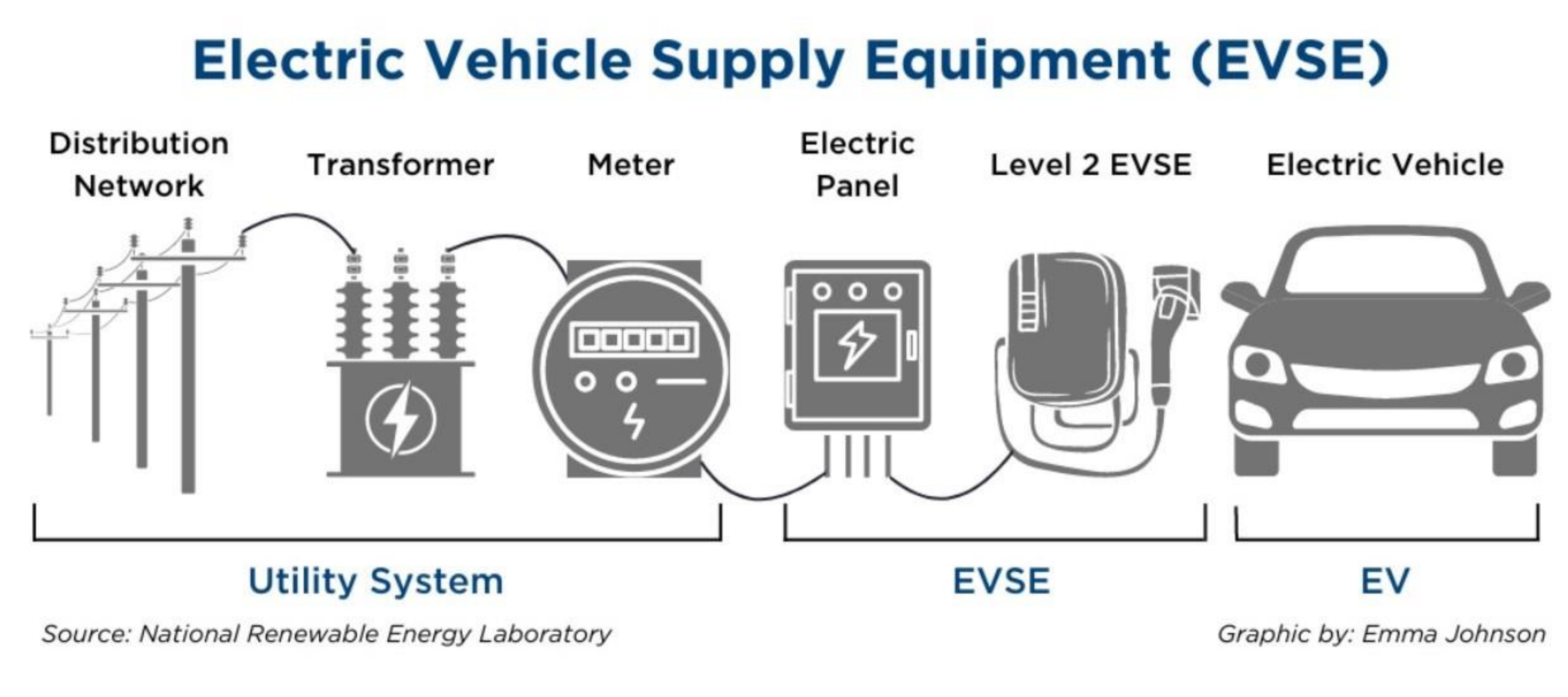
https://www.allaboutcircuits.com/textbook/alternating-current/chpt-1/what-is-alternating-current-ac

AC charging

- AC electricity is supplied from an electrical panel to car via EV supply equipment (EVSE) (L1-120V or L2-240V)
- Conversion to DC via car's on-board charger (OBC)
  - Rectification blocks reversal of polarity or current flow
  - Boosts voltage to match battery pack, 400V+



