

Plug-in Hybrid Cars (PHEVs)

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Terminology

HEV = Hybrid Electric Vehicle

Electric car = Battery Electric Vehicle (**BEV**)
or Plug-in Hybrid Electric Vehicle (**PHEV**)

ICE = Internal Combustion Engine car (gasoline or diesel)

Energy = kilowatts-hours (**kWh**)

Power = Energy/time = kilowatts (**kW**)

Pluginamerica.org, insideevs.com, plugshare.com

My Experience with PHEVs

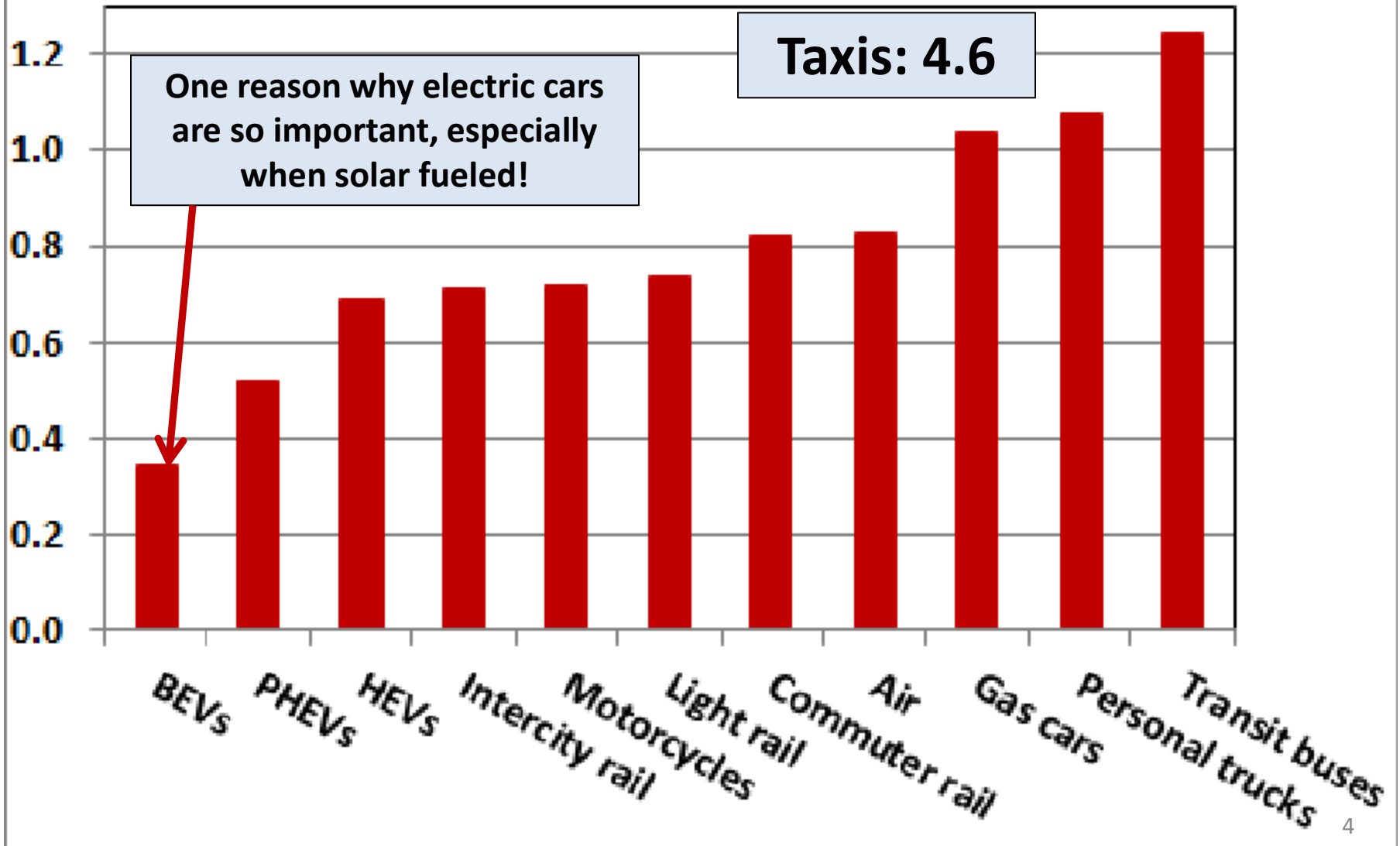
- 2005: Bought a 2005 Toyota Prius.
- 2009: Had Prius converted to a Hymotion PHEV.
- 2006: Bought a 2006 Toyota Highlander Hybrid (HiHy).
- 2013: Attempted to convert HiHy to a PHEV-failed!
- 2016: Bought a 2016 Toyota RAV4 Hybrid

PHEVs as a Bridge to BEVs

- Has no “range anxiety”.
- Provides an introduction to the advantages of electrical propulsion.
- Greatly reduces emissions of an HEV.
- Can mostly be fueled at home.

