Battery Electric Vehicles
Economic and Environmental Benefits
And Enjoyment!

L. David Roper
ROPERLD@VT.EDU

ICEV = Internal Combustion Engine Vehicle (e.g., Honda Civic)
HEV = Hybrid Electric Vehicle (e.g., Toyota Prius)
PHEV = Plug-in Hybrid Electric Vehicle (e.g., Prius Prime)
BEV = Battery Electric Vehicle (e.g., Tesla Model 3)
EV = PHEV or BEV

tinyurl.com/BEVs2019
El Niño increases global warming & La Niña decreases global warming.  

2016 was the hottest year on record!  
As was 2015, 2014, 2010 and 2005! 

Global warming could be decreased by making the air dirty again! 

Peak in UK coal extraction 

US Clean-Air Act 1963 

UK Clean-Air Act 1956
Environmental Aspect of BEVs

• Advantages
  – Much lower operating and maintenance costs reduce environmental footprint compared to ICEVs.
  – Reduction in pollutants
  – Refuel (charge) at home and using renewable energy
  – Reduction in carbon-dioxide emissions
  – Almost no noise pollution

• Disadvantages
  – Motors have some rare-earth and critical metals.
  – More carbon-dioxide emitted in manufacture than ICEV.
  – Tires can wear out slightly quicker than for ICEVs.
Energy-Usage Efficiency

kWh/passenger/mile

- BEVs
- PHEVs
- HEVs
- Intercity rail
- Motorcycles
- Light rail
- Commuter rail
- Air
- Gas cars
- Personal trucks
- Transit buses
High-Speed Train Routes in China (155-217 mph!)

Railway map of People's Republic of China
Colored lines showing CRH and other high speed rail services
Last update: 2018-01-15

99-217 mph
18,000 miles in 2018!
Plans for 24,000

New maglev train
Passenger rail in United States

Planned High-Speed Rail in U.S.
Causes of Global Warming
Too many people is basic cause!

We need renewable electrical energy & electric cars!
Electric Vehicles vs Gasoline Vehicles
GHG Emissions

2018 US ICEV average = 22 MPG
Toyota Prius Eco = 56 MPG

65 mpg ICEV for Tesla Model 3.

2018 data: ICEV = 80 MPG
2015 data: ICEV = 68 MPG

With solar panels on house
ICEV = infinite MPG!

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Well to Wheel Greenhouse Gas Emissions Comparison

- **Vehicle use (exhaust)**
- **Other vehicle (HFC, N2O, CH4)**
- **Fuel cycle**

<table>
<thead>
<tr>
<th></th>
<th>2010 (Gasoline)</th>
<th>2020 (Gasoline)</th>
<th>2025 (Gasoline)</th>
<th>Plug-in hybrid (PHEV20)</th>
<th>Fuel cell vehicle</th>
<th>Electric vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG emissions (g/mi)</td>
<td>500</td>
<td>400</td>
<td>300</td>
<td>200</td>
<td>100</td>
<td>50</td>
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</tbody>
</table>
Well to Wheel Smog-Forming Pollution Emissions Comparison [NOx + ROG]

- Vehicle use (exhaust)
- Vehicle use (evap)
- Fuel cycle

ROG + NOx emissions (g/mi)

<table>
<thead>
<tr>
<th>Year</th>
<th>ROG + NOx emissions (g/mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline (2010)</td>
<td>0.35</td>
</tr>
<tr>
<td>Gasoline (2020)</td>
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<tr>
<td>Gasoline (2025)</td>
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<tr>
<td>Plug-in hybrid (PHEV20)</td>
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<tr>
<td>Fuel cell vehicle</td>
<td>0.10</td>
</tr>
<tr>
<td>Electric vehicle</td>
<td>0.05</td>
</tr>
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</table>
Average BEV vs Average ICEV Fuel Cost

- **2018 US average ICEV MPG** = 22
- **2018 average BEV MPGe** = 102 (1 gallon = 33.7 kWh)
  - Tesla Model 3 = 130 MPGe!
- **2019 US average $/gallon** = $2.49
- **2018 US average $/kWh** = $0.125
- ICEV $/mile = $2.49/22 = **$0.113**
- BEV $/mile = $0.125/3.03 = **$0.0413**
- **ICEV/BEV = 2.74**
- Electricity price is more stable than gasoline price.
BEV vs ICEV Fuel Cost
Note: Regular gasoline price is the retail price including taxes for all formulations of regular grade gasoline. Crude oil price is composite refiner acquisition cost of crude oil. Source: U.S. Energy Information Administration, *Petroleum Marketing Monthly*, May 2019.
Considering inflation $0.13/kWh in 2015 is equivalent to $0.106/kWh in 2005.
Most Efficient BEV vs Most Efficient HEV
Hyundai Ioniq Electric vs Prius Eco Fuel Cost

