Electric Vehicle
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Infrastructure Training Program

Electric Vehicles

Module #1 - Electric Vehicles (EVs) Sections

1.1 – Introduction to Electric Vehicles(EVs)

1.2 – The History of EVs

1.3 – EV Types & Technology

1.4 – Modern EVs

1.5 – Commercial and Industrial EVs

1.1 – Introduction to Electric Vehicles (EVs) Overview

Section 1.1 introduces the Electric Vehicle (EV) and the industry supporting electrified transportation. This includes market drivers, types of EVs, and the equipment used to charge these vehicles.

Because the EV industry is growing and changing so quickly this presentation in a snapshot in time, newer vehicles are arriving in the market every day and may yet to be included in the presentation. New technology for charging or supplying energy to EVs is constantly being updated as well, for example wireless charging is here and will very soon become a sector leader!

1.1 – Introduction to Electric Vehicles (EVs)
Learning objectives

Upon completion of this section, students should be able to…

1. Demonstrate an understanding of market drivers in the EV industry.
2. Define basic terms used in the EV industry.
3. Distinguish between the different fuel choices for the transportation sector and appraise the advantage and disadvantages of each.
4. Explain who is involved in the EV industry.

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Module 1 – Section 1
Intro to Electric Vehicles

1.1 – Introduction to Electric Vehicles (EVs)
Why EVs now? (market drivers)

Advances in technology, most notably batteries, lightweight composite materials and on-board computer systems have made modern electric vehicles practical and cost effective.

Coupled with high petroleum prices and a finite supply of oil, electric vehicles have finally become a viable alternative to petroleum powered transportation.

1.1 – Introduction to Electric Vehicles (EVs)
Why EVs now? (market drivers)

The Technology is here!

- **Car manufacturers –** are developing and releasing new hybrid, plug-in hybrid, and battery electric vehicles each year.
- **Battery manufacturers –** are developing new batteries that will last longer and cost less.
- **EV charging equipment manufacturers –** are now producing DC fast chargers with the capacity to transfer up to 350kW of power to an EV.

1.1 – Introduction to Electric Vehicles (EVs)
Why EVs now? (market drivers)

The Three Great Challenges of Fossil Fuel

- Supply/Demand
- Climate Change
- National Security

1.1 – Introduction to Electric Vehicles (EVs)
Terms and Acronyms of the Industry

1. **Battery Electric Vehicle (BEV)** – Type of EV that uses energy stored in rechargeable battery packs for propulsion.
2. **Electric Heavy-Duty Vehicle (EHDV)** – A large battery powered vehicle (i.e. Trucks, Vans, etc.)
3. **Extended Range Electric Vehicle (EREV)** – A vehicle that operates as a battery electric vehicle for a certain number of miles, after the battery has been discharged, a gas engine powers an electric generator for 'extended-range' driving.
4. **Electric Vehicle (EV)** – Any vehicle that uses one or more electric motors (traction motors) for propulsion.
5. **Hybrid Electric Vehicle (HEV)** – Is a vehicle which combines a conventional internal combustion engine (ICE) with an electric propulsion system.
6. **Lithium-Ion (Lion)** – Is the chemical compound symbol for the compound inside lithium ion batteries.
7. **Plug-in Electric Vehicle (PEV)** – Is any vehicle that can be recharged from any external source of electricity.

1.1 – Introduction to Electric Vehicles (EVs)
Terms and Acronyms of the Industry

8. **Plug-in Hybrid Electric Vehicle (PHEV)** – A vehicle that combines an electric vehicle battery from any external source of electricity, and an internal combustion engine for propulsion.
9. **Partial Zero Emission Vehicle (PZEV)** – A vehicle that has zero evaporative emissions from its fuel system, has a 15-year (or at least 150,000-mile) warranty on its emission-control components, and meets Super Ultra Low Emission Vehicle tailpipe-emission standards.
10. **Super Ultra Low Electric Vehicle (SULEV)** – This Electric Vehicle classification is based on producing 90% less emissions than an equivalent gasoline-powered vehicle.
11. **State of Charge (SOC)** – Is the available capacity of the battery, expressed as a percentage.
12. **Ultra Low Electric Vehicle (ULEV)** – This Electric Vehicle classification is based on producing 50% less emissions than an equivalent gasoline-powered vehicle
13. **Zero Emission Vehicle (ZEV)** – This Electric Vehicle classification is based on a vehicle that produces no emissions from the on-board source of power.

1.1 – Introduction to Electric Vehicles (EVs)
Why Electric?

With so many alternatives to fossil fuel powered vehicles why choose EV?

- Propane and Natural Gas
- Bio-fuels
- Compressed Air Cars
- Fuel Cell
- Others?

1.1 – Introduction to Electric Vehicles (EVs)
Who is the EV Industry?

The EV industry is made up of:

- Car Manufactures
- EV Charging Equipment Manufactures
- Standards, Research, and Advocacy Groups

1.1 – Introduction to Electric Vehicles (EVs) Questions?

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Module 1 – Section 2
The History of EV's

1.2 – The History of Electric Vehicles
Overview

EVs got their original start in the days when the horse and buggy was the primary mode of transportation. In fact, the first crude electric vehicle can be traced back to 1832!

For as long as vehicles have been powered by internal combustion engines, electric powered vehicles have been available and early on they were the first choice of consumers.

Section 1.2 reviews the history of the EV from the heyday period from 1880 – 1920s to its resurgence in the late 2000s when technology began to bring the EV back into favor. The electric drive has long had advantages over alternative methods of transportation, as well as the ongoing issue of energy storage.