Passenger Travel Energy Use

kWh/passenger/mile



PHEV versus HEV

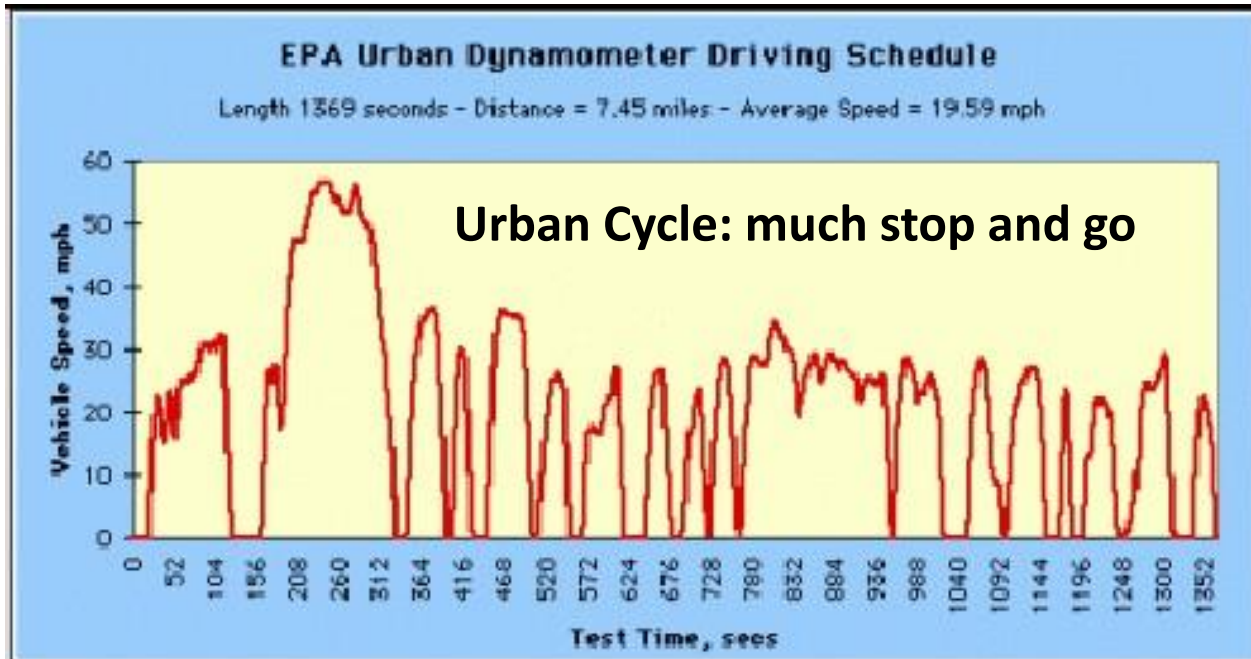
Same components as in an HEV +

- Larger battery (Prius 1.3 kWh vs Prius Prime 8.8 kWh)
- Different eCVT
- Different computer controls to allow motion using battery only until its charge gets below some value
- Charger to connect to a charging station to charge the larger battery (**3.3 kW or 6.6 kW**)
- External J1772 receptacle for 120-volts or 240-volts charging
- Portable charging station stored in trunk for 120-volts charging anywhere; some can be converted to 240-volts
- Dash display to show the State Of Charge (SOC)
 - and energy usage
 - and location of level-2 charging stations

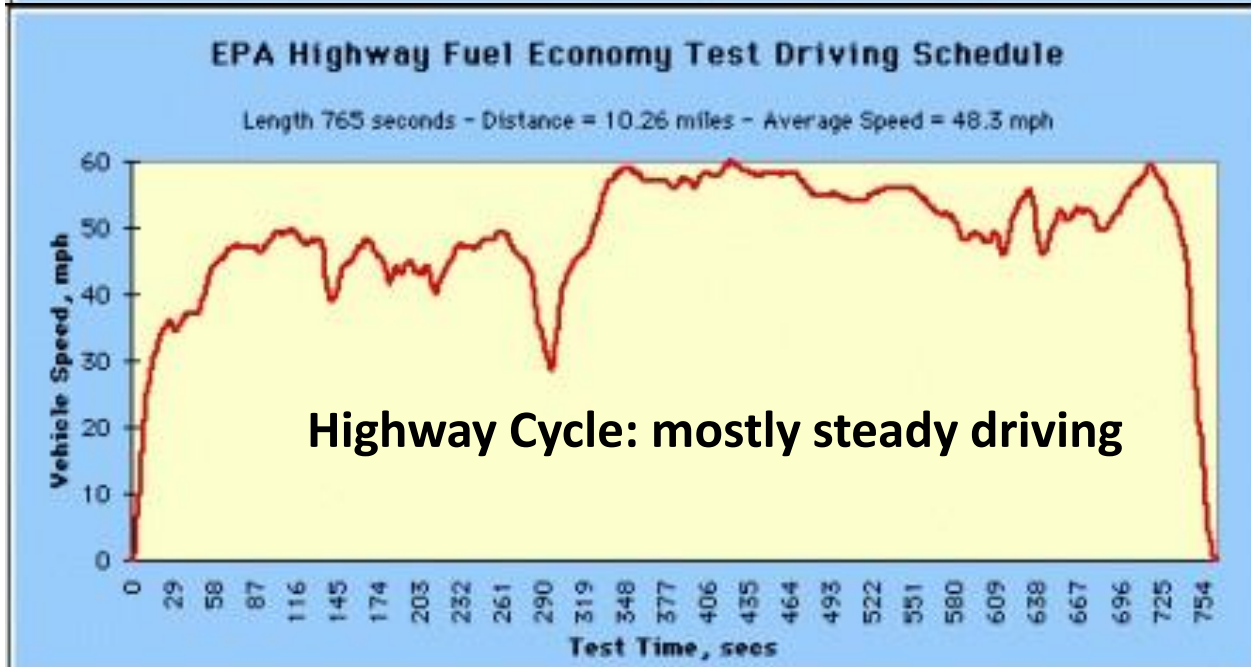
Regeneration for HEVs, PHEVs & BEVS

- The electric motor is used as a generator to charge the battery.
- When brakes are engaged except in emergencies and at very low speeds, due to kinetic energy.
- When going down a hill due to gravity.
- When accelerator is not being depressed, due to kinetic energy.