- Toyota Prius Eco (hybrid) MPG = 56
- Hyundai Ioniq Elect. MPGe = 136
- 2019 US average $/gallon = $2.49
- 2018 US average $/kWh = $0.125
- ICEV $/mile = $2.49/56 = $0.0445
- BEV $/mile = $0.125/4.04 = $0.0309
- ICEV/Honda-Ioniq-Electric = 1.44
  - About ½ of average BEV vs average ICEV
Tesla Model 3 vs. Toyota Corolla — 5 Year Cost Estimates

High gas price, high electricity price scenario

<table>
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<tr>
<th>Cost</th>
<th>Model</th>
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</thead>
<tbody>
<tr>
<td>$30,052</td>
<td>Toyota Corolla LE Hybrid</td>
</tr>
<tr>
<td>$31,690</td>
<td>Tesla Model 3 SR+</td>
</tr>
<tr>
<td>$31,802</td>
<td>Toyota Corolla L</td>
</tr>
<tr>
<td>$37,839</td>
<td>Toyota Corolla XSE</td>
</tr>
</tbody>
</table>

Least expensive TM3 with 240-miles range

Assumptions: $5/gallon for gasoline, $0.20/kWh for electricity, 15,000 miles/year, maintenance estimates from Edmunds and Paul Fosse/CleanTechnica, $3,750 tax credit for Model 3, $5,000 down payment and 5.5% 5-year loan for remaining portions of upfront costs of cars, Kelley Blue Book estimates for 5-year resale value. Full analysis here: https://cleantechnica.com/tag/tesla-model-3-vs-toyota-corolla/

Chart: CleanTechnica • Source: CleanTechnica
0-30 mph Acceleration is a BIG DEAL!

- High torque at low speed! Triple acceleration same efficiency as for ICE.
- Can get to the next traffic light far ahead of ICE cars with no roar.
- Can maneuver much better in tight traffic.
Why BEVs Have Only One Gear

• Electric motors have high maximum RPM (Chevy Bolt EV: 8,810 RPM)
• Electric motors have high efficiency over a broad RPM range.
• Electric motors produce high torque at low RPM.
Questions about BEVs

• Q: What do you do when you run out of electricity?
• A: What do you do when you run out of gasoline? You don’t, because you watch the fuel gauge. You fill it up when needed.
• Q: Do you have “range anxiety” when you drive?
• A: No, because I plan my trip.
• Q: What do you do when you go up a steep hill?
• A: You step on the accelerator and pass the gasoline cars.
• Q: Is the battery dangerous?
• A: Not nearly as dangerous as a tank of gasoline!
‘Driving an Escalade to buy groceries is like hanging a picture with a sledge hammer!’
EV Buying Experience

• Dealers are often poorly informed about plug-ins features and technology.
• Dealers are often poorly informed about different available charging possibilities.
• Customers are often poorly informed about plug-ins features and technology and charging.
• Dealers do not like the fact that it takes longer to inform customers about plug-ins than ICEs.
• Dealers do not like low maintenance costs for BEVs.
• For the above reasons Tesla decided to not sell their cars through dealers.
What about BEV Batteries?

• BEV batteries are guaranteed for defects for 8 years and 100,000 miles. (Tesla Model 3 Long Range for 120,000 miles)

• Lithium-ion batteries lose capacity with time.

• Tesla Model 3 has a 70% degradation warranty within 8 years. Most will degrade much less than that depending on how they are driven and charged. Projected lifetime (70% capacity) = 300,000-400,000 miles.

• New batteries that will last longer and cost less are being developed. Tesla states next battery will last 1-million miles!
Battery Reuse and Recycling

• When capacity down to about 70% they can be used to store solar and wind energy and to store energy during time-of-day (TOD) low rates to be used during TOD high rates.

• When reused batteries are down to about 20% they can be recycled.