1.2 – The History of Electric Vehicles
Learning objectives

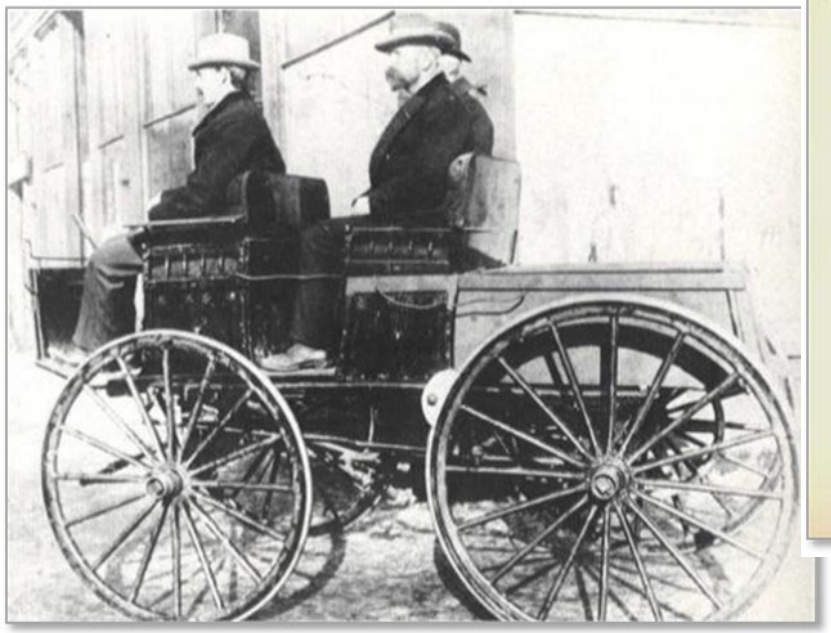
Upon completion of this section, students should be able to…

1. Recall the early history of EVs from the late 1880 – 1920s and what drew people to electrified transportation originally.
2. Recognize the late 2000s as the resurgence era of the modern day EV.
3. Demonstrate an understanding that improving technology has increased interest in EVs throughout history.

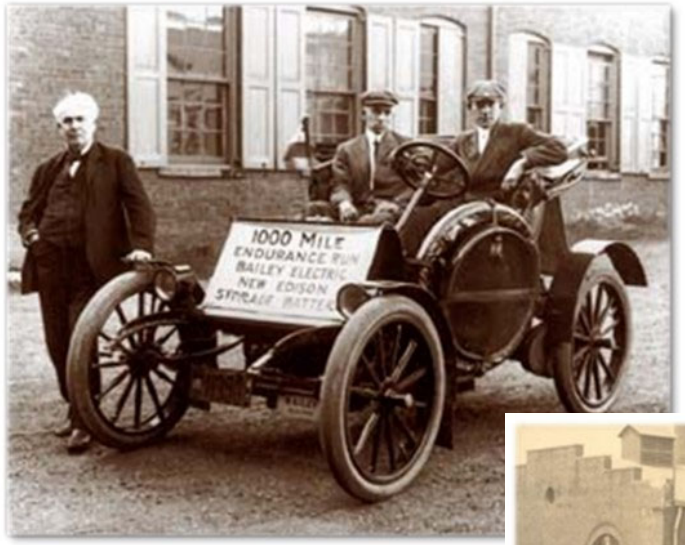
1.2 – The History of Electric Vehicles
Early Electric Vehicles

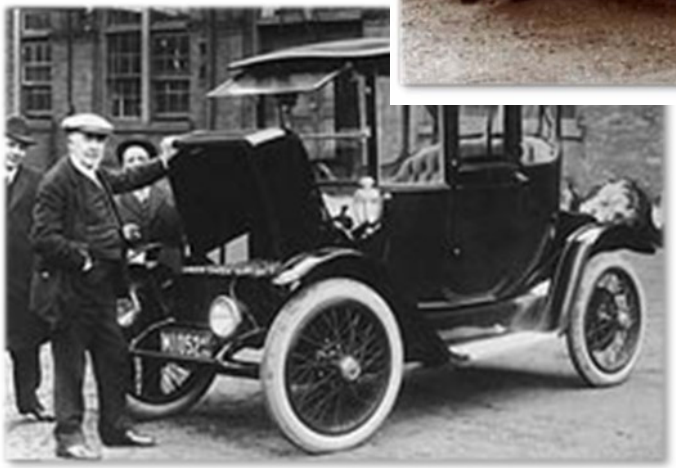
- Some of the very first automobiles were electric.
- William Morrison might have made the first electric car in the US in 1886.
- By 1900, the electric automobile was in its heyday. Of the 4,192 cars produced in the United States 28 percent were powered by electricity. Electric autos represented about one-third of all cars found on the roads of New York City, Boston, and Chicago.

1.2 – The History of Electric Vehicles
Morrison EVs, Des Moines, IA c.1890



1.2 – The History of Electric Vehicles
1910 Thomas Edison and the Bailey EV





1.2 – The History of Electric Vehicles
Why early EVs were so popular

EARLY EVs

- They were quiet (They didn't scare horses!)
- They were clean to operate
- They were easy to start
- They were mechanically simple

EARLY Internal Combustion Engines

- They were noisy
- They were smoky and oily
- They were hard to start (hand cranked)
- They were mechanically complicated

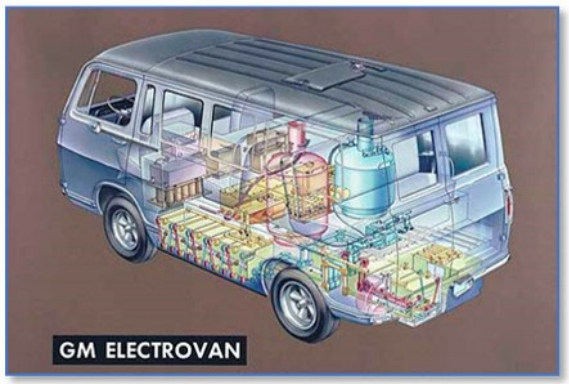
1.2 – The History of Electric Vehicles
The end of an era, by the 1920s EVs had lost favor

- Gasoline engines were more reliable
- Gasoline cars had more power and speed
- Gasoline engines now had electric starters
- Electric cars had limited range
- Electric cars required long charge times
- Electric car public charging stations were rare

1.2 – The History of Electric Vehicles
1930 – 1990 The developmental years for EVs

Through the decades, many types of electric vehicles were produced, however they were still plagued by:

- Limited range
- Heavy batteries
- High cost
- Poor public acceptance
- EVs face many of the same obstacles today



1.2 – The History of Electric Vehicles
1930 – 1990 The developmental years for EVs

Throughout the decades, many attempts were made to design and produce a viable electric vehicle.