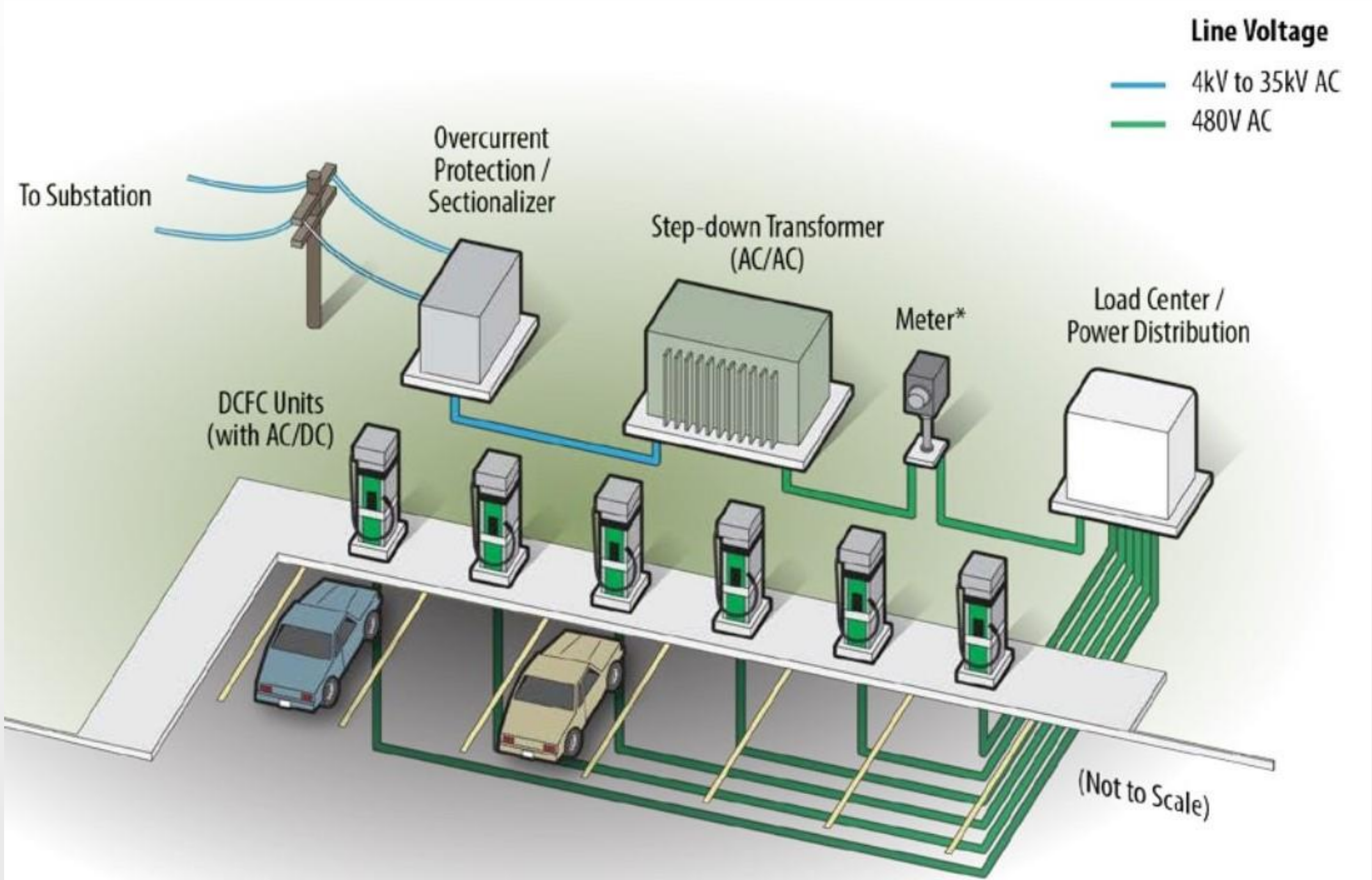
AC Charging Components



AC charging

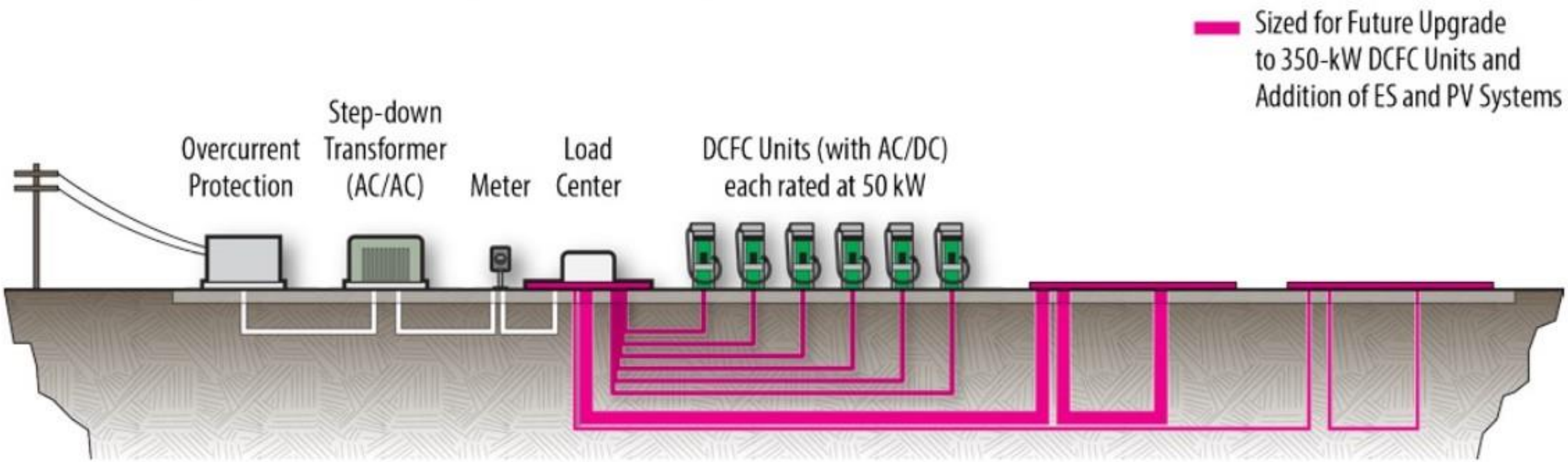
- Power levels for L2 charging range from ~3-19 kW depending on the circuit's amperage (current level)
  - 20 amp breaker (16 amps continuous) @240V = 3.8kW
  - 100 amp breaker (80 amps continuous) @240V= 19.2kW
- Max power acceptance varies by vehicle 3.6-19.2kW
- During July's AFV-TAG we'll cover ways to potentially save money with managed L2 charging (moving charging to off peak hours)

DC Fast Charging (DCFC) components



DC Fast Charging (DCFC)

Future Proofing Infrastructure



A) DCFC complex with 50-kW chargers and no ES and PV systems at initial installation

ES= Energy Storage (battery buffer) PV= Solar System

Demand charges: $/kW ($/kilowatts)

Utilities charge for higher power delivery on tap

- Grid must be kept in balance each fraction of a second where generation matches the demand (load)
- 'Spikey' loads are costly to balance

– Demand charge of $4/kW for 350kW = $1400 charge for that month

– Costs dominate @ low # of DCFC charging sessions per month

– Some utilities offer demand charge holidays until utilization is higher and the kWh sales dwarf the demand