• Toxco Inc. awarded $9.5-million DOE grant to recycle lithium batteries.
ICEV vs BEV Needed Maintenance

ICEV maintenance **NOT** needed for a BEV
- Mechanical brakes (used constantly)
- Oil and oil-filter regular changes
- Transmission fluid changes
- Mufflers and tail pipes
- Catalytic converters
- Belts
- Spark plugs
- Many engine moving parts to wear out

• BEV maintenance
- Mechanical brakes are **used only in emergencies and at low speed**. Otherwise **electricity regeneration** slows or stops a BEV.
- Electric motors can run 24/7 for many years without maintenance or repairs.
- Rotate tires at 10,000-miles intervals.
- Battery/electronics coolant changed at 50,000 miles.
- Solid-state electronics are very reliable.
Enjoyment!

• Very quiet.
• High acceleration!
• Most battery charging overnight at home.
  – No fumes or bad weather when charging.
• Much free < 10-kW charging.
• Low center of gravity enhances safety and performance (heavy battery underneath).
• One-pedal driving.
2019 U.S. Survey about Electric Cars

• 31% would consider getting an EV now.
• 27% would consider getting an EV in the Future.
• 5% are definitely planning to get an EV for their next vehicle. (2.5 times as many who got an EV in 2018.)
• 72% say automakers should provide more kinds of EVs.
• 73% say EVs will reduce oil use.
• 72% say EVs will reduce pollution.
• 65% say EVs will save money on fuel and maintenance for drivers.
Global Temperature Relative to 1880-1920 Average.
Highest 2 data points are projections for 2019 & 2020. The area under the red curve includes existing fields, discoveries and estimated as-yet-undiscovered fields.
Current crude-oil price = $55/barrel. A recent study shows that crude-oil price must be no higher than $10/barrel for ICEVs to match the operating cost of BEVs fueled by solar and wind energy!
Renewables are Passing Coal for U.S. Electricity Generation

Renewables = hydropower, wind, solar, geothermal and biomass.
(Note in inclusion of hydropower, which is arguably not renewable.)
Solar/Wind/Biomass are Passing Coal for U.S. Electricity Generation

Renewables = wind, solar, and biomass, not including hydropower.

Natural-gas curve bends downward because U.S. extraction is peaking.
### Tesla Model 3

<table>
<thead>
<tr>
<th>Model</th>
<th>EPA Range (miles)</th>
<th>Efficiency (MPGe)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Range *</td>
<td>220</td>
<td>131</td>
<td>$35,400</td>
</tr>
<tr>
<td>Standard Range Plus</td>
<td>250</td>
<td>141</td>
<td>$39,490</td>
</tr>
<tr>
<td>Long Range *</td>
<td>325</td>
<td>130</td>
<td>$45,900</td>
</tr>
<tr>
<td>AWD</td>
<td>322</td>
<td>116</td>
<td>$48,490</td>
</tr>
<tr>
<td>Performance (AWD)</td>
<td>310</td>
<td>116</td>
<td>$56,990</td>
</tr>
</tbody>
</table>

* = phone order. If leased, returned to Tesla.

**Autopilot software is included in all 5 versions. Order online.**

**US 2018 average price of a light vehicle was $37,577.**

**Federal tax credit = $1875 until 31 Dec 2019.**

**Average gasoline car in 2018: 25 MPG**
Chevrolet Bolt EV

Range: 259 miles  
MPGe: 119  
Price: $36,620

US 2018 average price of a light vehicle was $37,577.

Federal tax credit = $1875 until 31 Mar 2020.

There are two trims in order of increasing cost: LT & Premium.
### Nissan LEAF II e-Plus

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<tbody>
<tr>
<td>LEAF</td>
<td>150</td>
<td>112</td>
<td>$29,990</td>
</tr>
<tr>
<td>LEAF ePlus</td>
<td>226</td>
<td>108</td>
<td>$37,445</td>
</tr>
</tbody>
</table>

Federal tax credit = $7500.

US 2018 average price of a light vehicle was $37,577.

These two models have 3 variants in order of increasing cost: S, SV, & SL.
Hyundai Kona Electric

Range: 258 miles    MPGe: 120    Price: $36,450

US 2018 average price of a light vehicle was $37,577.
Hyundai Ioniq Electric

Range: 170 miles  MPGe: 133  Price: $30,315

US 2018 average price of a light vehicle was $37,577.
Kia Niro Electric

Range: 239 miles  MPGe: 112  Price: $39,495

US 2018 average price of a light vehicle was $37,577.
Kia Soul Electric

Range: 243 miles     MPGe: 101     Price: $33,950
## Tesla Model S AWD

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<tr>
<td>Standard Range ?</td>
<td>285</td>
<td>109</td>
<td>$78,000</td>
</tr>
<tr>
<td>Long Range (AWD)</td>
<td>373</td>
<td>111</td>
<td>$79,990</td>
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<tr>
<td>Performance (AWD)</td>
<td>345</td>
<td>104</td>
<td>$99,990</td>
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Autopilot software included in all 3 versions. Order online. ? = phone order. Free Supercharging!
## Tesla Model X AWD