- Many were “one-off designs” created by individuals or entrepreneurs.
- Some were developed by R & D departments of major manufacturers.
- And some designs of electric vehicles had been outstandingly successful!

1.2 – The History of Electric Vehicles
1930 – 1990 The developmental years for EV

- In the early 1990s new federal and state regulations created a renewed interest in EVs
- Major automakers returned to the drawing board and began modifying existing vehicles to to EVs.
- GM partners with AeroVironment to design what would become the EV 1, which one employee called "the world's most efficient production vehicle."

In 1996 GM released the EV1

1.2 – The History of Electric Vehicles
1930 – 1990 The developmental years for EV

- In 1997 Toyota releases the first mass-produced hybrid, the Prius.
- As of January 2017, the Prius liftback is the worlds top selling hybrid car with almost 4 million units sold.

1.2 – The History of Electric Vehicles
Questions?

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Module 1 – Section 3
EV Types & Technology

1.3 EV Types & Technology Overview

Section 1.3 introduces the three main types of electric vehicles including the Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Battery Electric Vehicles (BEVs) and their unique drivetrain architecture.

1.3 EV Types & Technology
Learning objectives

Upon completion of this section, students should be able to…

1. Contrast the difference between a HEV, PHEV and BEV.
2. Explain the advantages of each of the three types of EVs.
3. Describe the major components of EVs.
4. Diagram the unique drivetrains of the three types of EVs.

1.3 EV Types & Technology
Key components of Electric Vehicles - motors

Terminology:

- Internal combustion engine (ICE): an engine that generates power by burning gasoline, oil, or other fuel with air inside the engine, the hot gasses produced being used to drive a piston.
- Electric machine (EM): is a general term of electric motors/generators used in modern EVs.
- Modern EVs use 3 phase AC motor/generators

3 Phase AC Motor types:

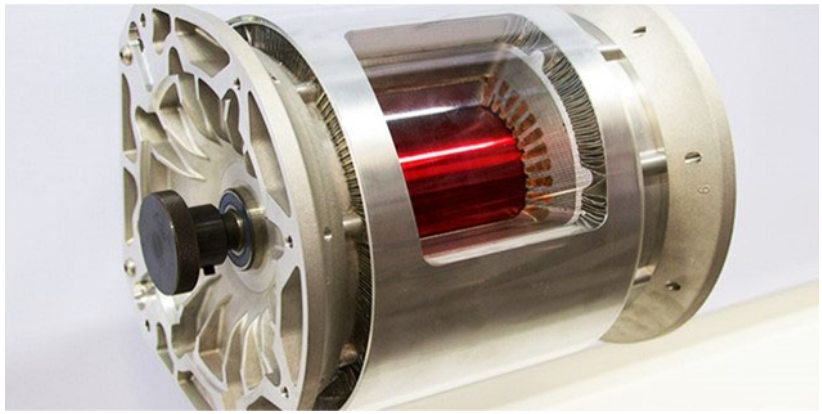
Permanent magnet (PM) motor

- Used in most EVs today
- High efficiency, high torque
- Short power range

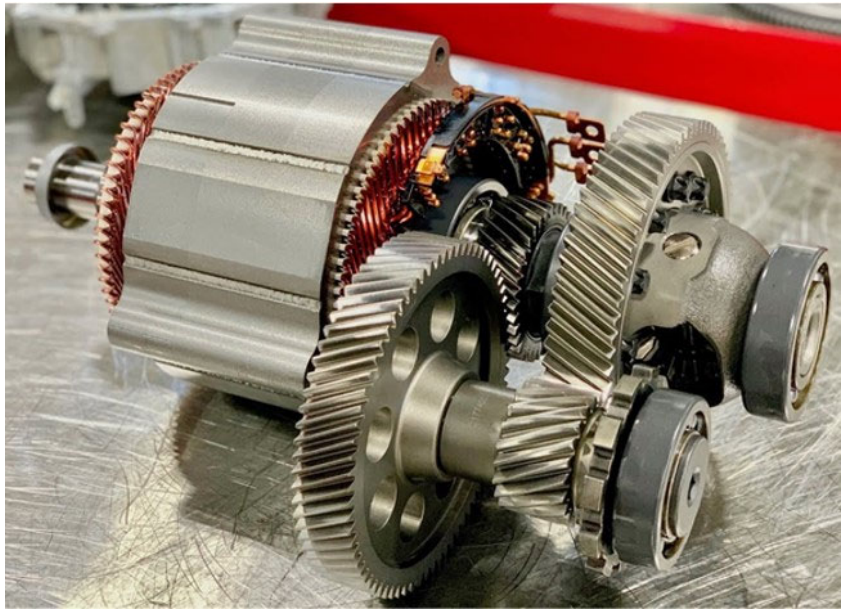
Induction motor

- Used by Tesla (S&X model)
- Simple, robust, with a wide speed range
- Less efficient

1.3 EV Types & Technology
Key components of Electric Vehicles - motors



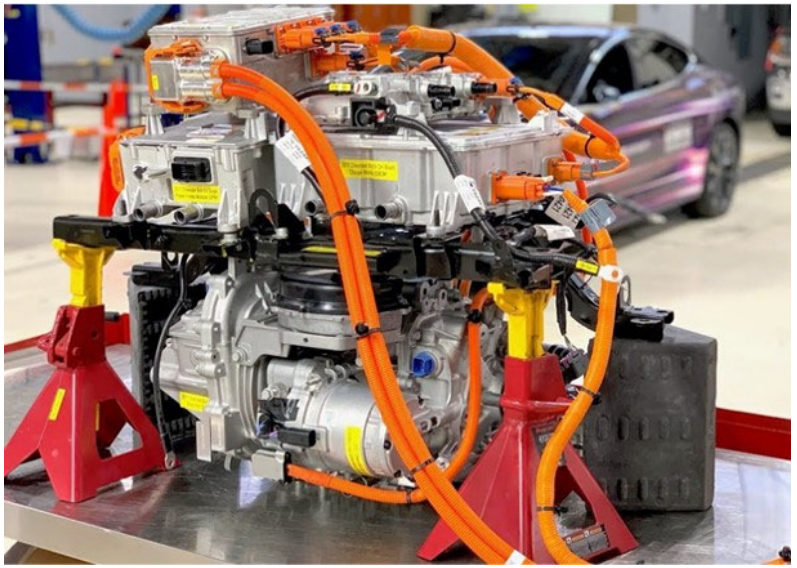
Tesla induction motor with cut away for display.