DCFC: Charge Rate vs Energy Consumption

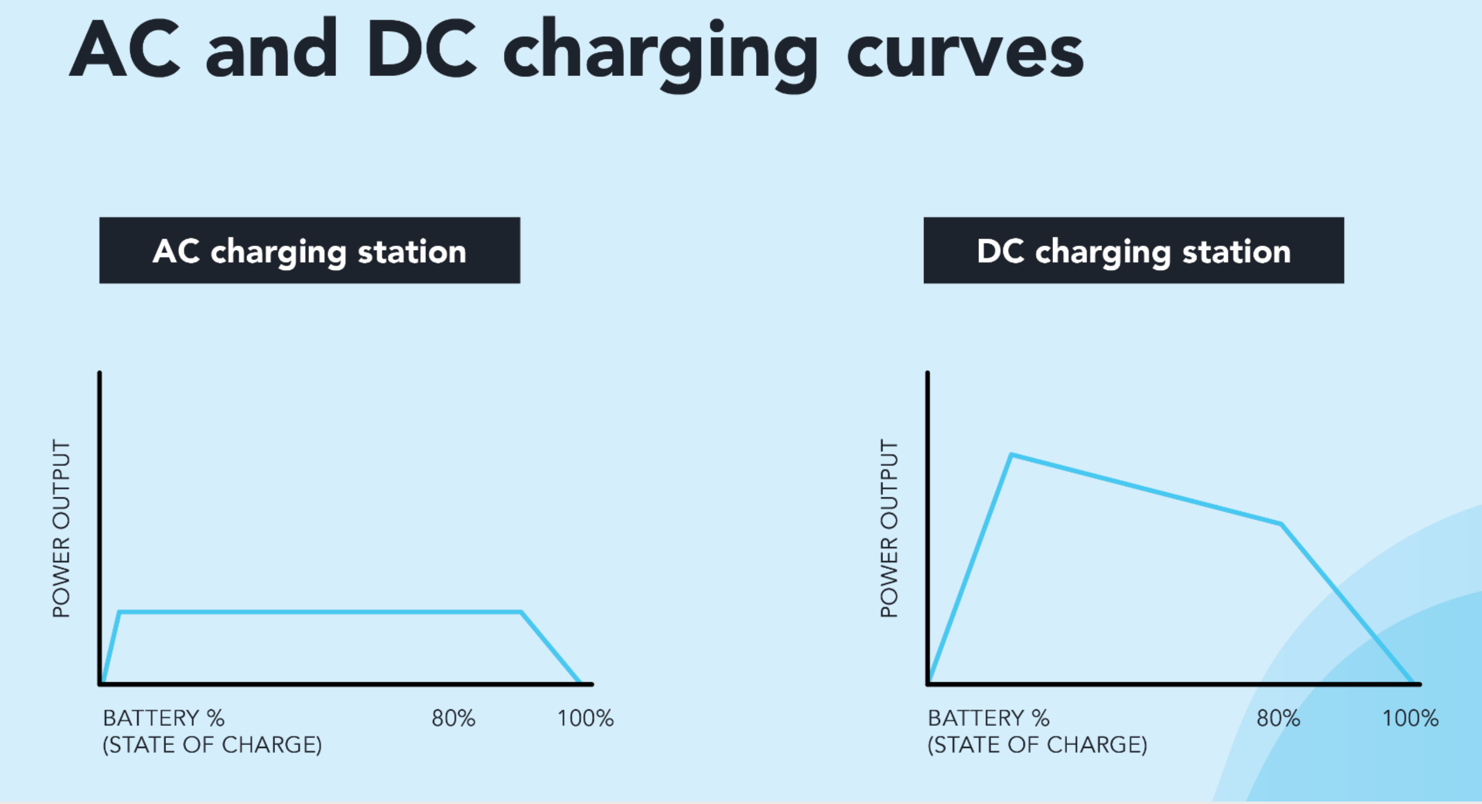
- Vehicles with higher energy consumption require bigger batteries
- Bigger batteries take longer to charge
- Higher charge rates (DCFC power levels) are needed to maintain reasonable recharge times
- Pickups: 350kW DCFC important for long distance travel to minimize dwell time, @50 kW
  could take 4 hours

  - AC L2 charging follows same logic
  - Upcoming pickups & vans to offer 19kW L2

Vehicle	Energy capacity of battery	Energy consumption	Charging time	Charging Power
Hyundai Ioniq 5	Useable: 74 kWh Total: 77 kWh	300 Watt-hours per mile	10 to 80% state of charge in 18 minutes, adding over 210 miles of range	350 kW
GMC Hummer EV	Usable: 213kWh Total: 247 kWh	717 Watt-hours per mile	20 to 80% charge in 42 minutes, or 100 miles of energy in about 12 minutes	350 kW

Charging Curves

- DCFC begins @high power level if battery is warm enough/not too hot
  - Each OEM tailors vehicle charging curves to protect batteries from heat/ cold
  - DCFC taper (accepting less power) begins ~50% State of Charge (SOC)
  - Tapers more aggressively near 80% SOC like reducing diesel flow near end of fill
  - DCFC beyond 80% SOC only when needed for max range
- AC charging has minimal taper (lower power levels)



The Future of Highway Corridors?

High Power Rural Chargers Connecting Urban Centers: Big Power in Small Places

- Is California the future for EVs?
- I-5 in central California has 4 separate Supercharger locations with over 48 stalls each delivering 250 kW/ port
- One location has 96 ports
- Each location is in sparsely populated rural areas

Dwell time: how long does the vehicle sit idle?

- Time where vehicle can be charged
  - What hours are vehicles used? 7am- 5pm?
  - Is the vehicle’s dwell time consistent?
  - Use above definitions & knowledge of vehicle use cases to consider where, when DCFC is needed to supplement L2
  - Refer to WSU Energy’s Milestones: 10 steps to fleet electrification paper

When & Why DC Fast Charging (DCFC)?