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<tr>
<td>Standard ?</td>
<td>295</td>
<td>93</td>
<td>$83,000</td>
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<tr>
<td>Long Range (AWD)</td>
<td>328</td>
<td>87</td>
<td>$84,990</td>
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<tr>
<td>Performance (AWD)</td>
<td>328</td>
<td>85</td>
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Jaguar i-Pace AWD

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<th>Range</th>
<th>MPGe</th>
<th>0-60</th>
<th>Cargo</th>
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<tbody>
<tr>
<td>$70,495</td>
<td>234</td>
<td>76</td>
<td>4.5</td>
<td>51</td>
</tr>
<tr>
<td></td>
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<td><strong>Cargo</strong></td>
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**Audie e-Tron AWD**
Tesla Model 3 Drive Train

AWD (Dual Motor) has another motor in front.
# BEV Comparisons

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<tr>
<td>TM3SR+</td>
<td>$38,990</td>
<td>240</td>
<td>132</td>
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<td>$37,595</td>
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<td>119</td>
<td>6.5</td>
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<td>NePlus</td>
<td>$37,445</td>
<td>226</td>
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<td>TMX</td>
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<td>325</td>
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TM3SR+ = Tesla Model 3 Standard Range +; CBEV = Chevy Bolt EV; NePlus = Nissan LEAF ePlus
TMX = Tesla Model X; JiPace = Jaguar iPace; AeTron = Audie eTron

Cargo = back seats in upright position
KiSoulE=Kia Soul Electric, TM3LR=Tesla Model 3 Long Range, HyKonaE=Hyundai Kona Electric
CBoltEV=Chevy Bolt EV, TM3AWD=Tesla Model 3 AWD, TM3S+=Tesla Model 3 Standard Plus
KiNiro=Kia Niro, NLEAFII+=Nissan LEAF II Plus, NLEAFII=Nissan LEAF II, AeTron=Audi eTron
TMSLR=Tesla Model S Long Range, TMXLR=Tesla Model X Long Range, JiPace=Jaguar iPace
Volkswagen BEV Plans

MQB = VW ICEV platform; MEB = VW BEV platform

VW plans to move quickly from ICEVs to BEVs!

50 BEV models
22 million BEVs
By 2028!

MQB = VW ICEV platform; MEB = VW BEV platform
VW plans to move quickly from ICEVs to BEVs!
Volkswagen BEV Plans

ID. Buzz
No specs yet

ID. Vizzion

ID. Beach Buggy
## Volvo Polestar 2

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<th>Price</th>
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<tr>
<td>218</td>
<td>4.8</td>
<td>94</td>
<td>$55,000</td>
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Volvo XC40 Recharge
**Mercedes-Benz EQC**

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<td>5.1</td>
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# Ford Mustang Mach-E

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</tr>
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<tbody>
<tr>
<td>Standard Range RWD</td>
<td>230</td>
<td>102</td>
<td>$39,000</td>
</tr>
<tr>
<td>Long Range RWD</td>
<td>300</td>
<td>102</td>
<td>$48,000</td>
</tr>
<tr>
<td>Long Range AWD</td>
<td>280</td>
<td>96</td>
<td>$52,000</td>
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<td>96</td>
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Federal tax credit = $7500

Average gasoline car in 2018: 25 MPG

US 2018 average price of a light vehicle was $37,577.
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<tr>
<td>Long Range AWD</td>
<td>280</td>
<td>96</td>
<td>$52,000</td>
</tr>
<tr>
<td>Performance (AWD)</td>
<td>280</td>
<td>96</td>
<td>$61,000</td>
</tr>
</tbody>
</table>

Federal tax credit = $7500

Average gasoline car in 2018: 25 MPG

US 2018 average price of a light vehicle was $37,577.
BEV Supercars: **Tesla Roadster 2**

<table>
<thead>
<tr>
<th>Range (mi)</th>
<th>0-60 mph (s)</th>
<th>Top Speed (mph)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>620</td>
<td>1.9</td>
<td>250</td>
<td>$200,000</td>
</tr>
</tbody>
</table>
### BEV Supercars: Porsche Taycan