EPA Driving Cycles

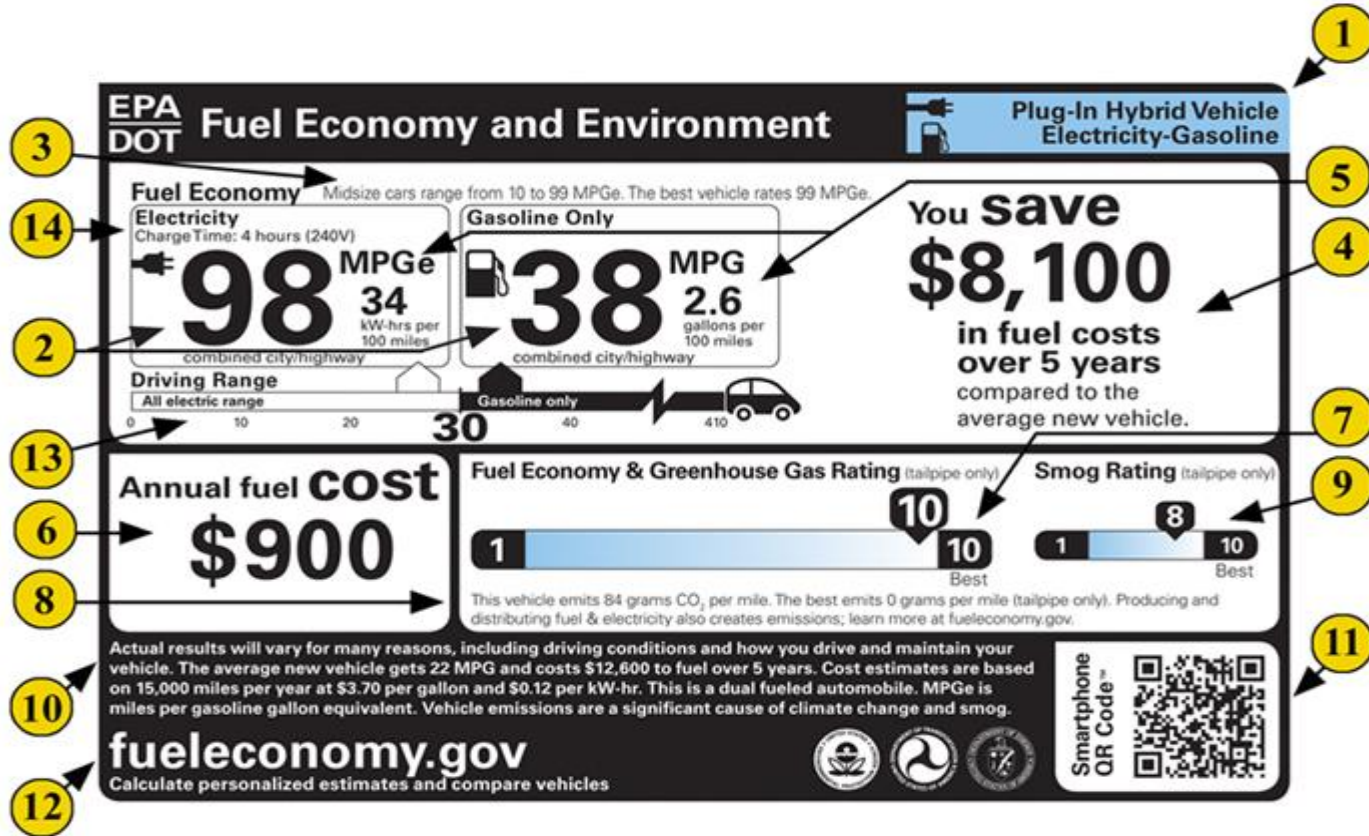


May not fit
your driving
method.



PHEV Monroney Label

for 2011 Chevrolet Volt Gen 1



- 1: Vehicle Technology & Fuel.
- 2: Fuel Economy.
- 3: Comparing to Other Vehicles
- 4: Save/Spend More of 5 Years Compared.
- 5: Fuel Consumption Rate.
- 6: Estimated Annual Fuel Cost.
- 7: Fuel Economy & Greenhouse Gas Rating.
- 8: CO₂ Emissions.
- 9: Smog Rating.
- 10: Details
- 11: QR Code.
- 12: Web page.
- 13: Driving Range.
- 14: Charge Time

2017 Chevy Volt

**EPA
DOT**

Fuel Economy and Environment

These estimates reflect new EPA methods beginning with 2017 models.



Plug-In Hybrid Vehicle
Electricity-Gasoline

Compact cars range from 14 to 116 MPGe.

The best vehicle rates 119 MPGe.

Fuel Economy

Electricity

Charge Time: 4.5 hours (240V)

106 MPGe

31

kWh per
100 miles

combined city/highway

Gasoline Only



42 MPG

2.4

gallons per
100 miles

combined city/highway

You **save**
\$3,750

in fuel costs
over 5 years

compared to the
average new vehicle.

A
A
B

Driving Range

All electric range



53 miles

Gasoline only



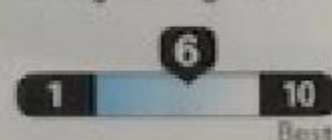
Annual fuel **cost**

\$650

Fuel Economy & Greenhouse Gas Rating (tailpipe only)



Smog Rating (tailpipe only)



This vehicle emits 51 grams CO₂ per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel & electricity also create emissions; learn more at fuelconomy.gov.

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 26 MPG and costs \$7,000 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at \$2.45 per gallon and \$0.13 per kWh. This is a dual fueled automobile. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fuelconomy.gov

calculate personalized estimates and compare vehicles



Smartphone
QR Code



2017 Prius Prime Plus

EPA
DOT

Fuel Economy and Environment

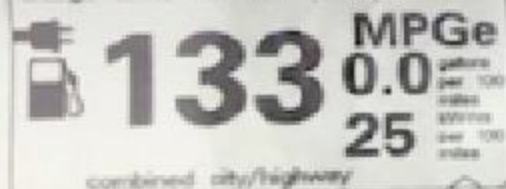


Plug-In Hybrid Vehicle
Electricity-Gasoline

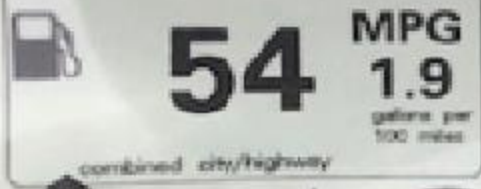
Fuel Economy Midsize Cars range from 13 to 314 MPGe. The best vehicle rates 118 MPGe.

Electricity + Gasoline

Charge Time: 2.0 hours (240V)



Gasoline Only



You save
\$ 4,000

in fuel costs
over 5 years
compared to the
average new vehicle.

Driving Range

Electricity + Gasoline



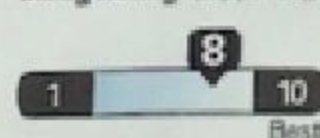
Annual fuel Cost

\$ 600

Fuel Economy & Greenhouse Gas Rating (tailpipe only)



Smog Rating (tailpipe only)



This vehicle emits 28 grams CO₂ per mile. The best emits 0 grams per mile (tailpipe only). Producing and consuming fuel and electricity also create emissions. Learn more at fuel economy.gov.