- Does fleet have large number of vehicles (100s)?
- Emergency vehicles:
  - Rapid turnaround, unknown dwell time, or high daily mileage
  - High power (200-350 kW) for rapid recharge
- Heavy duty vehicles with high daily mileage
  - Basic power needs calculator in development @ betoolkit.org
  - (kWh/mile * miles/ day)/ Dwell time
    = average power level needed to charge

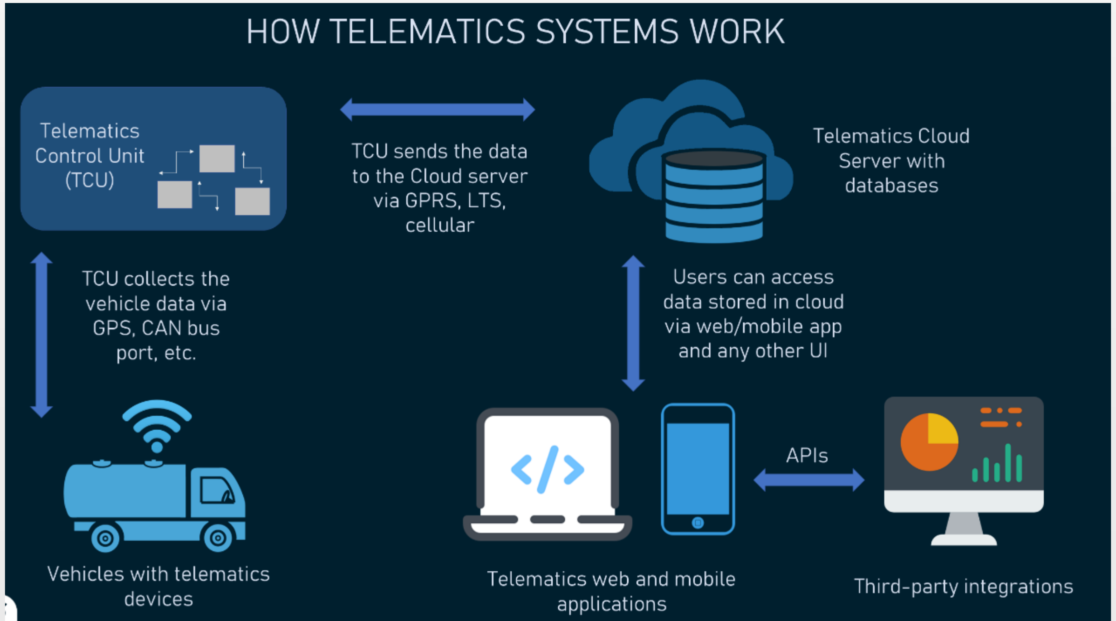
Use Cases

- DC Fast Charging (DCFC) vs AC Level 2 (L2)
  - AC L2 charging works well for vehicles that can sit for 2-10 hours depending on
    - Miles driven that day
    - Vehicle energy consumption affecting battery capacity

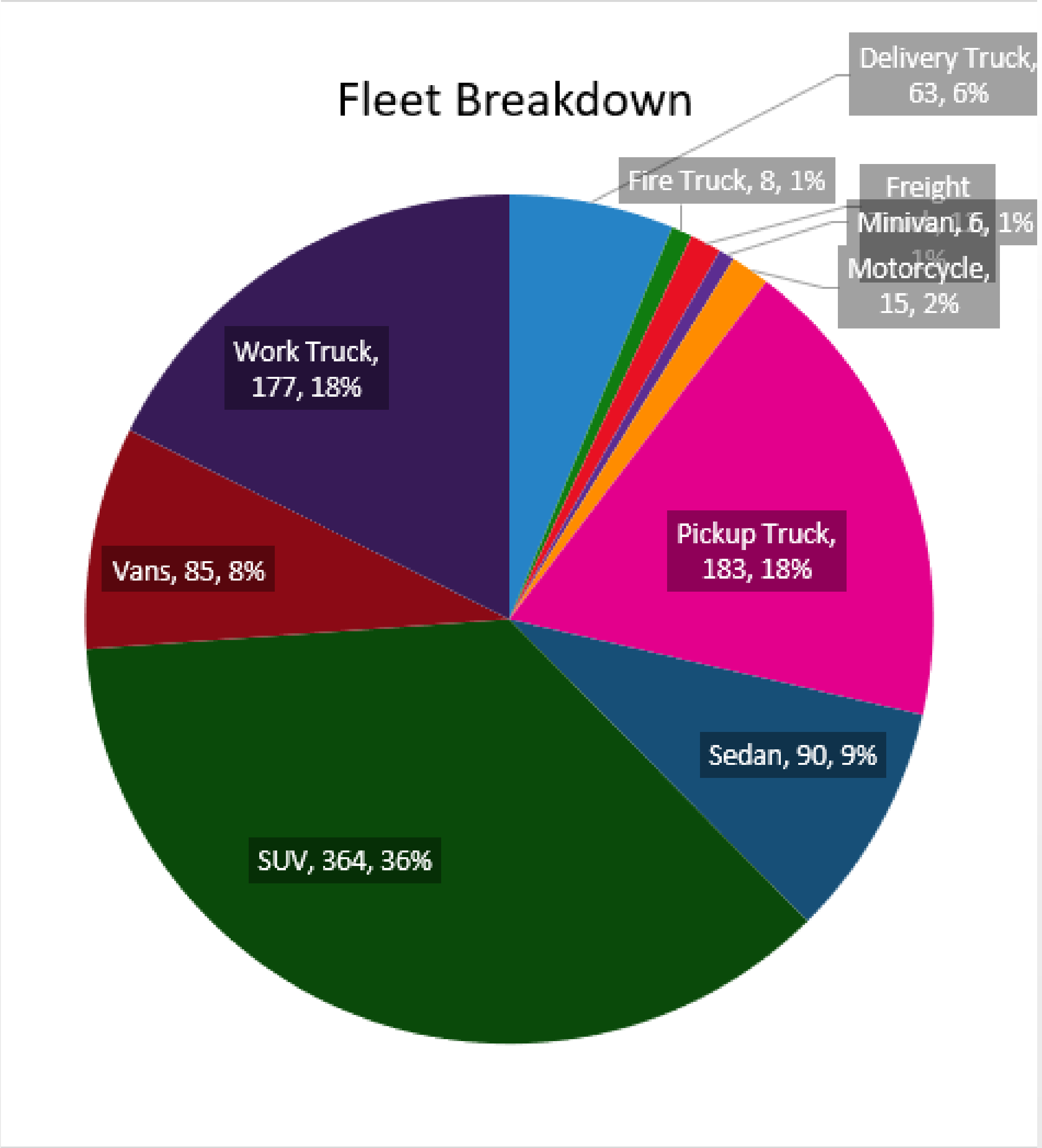
  ie how many kWh need to be replenished?