<table>
<thead>
<tr>
<th>Range (mi)</th>
<th>0-60 mph (s)</th>
<th>Top Speed (mph)</th>
<th>Price</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>226</td>
<td>3.9</td>
<td>153</td>
<td>$116,590</td>
<td>4S</td>
</tr>
<tr>
<td>229</td>
<td>3.0</td>
<td>161?</td>
<td>$150,900</td>
<td>Turbo</td>
</tr>
<tr>
<td>257</td>
<td>2.6</td>
<td>161</td>
<td>$185,000</td>
<td>Turbo S</td>
</tr>
</tbody>
</table>
BEV Mini-Compacts

**Smart ForTwo Electric**
- 68 miles
- 75 mph
- $24,550

**Chevrolet Spark EV**
- 82 miles
- 89 mph
- $13,500

**Mini Cooper SE Electric**
- 130 miles
- $29,900
Electric Trucks

- Rivian electric pickup and SUV (rivian.com).
- Tesla Cybertruck
- Ford F150 electric promised.
- Many Electric trucks promised
# Tesla Cybertruck

<table>
<thead>
<tr>
<th>Type</th>
<th>Range (Miles)</th>
<th>0-60 mph</th>
<th>Storage (ft^3)</th>
<th>Towing (lbs)</th>
<th>Clearance (in)</th>
<th>Price ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM RWD</td>
<td>250</td>
<td>6.5</td>
<td>100</td>
<td>7,500</td>
<td>16</td>
<td>$39,900</td>
</tr>
<tr>
<td>DM AWD</td>
<td>300</td>
<td>4.5</td>
<td>100</td>
<td>10,000</td>
<td>16</td>
<td>$49,900</td>
</tr>
<tr>
<td>TM AWD</td>
<td>500</td>
<td>2.9</td>
<td>100</td>
<td>14,000</td>
<td>16</td>
<td>$69,900</td>
</tr>
</tbody>
</table>
Tesla Cybertruck
**ZEV, LEV & PZEV Vehicles**

- **ZEV**: Regulation that requires automakers to sell electric cars and trucks; the exact number of vehicles is linked to the automaker’s overall sales within the state.

- **LEV**: Sets maximum emissions allowed; **ULEV**, **SULEV**.

- **PZEV**: “…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 Emissions Vehicle (SULEV) tailpipe-emission standards”
ZEV States in U.S.

• 2013: Multi-state ZEV Task Force formed: California, Connecticut, Maryland, New York, Oregon, Rhode Island & Vermont.
• 2018: Maine, Massachusetts & New Jersey joined the ZEV Task Force.
• 2019: Colorado joined the ZEV Task Force
• Delaware, District of Columbia, Pennsylvania & Washington follow the California LEV standards.
Other battery chemistries are possible; e.g. solid state.
Charging BEVs

• **Level-1**: 120-volts AC, 1.12-kW, for all EVs (Everywhere!) (SAE-J1772 portable charging station that comes with the EV)

• **Level-2**: 240-volts AC, 3.3-kW to 19-kW charging station with SAE-J1772 plug, for all BEVs & PHEVs (Your parking space, Kroger, InnVT, Campus Automotive)

• **Level-3**: 480-volts DC, 35-kW - 350-kW, only for BEVs (Blacksburg Town Hall 40-kW)
  - CHAdeMO standard (Asian) (maximum 150-kW in 2017)
  - SAE CCS standard (USA & Europe) (Level-2/3 one plug)

Most charging occurs at home in a garage, driveway or parking space.
Charging BEVs

• SAE-J1772 cord that comes with an EV can have a pigtail that allows level-2 charging with a standard 240-volts outlet or 120-volts outlet.
• An adaptor is available to allow Teslas to charge at level-2 SAE-J1772 charging stations.
• 350-kW charging stations being installed.
• Tesla Wall Connector: 240-volts AC, 20-kW for Tesla BEVs, but adaptor can allow other BEVs.
• Tesla Superchargers: 480-volts DC, 150-kW only for Tesla BEVs (V3 now installing for 250-kW)
Charging

• Most charging takes place overnight at home.
• Tesla has by far the most fast (Superchargers) and **overnight** charging stations at hotels for long trips.
• **Electrify America** is quickly building fast charging stations for all BEVs. (I-81 Exit 155 and Wytheville)
• [Plugshare.com](http://plugshare.com) is the best web page for finding charging stations.
• [ABetterRoutePlanner.com](http://abetterrouteplanner.com) is an excellent program for planning BEV trips.
• Tesla has excellent navigation showing where Superchargers are and how long to charge there.
  – Shows number of charging stalls available at next SC.
Tesla Supercharger in Carlisle PA
Tesla Supercharger in Future

Largest has 50 stations in Shanghai China! Plans to finally have all Superchargers on solar energy.
Charging starts off fast and decreases slowly at first and then decreases faster toward the end.