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 26 MPG and costs \$7,000 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at \$2.45 per gallon and \$0.13 per kW-hr. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fuel economy.gov

Calculate personalized estimates and compare vehicles



Smartphone
QR Code



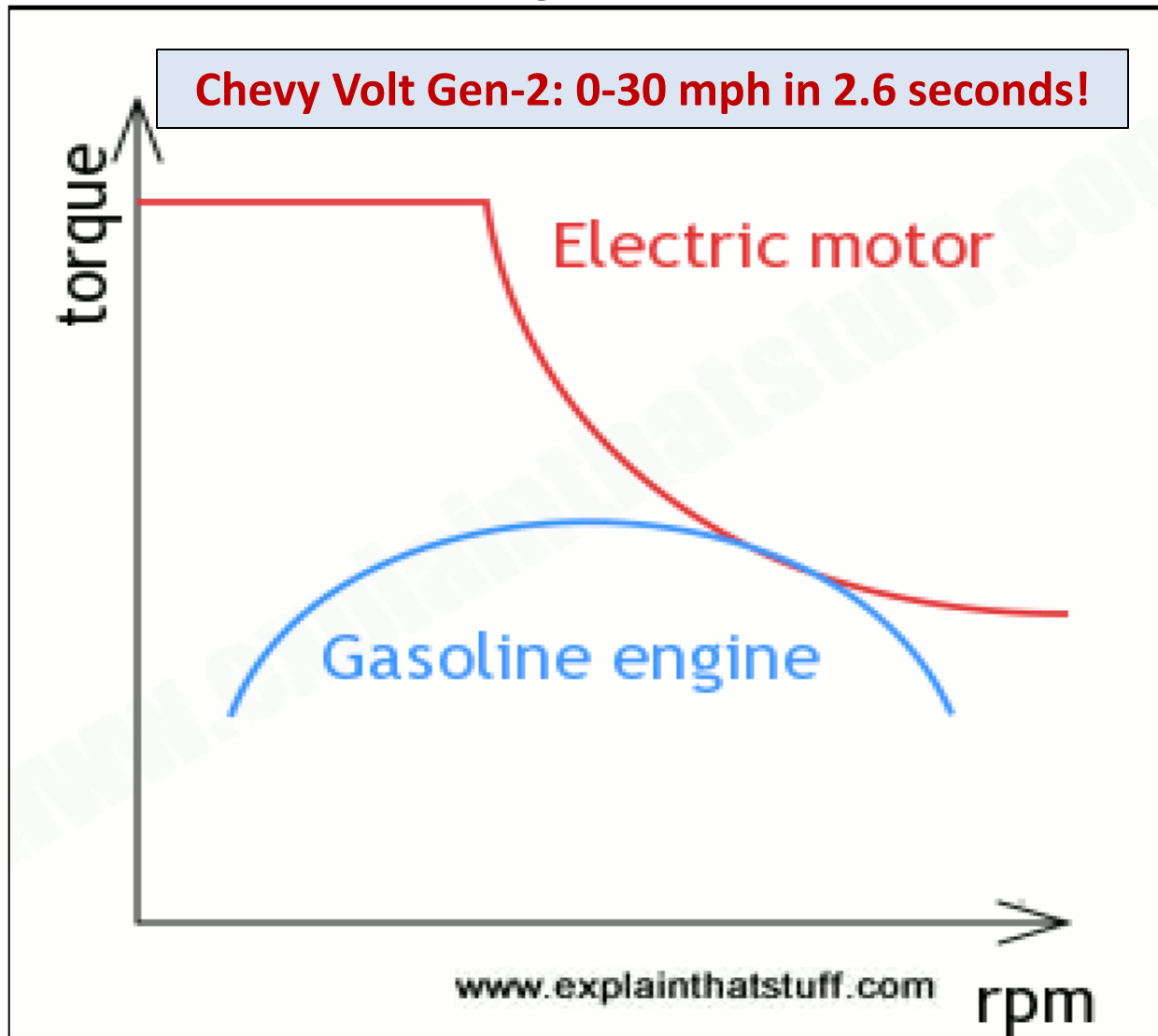
Charging a PHEV

- All have standard SAE J1772 inlet.
- Comes with portable level-1 120-volts charging station. It can be converted to 240-volts.
- Can be charged at all level-2 240-volts charging stations. ~9 are in Blacksburg.
- **Cannot be charged at level-3 480-volts DC charging stations.**