General Motors permanent magnet electric motor from Bolt EV.

1.3 EV Types & Technology
Key components of Electric Vehicles – power electronics

- Inverter: converts DC from the battery to AC three phase for the motor.
- DC to DC converter: increases or decreases battery voltage dependent on requirements.
- Rectifier: converts AC from external source (grid) to DC for the battery
- Energy Management System (EMS): A system that controls the flow of energy from multiple energy sources.



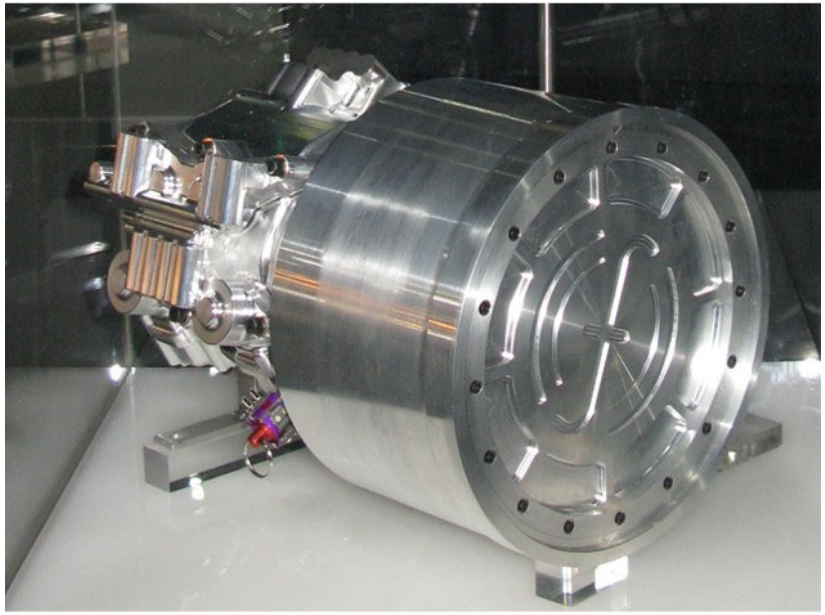
Chevrolet Bolt EV High Voltage Components.

1.3 EV Types & Technology
Key components of Electric Vehicles – battery

- EVs today use lithium ion batteries almost exclusively as an energy storage system (ESS)
- ESS could also be ultracapacitor or fuel cell in the future.
- Battery capacity per pound continues to improve as costs per kWh continue to fall.

1.3 EV Types & Technology
Key components of Electric Vehicles - Regenerative Braking

- Regenerative braking is an energy recovery systems which slows an EV by converting kinetic energy into electric energy to be stored in the EV battery for future use.
- Regenerative braking uses the electric motor of an EV as an electrical generator.



1.3 EV Types & Technology
Key components of Electric Vehicles - Powertrains

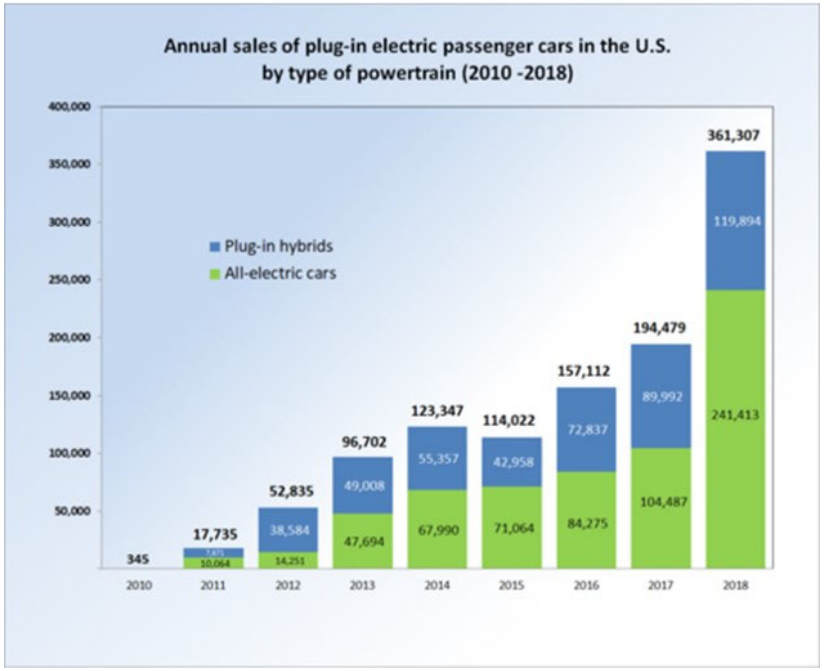
- Series Hybrid – ICE turns a generator, which supplies current to an electric motor, which then rotates the vehicle's Electric drive. A battery or super-capacitor can be used to store extra energy.
- Parallel Hybrid – (road-coupled hybrid) Can simultaneously transmit power to their drive wheels from two-distinct sources – for example an ICE and battery powered electric drive.
- Series/Parallel Hybrid – (power split hybrid) these drives can act as either a series or a parallel drive