Charging from 10% to 80% is quick and typically provides ample range to travel between most Superchargers. Charging from 80% to 100% doubles the charge time because the car must reduce current to top off cells. Actual charge times may vary.
I have used several of them.
Orange = 480-volts DC fast chargers
Green = 240-volts AC chargers

Plugshare.com

I recommend installing level-2 240-volts charging stations at Sweet Springs, Union, Rainelle & Hillsboro WV.
Tesla Superchargers

About 450 stations, average 6 stalls. Building about 1/day.

On I-81: Bristol TN, Wytheville, Lexington, Staunton, Mt. Jackson, Strasburg, Martinsburg WV, Hagerstown MD

Soon: Roanoke
Soon: Lynchburg on US-460

Roper home charger: 9.6 –kW; Tesla Superchargers: 150-kW being updated to 250-kW.
The 2 gray arrows show the SCs being built in Salem VA, near Roanoke and I-81, and Lynchburg. The one at Lynchburg allows direct Tesla travel between Blacksburg/Roanoke and Richmond and direct travel between Charlottesville and northern North Carolina.
Tesla Model 3 trip from Blacksburg VA to Fort Worth TX

TM3 wants 5 Supercharging stops; I need 3 stops/day over 2 days. Charge to 100% at hotel.
I pay APCO about $0.11/kWh in our garage.
Tesla Destination Chargers

At hotels, parks, businesses, multi-family complexes and workplaces. Usually there is no fee to use Destination Chargers.
Electrify America Chargers Plans

Two near Blacksburg: I-81 exit 156 near Fincastle, Wytheville Sheetz Station
None for WV!
Electrify America Chargers

Total = 450 stations, average of 6 stalls

Two near Blacksburg:
I-81 exit 156 near Fincastle,
Wytheville Sheetz Station
None for WV!
Electrify America Chargers Plans

Cycle 2 investments will be made in 18 metropolitan areas across the country.

[Map showing 18 metropolitan areas across the United States, with labels for each area such as Seattle MSA, Portland MSA, Los Angeles MSA, Phoenix MSA, Dallas MSA, Houston MSA, Atlanta MSA, and Miami MSA. The map indicates Cycle 1 and 2 Metro, New Cycle 2 Metro, and Cycle 1 Station.]
Other U.S. Charging Networks

- Blink ~1680 sites
- Chargepoint ~6083 sites
- eVgo ~774 sites
- Greenlots ~392 sites
- Semaconnect ~1166 sites
- Webasto ~164 sites

Many < 10-kW chargers have no fee to use.
With a $450 adapter, Teslas can use CHAdeMO stations as well as Superchargers, for a total of 2818 locations and 9350 charging stations!
Fuel in the Middle of “Nowhere”?

- Here is an estimate of 5-billion 120-V electrical outlets in the US: How many electrical outlets exist in the United States?
- Here is a survey of 186,000 gasoline stations in the US: How many gas stations are there in the U.S?
Exponential growth!
EVs = PHEVs & BEVs
If this analysis is approximately correct, about half of the cars in the world will be electric by about year 2035 and almost all cars will be electric by 2100. Probably by 2100 almost all electric cars will be BEVs with few PHEVs.
Plug-In Hybrids (PHEV)

- Toyota Prius Prime: 22 miles EV
- Mitsubishi Outlander: 22 miles EV, AWD
- Honda Clarity: 48 miles EV
- Chrysler Pacifica: 32 miles EV, van
- BMW Rex: 72 miles EV, 2.4-gallons gasoline
- Ford Fusion Energi; 19 miles EV
- Hyundai Ioniq: 27 miles EV
- Kia Niro/Optima: 27 miles EV
- Several more expensive (Cadillac, Porsche, Volvo, etc.)
Why Not Fuel-Cell Cars?

- They are very complicated:

  - Requires a lithium-ion or NiMH battery similar to a PHEV!
  - Hydrogen fuel is not easy to obtain. Most is made from methane and water, which produces carbon dioxide with the hydrogen! Should be made by solar!
  - Better for heavy-duty vehicles, such as trucks.