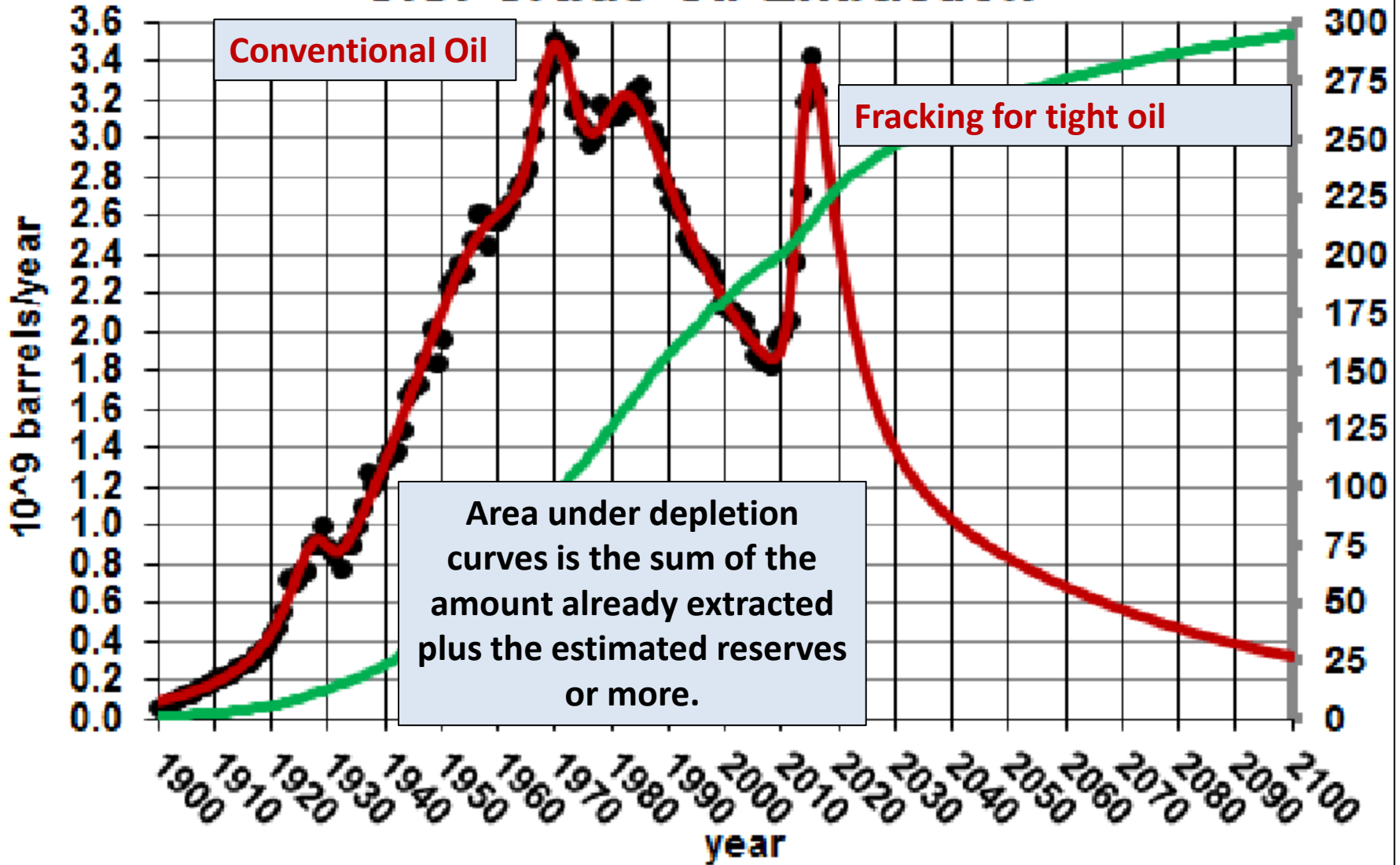


0-30 mph Acceleration is a BIG DEAL!

- **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.