1.3 EV Types & Technology

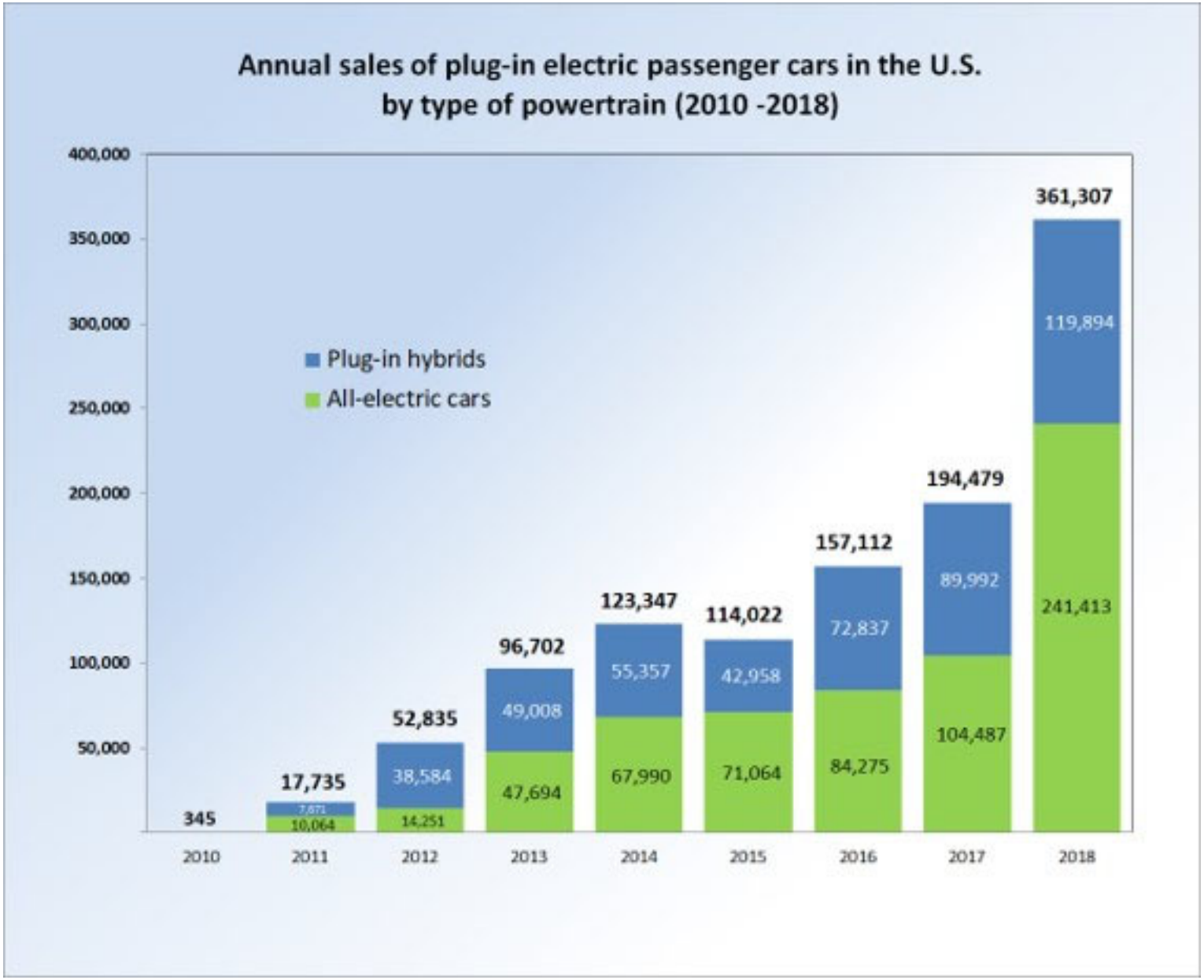
Types

There are three major types of electric vehicles.

- Hybrid Electric Vehicle (HEV)
- Plug-in Hybrid Electric Vehicles (PHEV)
- Plug-in all Electric Vehicle (PEV) or battery electric vehicles BEV)



Historical trend of annual sales of plug-in electric passenger cars in the U.S. by type of powertrain (2010-2018)



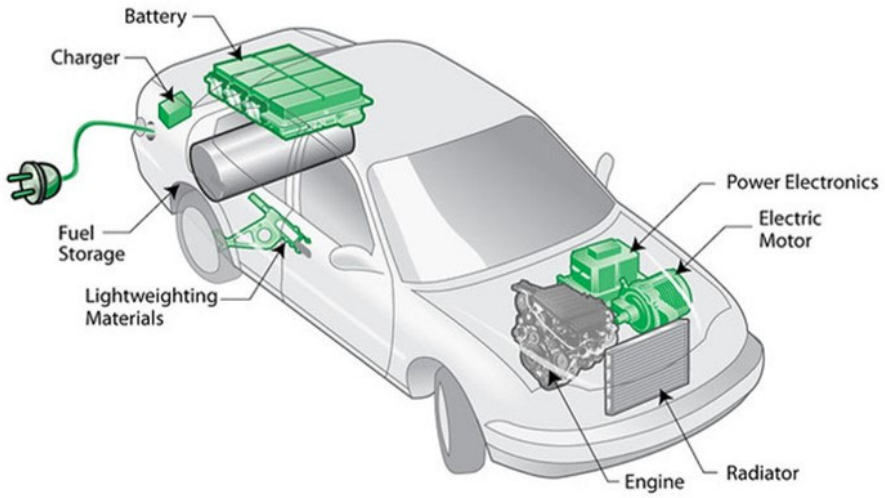
Historical trend of annual sales of plug-in electric passenger cars in the U.S. by type of powertrain (2010-2018)

1.3 EV Types & Technology
Types – Hybrid Electric Vehicle (HEV)

- Of all modern EVs, the Hybrid Electric Vehicle (HEV) has been available the longest.
- HEVs are readily available in the marketplace.
- They have a proven reliability record.
- They do not require an external charging source.