Fleet Data Analysis to Inform Decisions

- WSU Energy offers free fleet analysis
- Data can be a fleet's best friend
  - Understand best use cases from fleet data
- Companies like Sawatch labs can analyze your whole fleet, ICE & EV to help make informed decisions & save money



- Large fleets will benefit from mix of L2 & DCFC



DCFC vs L2 Costs

- Equipment for 4 port DCFC is about 10-20x more expensive than 4 ports AC L2
  - L2 design & install can also be significantly less expensive
  - L2 can be done by EV experienced electricians
  - DCFC needs Electrical Engineers to plan & design
- DCFC can serve many vehicles while L2 may be closer to 1 vehicle per port

DCFC vs L2 Costs

- Approximate Pre-covid costs

Note: Transformer upgrades are only needed for large L2 installations

Ask your utility if they can cover such costs with a “Make Ready” program

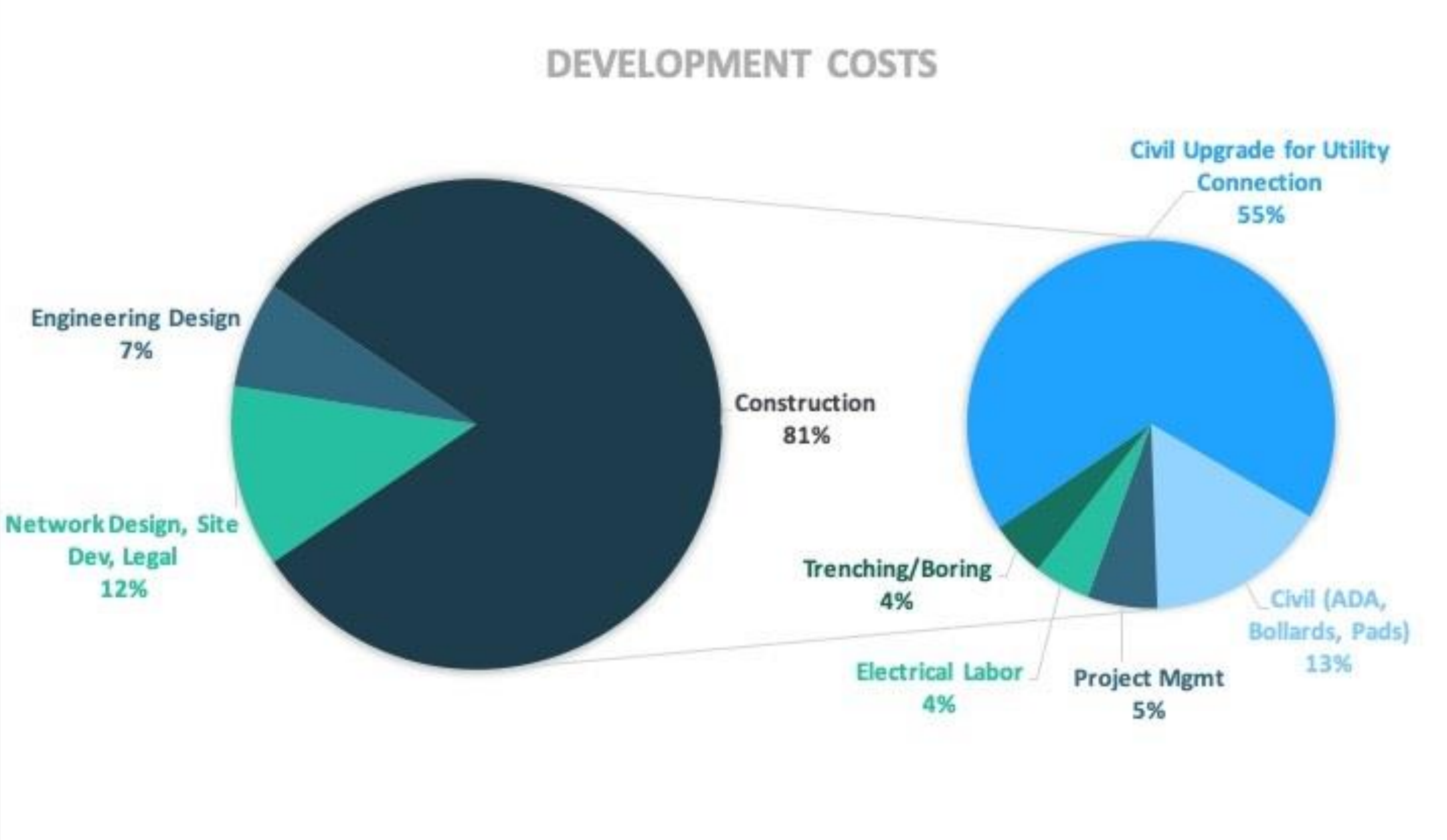
EXHIBIT 1

Cost ranges for charging infrastructure components.