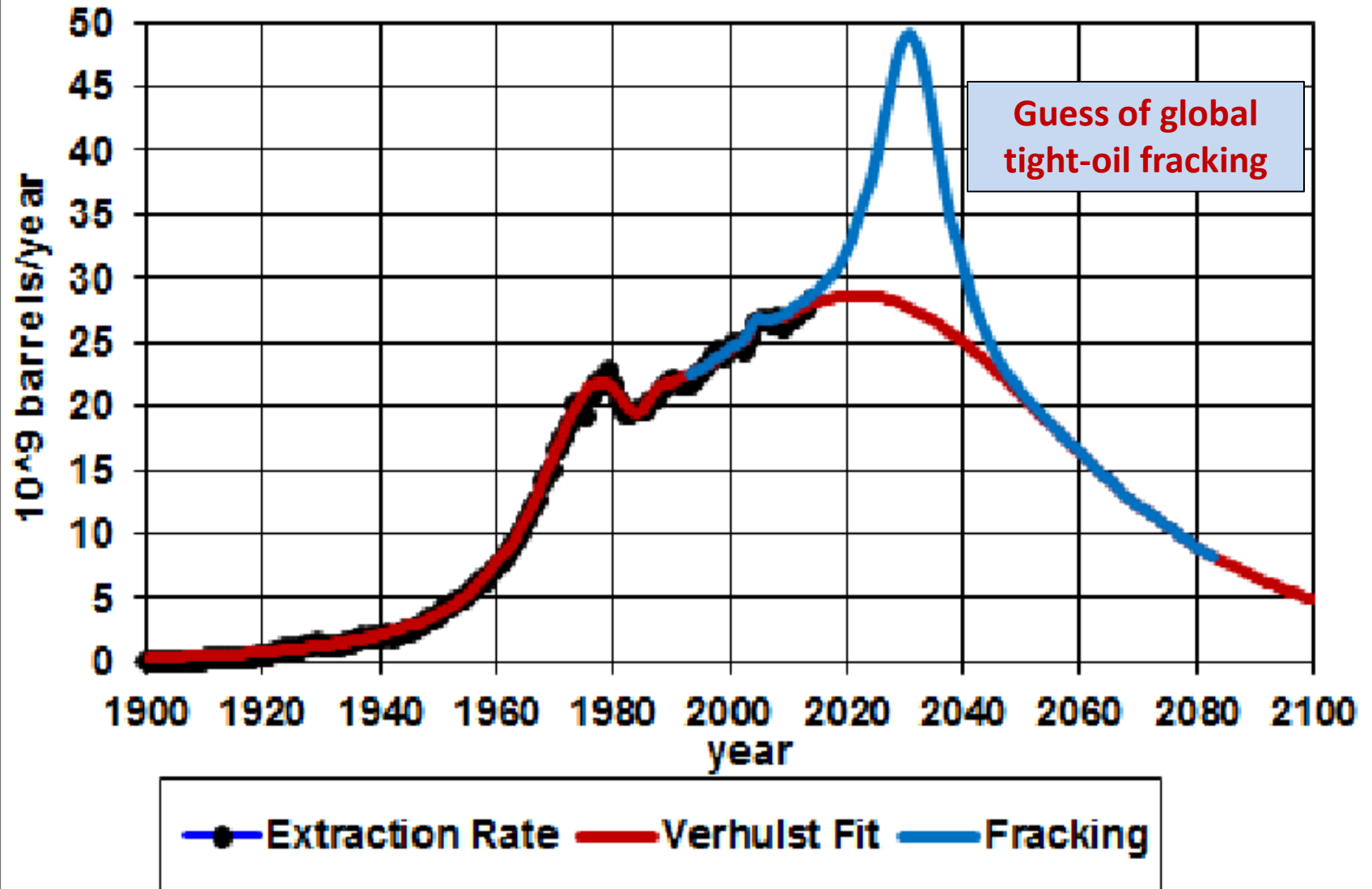


U.S. Crude Oil Extraction

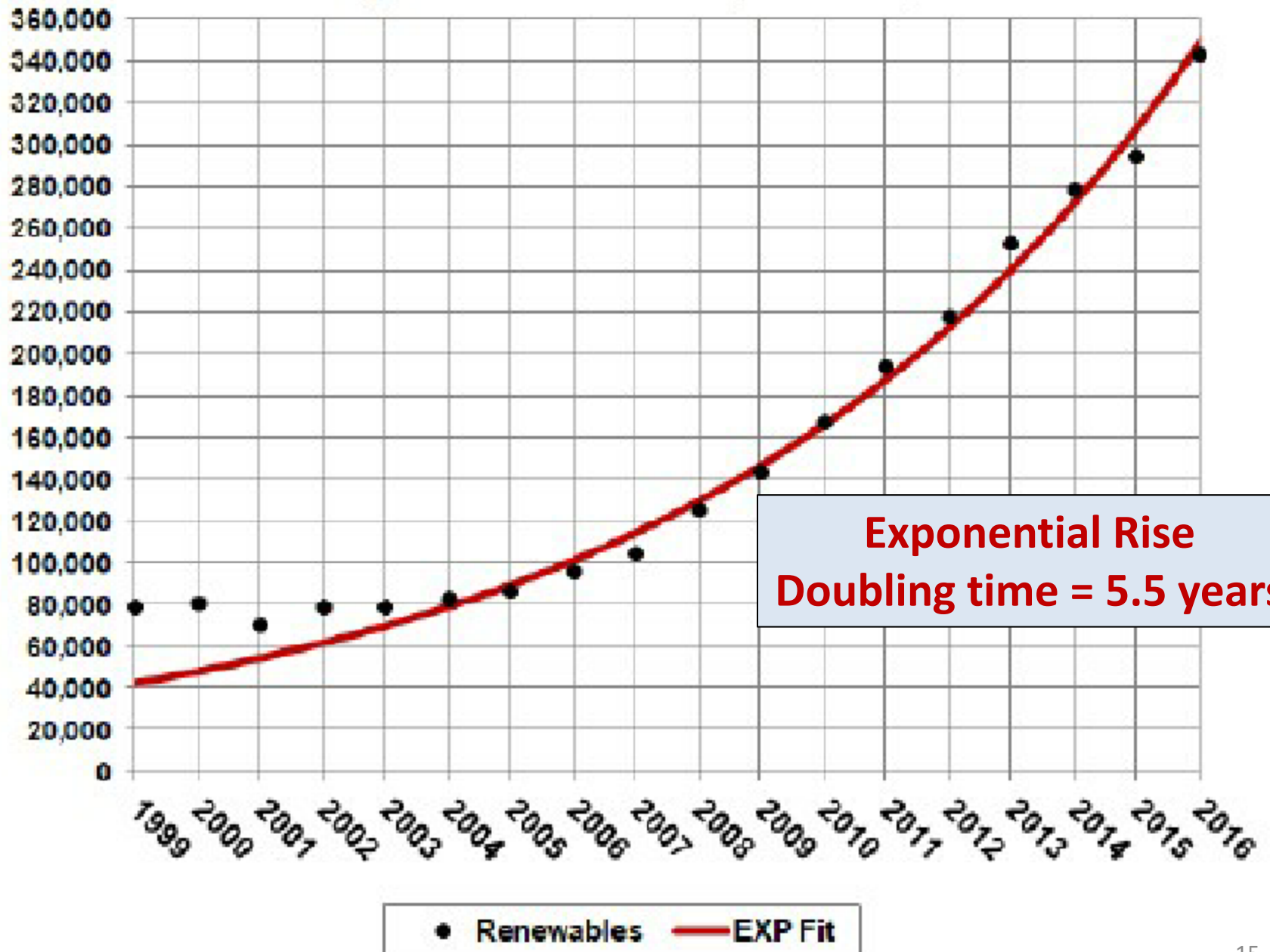


● Extraction — Fit — Amount Extracted (10⁹ bbl)

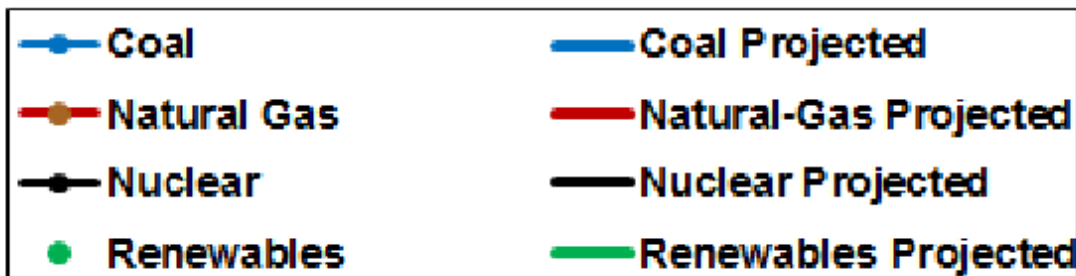
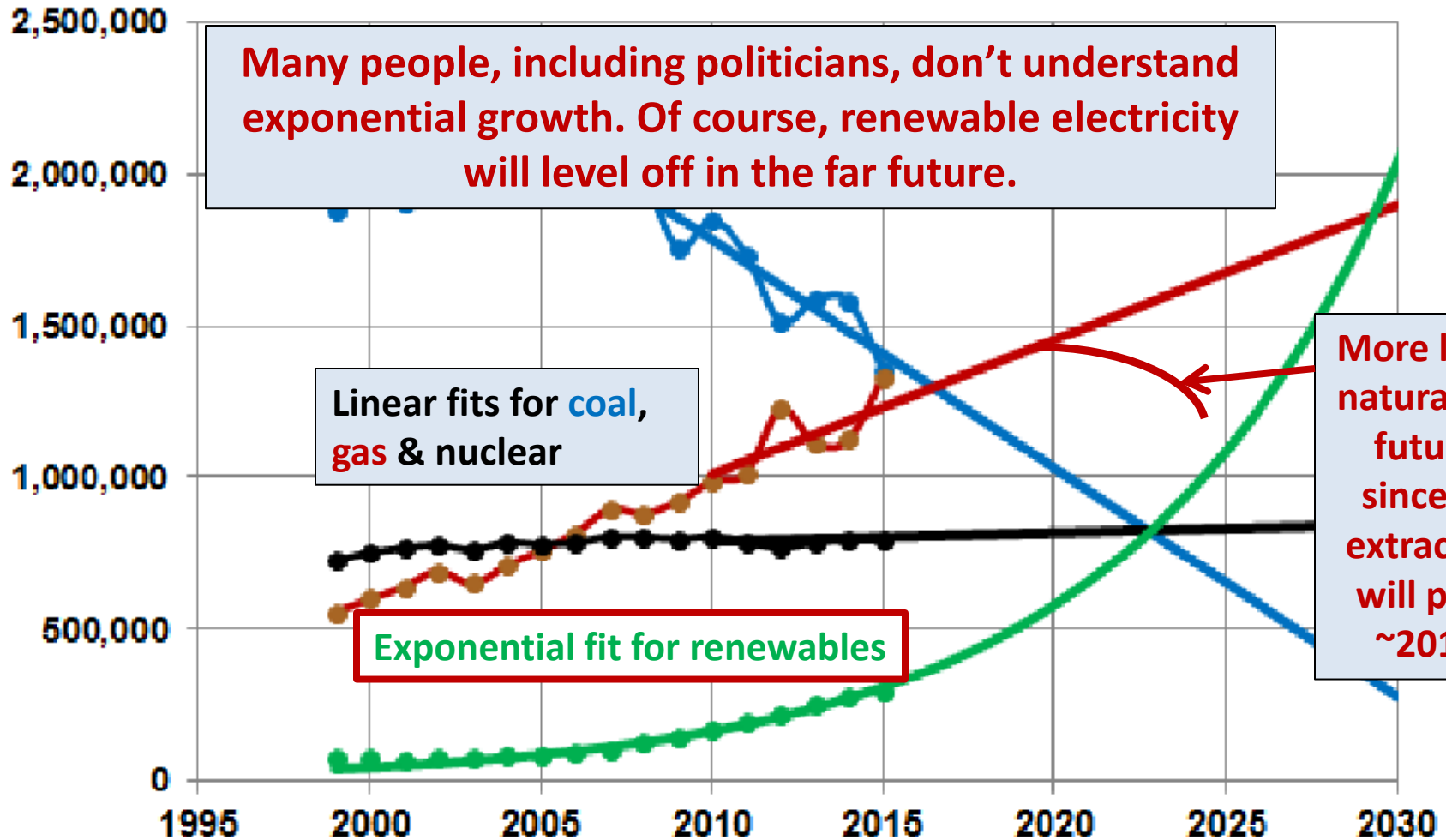
World Crude Oil Extraction Projection