1.3 EV Types & Technology
Types – Hybrid Electric Vehicle (HEV)

A hybrid combines power from an electric motor and an internal combustion engine (ICE) to propel the vehicle.



- Hybrids can be broken up into two groups, mild hybrids and full hybrids.
- In a mild hybrid the electric motor can't propel the car on its own.
- In a full hybrid both the electric motor and the engine can power the car through the transmission at the same time. This is known as a parallel hybrid.

1.3 EV Types & Technology
Types – Hybrid Electric Vehicle (HEV)

- Since hybrids do not require an external charging source, they don't require an electrician.
- However, to be able to effectively communicate with the consumer, the electrician must know what a hybrid is and how it works.
- Now, let's get on to EVs that can utilize and external source of energy.

1.3 EV Types & Technology
Types – Plug-in Hybrid Electric Vehicle (PHEV)

- PHEV combines a hybrid drive system with the ability to charge the vehicles battery from an external power source.
- The PHEV runs on batteries until nearly depleted then the ICE powers an onboard generator to charge the batteries to extend the range or powers the vehicle depending on the type of drivetrain.
- Charge port is typically SAE J1772 AC power up to 6600W

1.3 EV Types & Technology
Types – Plug-in Hybrid Electric Vehicle (PHEV)

Unlike a hybrid, in many cases the ICE in a PHEV does not propel the vehicle through a transmission.

Some manufactures refer to PHEVs as Extended Range Electric Vehicles (EREV)

Operational modes of PHEVs:

Charge-depleting mode: allows a fully charged PHEV to operate exclusively on battery power till depleted.

Blended mode: ICE and Electric Drive, typical of some vehicles that can't maintain high speeds with out ICE

Charge-Sustaining mode: mostly used by hybrids (HEV) combines the vehicles 2 power sources to be as efficient as possible.

Mixed Mode: all the above.

1.3 EV Types & Technology
Types – All Electric Vehicle (EV)

- 100% all electric vehicles are propelled by an electric motor powered by batteries.
- They do not have an internal combustion engine.
- They have zero tailpipe emissions.
- Most have lithium-ion batteries.
- All must be re-charge from an external power source.
- Range anxiety, the fear of running out of power, is a huge obstacle to all electric vehicles.

1.3 EV Types & Technology
Questions?

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Module 1 – Section 4
Modern EV's

1.4 Modern EVs
Overview

Section 1.4 introduces the modern day EV. Advances in technology, most notably batteries, light weight composite materials, and on-board computer systems have made modern electric vehicles practical and cost effective. Today EVs are available from dozens of traditional and EV only car manufacturers. A small sample of the vehicles currently available will be reviewed in the section to prepare today's electrician with an understanding of what is currently available in the market.

1.4 Modern EVs
Learning objectives

Upon completion of this section, students should be able to…

1. Recognize the different vehicle types and the benefits of each to the consumer.
2. Have an awareness of the various EVs available in the market today.
3. Understand what variables effect the charge time for an EV.
4. Ability to communicate effectively about vehicle range and charge time

1.4 Modern EVs
Vehicle types

Vehicle Types:

- Hatchback
- Sedan
- Station Wagon
- Multi-Purpose Vehicle (MPV)
- Sport Utility Vehicle (SUV)
- Crossover
- Coupe
- Convertible
- Pickup Truck
- Sports Car
- Minivan

While the automotive industry's jargon is vast and seemingly unending, the most imperative terms in reference to car types are listed here

The 2019 Chrysler Pacifica PHEV minivan.

1.4 Modern EVs
Example EV

The following slides are examples of EV currently available in the marketplace.






1.4 Modern EVs
AUDI e-tron

Vehicle Type: SUV

Drive: All Electric

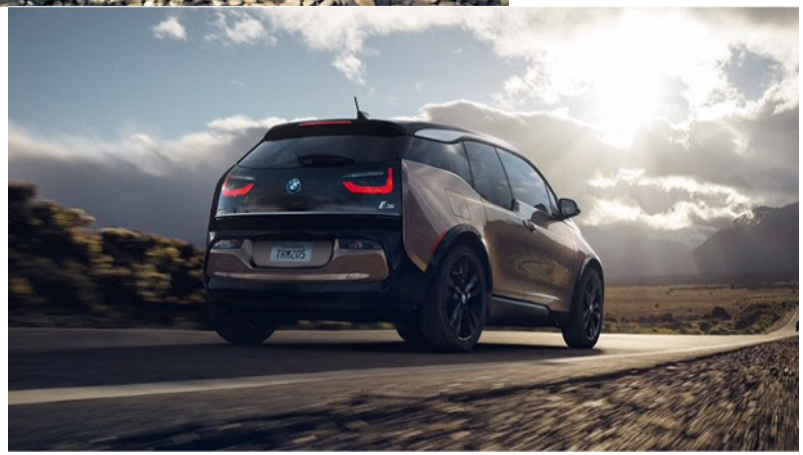
Range: 204 miles

Battery Capacity: 95kWh

Charging: CCS
AC@9.6kW
DC@150kW

Acceleration (0-60 mph): 5.5 seconds

1.4 Modern EVs
BMW i3



Vehicle Type: 4 door Hatchback

Drive: All Electric and PHEV versions

Range: 114 miles (PHEV version 180 miles)

Battery Capacity: 33kWh

Charging: CCS AC@7.4kW

Acceleration (0-60 mph): 7.2 seconds

1.4 Modern EVs
Chevrolet Bolt

Vehicle Type: Crossover

Charging: CCS

Acceleration (0-60 mph): 6.5 seconds

Drive: All Electric

Range: 238 miles

Battery Capacity: 60 kWh

1.4 Modern EVs
Hyundai Kona Electric

Vehicle Type: Crossover

Drive: All Electric

Range: 258 miles

Battery Capacity: 64kWh

Charging: CCS

Acceleration (0-60 mph): 7.6 seconds

1.4 Modern EVs
Jaguar I-PACE

Vehicle Type: Sport Crossover

Drive: All Electric

Range: 234 miles

Battery Capacity: 90kWh

Charging: CCS DC@50kW

Acceleration (0-60 mph): 4.0 seconds

1.4 Modern EVs
Kia Niro

Vehicle Type: Crossover

Drive: All Electric

Range: 239 miles

Battery Capacity: 64kWh

Charging: CCS AC@7.2kW, DC@80kW

Acceleration (0-60 mph): 7.8 seconds

1.4 Modern EVs
Nissan Leaf

Vehicle Type: Hatchback

Drive: All Electric

Range: 151 miles

Battery Capacity: 40kWh

Charging: CHAdeMO and J1772

Acceleration (0-60 mph): 8.9 seconds

1.4 Modern EVs
Tesla Model 3

Vehicle Type: Sedan

Drive: All Electric

Range: 325 miles (long range model)