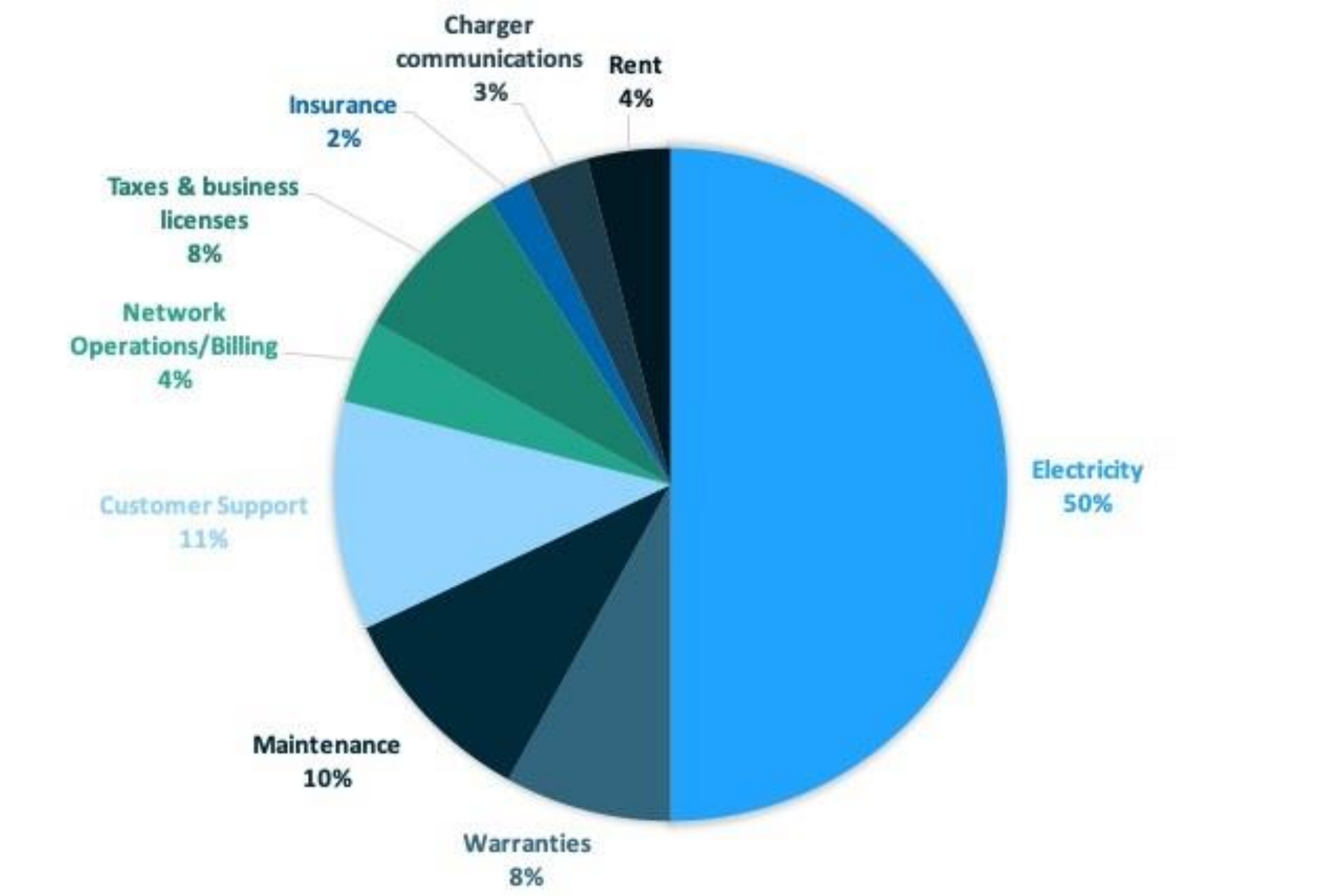
COST ELEMENT	LOWEST COST	HIGHEST COST
Level 2 residential charger	$380 (2.9 kW)	$689 (7.7 kW)
Level 2 commercial charger	$2,500 (7.7 kW)	$4,900 (16.8 kW); outlier: $7,210 (14.4 kW)
DCFC (50 kW)	$20,000	$35,800
DCFC (150 kW)	$75,600	$100,000
DCFC (350 kW)	$128,000	$150,000
Transformer (150–300 kVA)	$35,000	$53,000
Transformer (500–750 kVA)	$44,000	$69,600
Transformer (1,000+ kVA)	$66,000	$173,000
Data contracts	$84/year/charger	$240/year/charger
Network contracts	$200/year/charger	$250/year/charger
Credit card reader	$325	$1,000
Cable cost	$1,500	$3,500

Note: DCFC denotes direct-current fast chargers.

DCFC Development Costs



DCFC Operational Costs



Importance of Utility Relationship

- Working with utility early to plan & coordinate helps reduce costs, deploy appropriate equipment
  - Have electrical engineers to help plan DCFC
  - Sizing transformers or electrical panels, wiring etc to serve future needs: L2 & DCFC
- Energy from L2 AC will invariably be cheaper so important to consider why/ when there is a DCFC need
- Demand charges increase total DCFC energy cost
- Pay more for speed

Now You Know Utility Speak

- Charging install costs depend on factors like
  - Available power capacity at site: increasing electrical capacity can raise costs for DCFC & large L2 installs
  - Distance to trench to run wire and conduit
    - Dig once: future proofing for needs 5-10 years out
  - Paved parking: digging dirt/ gravel cheaper than paved
- Ask your utility about electrical capacity at sites you plan to charge EVs
- Ask if utility can cover all/part of “Make Ready” costs

Capacity Questions for your Utility

- Capacity needs depend on how fast vehicles need to charge (recall dwell time)
- Higher speed costs more but may be the best solution in some cases to have high uptime (higher electric mileage = more fuel savings)
- DCFC has wide power range from 20 kW to 360 kW+
- HD trucks will be 500kW to1MW+ (XFC): multiple class 8 semis charging @ depot may require a new substation, 5-10 years lead time
- How many ports to install at what power levels?: ie 4 ports @ 350 kW or 12 ports @50 kW, mixture etc

Conversations with your Utility

- Important to share fleet electrification plans
- Important for Utility to know fleet's total vehicle count per location (planning): how many cars pickups class 4-8 etc
  - Electrification is accelerating
  - Experts state nearly all ground based transport will move to electric sooner than expected
- Utilities have electrical engineers who may help advise early in process to save $$ in future
- Discuss & learn **interoperability** best practices
- Early planning is very important

Thank you!

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