U.S. Electricity from Renewables (GWhours)



U.S. Electricity Projection (GWhours)



US Tax Credit for Plug-In Vehicles

- For vehicles acquired after December 31, 2009, the credit is equal to \$2,500 plus, for a vehicle which draws propulsion energy from a **battery with at least 5 kilowatt hours of capacity, \$417**, plus an additional **\$417 for each kilowatt hour of battery capacity in excess of 5 kilowatt hours**. The total amount of the credit allowed for a vehicle is **limited to \$7,500**.
- The credit begins to phase out for a manufacturer's vehicles when at least 200,000 qualifying vehicles have been sold for use in the United States (determined on a cumulative basis for sales after December 31, 2009).

Expiration of EV Tax Credits

\$7,500 Federal Credit (US) Phase-Out Estimates (data through 12/2016)

AUTOMAKER	Current	9M Change	FY-2017	Q1-18	Q2-18	Q3-18	Q4-18	Q1-19	Q2-19	Q3-19	Q4-19	Q1-20	Q2-20	Q3-20	Q4-20	Q1-21
General Motors	124,290	+24,031	180	195	7,500	7,500	3,750	3,750	1,875	1,875						Inside EVs
Nissan	103,597	+11,075	128	143	158	173	188	7,500	7,500	3,750	3,750	1,875	1,875			
Tesla*	110,849	+38,854	175	199	7,500	7,500	3,750	3,750	1,875	1,875						
Ford	84,681	+21,318	110	120	130	142	157	169	183	198	7,500	7,500	3,750	3,750	1,875	1,875
Toyota	47,248	+2,422	82	96	108	120	135	150	165	180	195	7,500	7,500	3,500	3,500	1,875
BMW	37,050	+14,446	72	84	96	111	126	141	156	171	186	7,500	7,500	3,500	3,500	1,875

 -countdown phase
 -unlimited \$7,500 credits
 -unlimited \$3,750 credits
 -unlimited \$1,875 credits
 -no credits available

Current Expectations For \$7,500 Federal Credit Phase-Out For Major US EV Makers.

Grey shaded areas are expected cumulative future sales in thousands.

Colored blocks indicate stage of the Federal credit a particular OEM is at.

Chevrolet Volt PHEV (Gen 2)

- Electric Range: **53 miles**
- Total Range: **420 miles**
- Battery Capacity: **18.4 kWh, 14 usable**
- Hybrid Efficiency: **42 MPG**
- Electric Efficiency: **106 MPGe**
- MSRP: **\$33,220**
- Federal Tax Credit: **\$7,500**

[Brochure](#)
[Owners Manual](#)



Chevrolet Volt PHEV (Gen 2)

- Engine: 1.5-liter, 101 hp (75 kW) [**1-hp = 0.7457-kW**]
- 2 Motor/Generators
 - 64-hp (48 kW) - **MGA**
 - 117-hp (87 kW) - **MGB**
- Effective power: 149-hp (111-kW)
- 2 Planetary gear sets – **PG1 & PG2**
- Three clutches
 - one a ratchet – **CR**
 - two computer operated – **C1 & C2**
- Battery: 192 Li-Ion cells, 360 volts, 120 kW, 403 lbs

Chevrolet Volt 2017

LITHIUM-ION BATTERY The advanced 18.4 kWh lithium-ion battery was designed to be lightweight, powerful and efficient. The all-new battery cell delivers 20 percent more energy by volume!