Battery Capacity: 74kWh

Charging: Tesla

Acceleration (0-60 mph): 5.1 or less seconds

1.4 Modern EVs
Tesla Model S

Vehicle Type: Sedan

Drive: All Electric

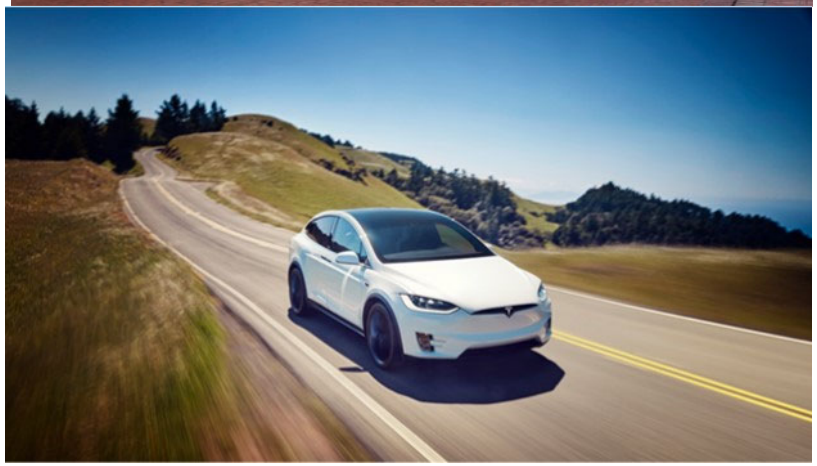
Range: 335 miles (long range model)

Battery Capacity: 100kWh

Charging: Tesla

Acceleration (0-60 mph): 4.1 or less seconds

1.4 Modern EVs
Tesla Model X



Vehicle Type: SUV

Drive: All Electric

Range: 295 miles (long range model)

Battery Capacity: 100kWh

Charging: Tesla

Acceleration (0-60 mph): 4.7 or less seconds depending on model

1.4 Modern EVs
Questions?

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Module 1 – Section 5
Commercial & Industrial EV's

1.5 Commercial and Industrial EVs

Section 1.5 introduces commercial and industrial vehicles available with electric or hybrid drives and the equipment used to charge them.

Considering almost a quarter of transportation-related emissions come from the medium and heavy-duty trucks used primarily for freight transportation, electrification of this sector has the ability to significantly reduce current emission levels. This has convinced many States to incentivize the purchase of commercial vehicles used for transport and delivery.

1.5 Commercial and Industrial EVs
Learning objectives

Upon completion of this section, students should be able to…

1. Recognize and describe the various types of commercial / industrial electric vehicles in the marketplace.
2. Assess the charging equipment requirements for commercial / industrial electric vehicles.
3. Explain to a customer the power requirements for the charging of commercial / industrial electric vehicles.

1.5 Commercial and Industrial EVs
Types

Types of commercial and industrial electric vehicles.

- Low speed industrial vehicles
- Light and heavy-duty trucks
- Delivery Vans
- Cargo-handling equipment
- Semi-trailer trucks
- Battery Electric Busses
- Refuse trucks

1.5 Commercial and Industrial EVs
Low speed industrial vehicles

Commercial and industrial low speed EVs are used throughout heavy and light industry for moving people and materials.

Examples of these vehicles:

- Personnel Carriers
- Utility Vehicles
- Stockchasers
- Tow Tractors
- Material Carts

1.5 Commercial and Industrial EVs
Low speed industrial vehicles

Commercial and industrial low speed EVs features:

- Maximum speed of 20 mph or less depending on type
- Typically lead acid batteries configured for 24, 36, or 48 volt operation
- Charge on 120 VAC circuit at 1000W or less (dedicated circuit is suggested)

1.5 Commercial and Industrial EVs
Light and medium duty trucks

Light and medium duty trucks are in development by both traditional and EV only vehicle manufacturers.

2019 has seen a lot of growth in the sector of electric drive trucks driven by dropping battery costs and incentives for zero-emission trucks.

General Motors, Ford, and Daimler Chrysler have all reported electrified versions of their most popular trucks are in development.

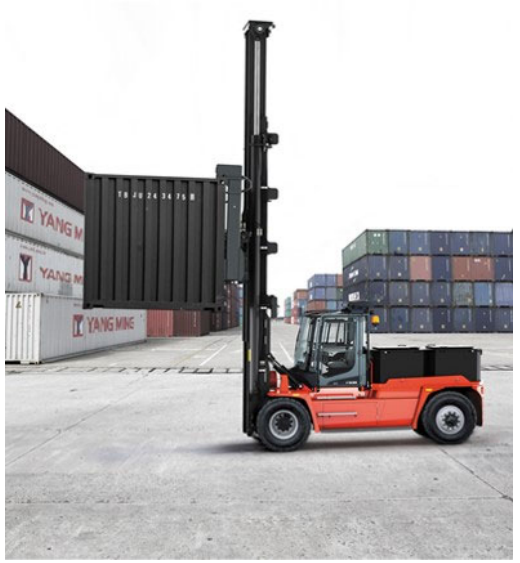
1.5 Commercial and Industrial EVs
Delivery Vans

- With everything being delivered today including lunches at work, groceries, and toilet paper the use of delivery trucks and vans has never been greater.
- UPS estimates that 35,000 of its delivery vans require a range of less than 100 miles a day to complete current routes.
- Significant saving in fuel costs can be obtained by transitioning to electric delivery vans.

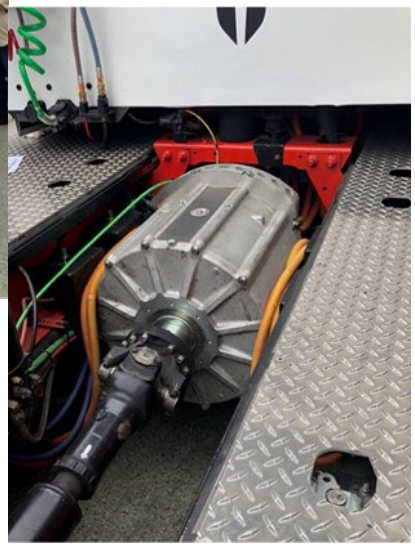
1.5 Commercial and Industrial EVs
Cargo-handling equipment

Electrified cargo handling equipment commonly used in seaports are becoming increasing available. These include:

- Forklifts
- Rubber Tired Gantry (RTG) crane
- Side and top container handlers
- Yard tractors
- Drayage trucks



1.5 Commercial and Industrial EVs
Semi-trailer trucks (class 7 & 8 heavy-duty)



- Electrified Semi-trailer trucks are currently in development by over a dozen traditional and non-traditional truck manufacturers.
- Battery capacity is at 300kW hours or more giving many of these trucks a range of 300 miles or more before requiring a charge.

1.5 Commercial and Industrial EVs
Battery Electric Buses

- Battery electric buses are available from multiple manufacturers and are typically being tested in dense urban areas due to their limited range.
- Regenerative braking is particularly valuable in buses because of the constant braking at bus stops.
- Various charging methods are being utilized beyond the traditional cord and plug method, including above and below bus charging.

1.5 Commercial and Industrial EVs
Refuse trucks (garbage trucks)

The Mack LR BEV Refuse Truck

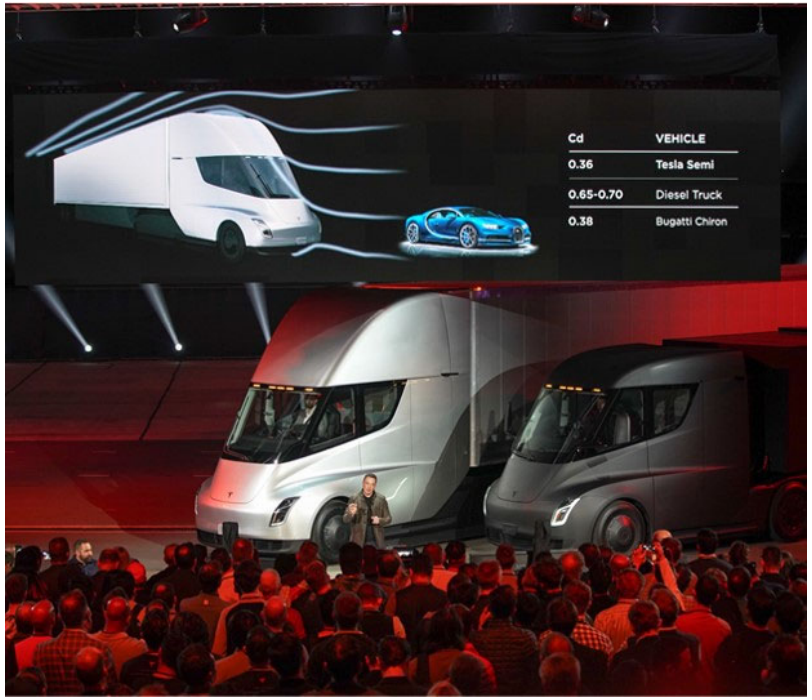
- Two 130-kW motors producing 496 peak horsepower and 4,o51 lb-ft. of torque.
- Four NMC lithium-ion batteries (Lithium Nickel Manganese Cobalt Oxide)
- Battery operate 600-750 volts, depending on state of battery charge
- 150kW charging via SAE J1172-compliant charMAging system

1.5 Commercial and Industrial EVs
Fleet charging considerations

Fleet charging of medium and heavy-duty commercial vehicle have many unique characteristics that must be considered long before the real work can begin.

- Vehicle availability
- Power demand
- Scale of fleet
- Charging equipment capacity
- Serving utility capacity

1.5 Commercial and Industrial EVs
Fleet charging considerations – Vehicle



Vehicle availability?

- Is an electric version of the fleet required vehicle readily available in the marketplace?
- Does the vehicle have the required range and capacity?
- How often would the vehicle require charging?

1.5 Commercial and Industrial EVs
Fleet charging considerations – Power Demand

Consider the battery capacity of the fleet vehicle(s)

- Nissan Leaf 40-kWh
- Sprinter panel van 125-kWh
- Freightliner eCascadia Semi 550-kWh

Consider the charging equipment capacity

- Current passenger vehicle charging at 25 to 350 kW of power.
- Next generation medium to heavy duty vehicle charging equipment is expected to be 1MW or more.

Consider the scale of fleet

- How many vehicles will need to be charging at once?

1.5 Commercial and Industrial EVs
Fleet charging considerations – Utility

Engagement with the serving utility should be completed very early in the process!

Does the utility have local capacity to meet the design needs?

What will the infrastructure costs be?

Are any programs available to incentivize off peak charging?

1.5 Commercial and Industrial EVs
Fleet charging considerations - Costs

Cost consideration:

Powering a light-duty EV with electricity costs 3 to 5 cents per mile *VS* 14 cents for a 27.5 mpg vehicle. At 15,000 miles a year that's a savings of $1,600 a year per fleet vehicle.

AC level#2 EVSE can cost $2,500 – $10,000 each to install

DC quick charging equipment can cost as much as $50,000 each to install.

1.5 Commercial and Industrial EVs
Questions?