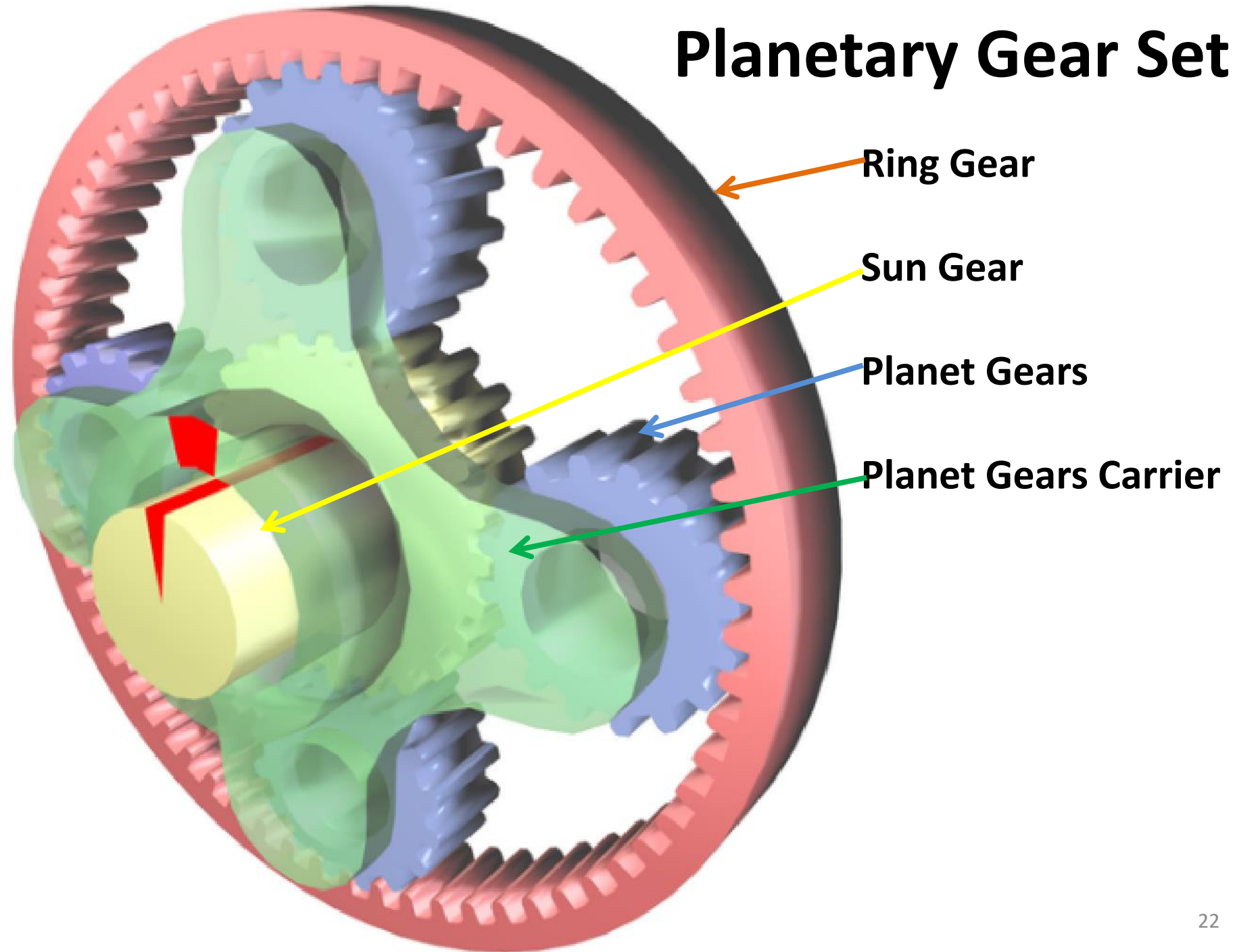
GENERATOR When the battery runs low, the gas-powered generator kicks in to extend the range over 360 miles more.²

Battery = 18.4 kWh
Usable = 14 kWh

REGENERATION Volt empowers you to put energy back into your battery through regenerative braking and a steering wheel-mounted Regen on Demand paddle.

ELECTRIC DRIVE UNIT The Electric Drive Unit in Volt propels the vehicle with energy either from the vehicle's battery or

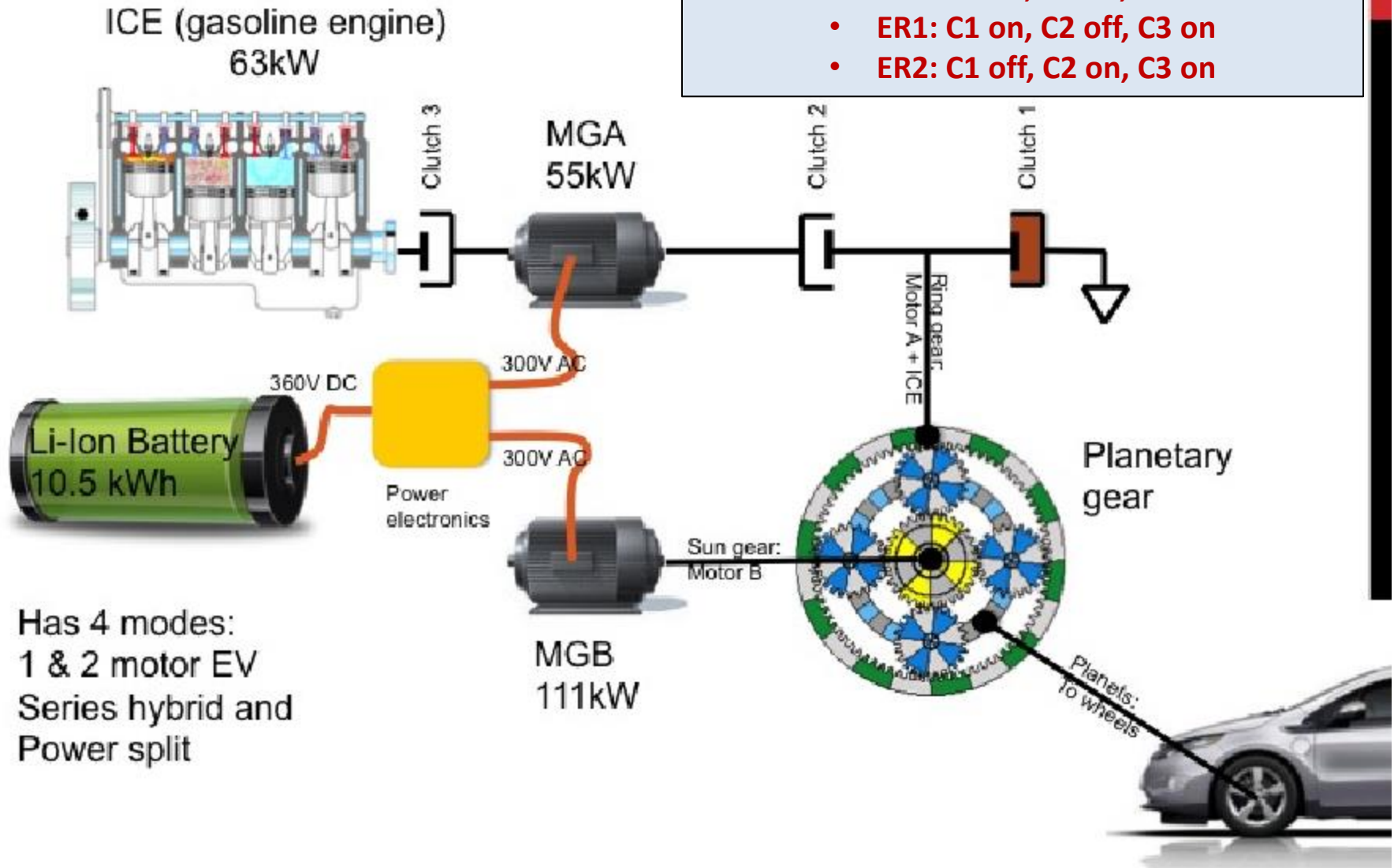
Planetary Gear Set



1ST GENERATION VOLTEC: SERIES HYBRID

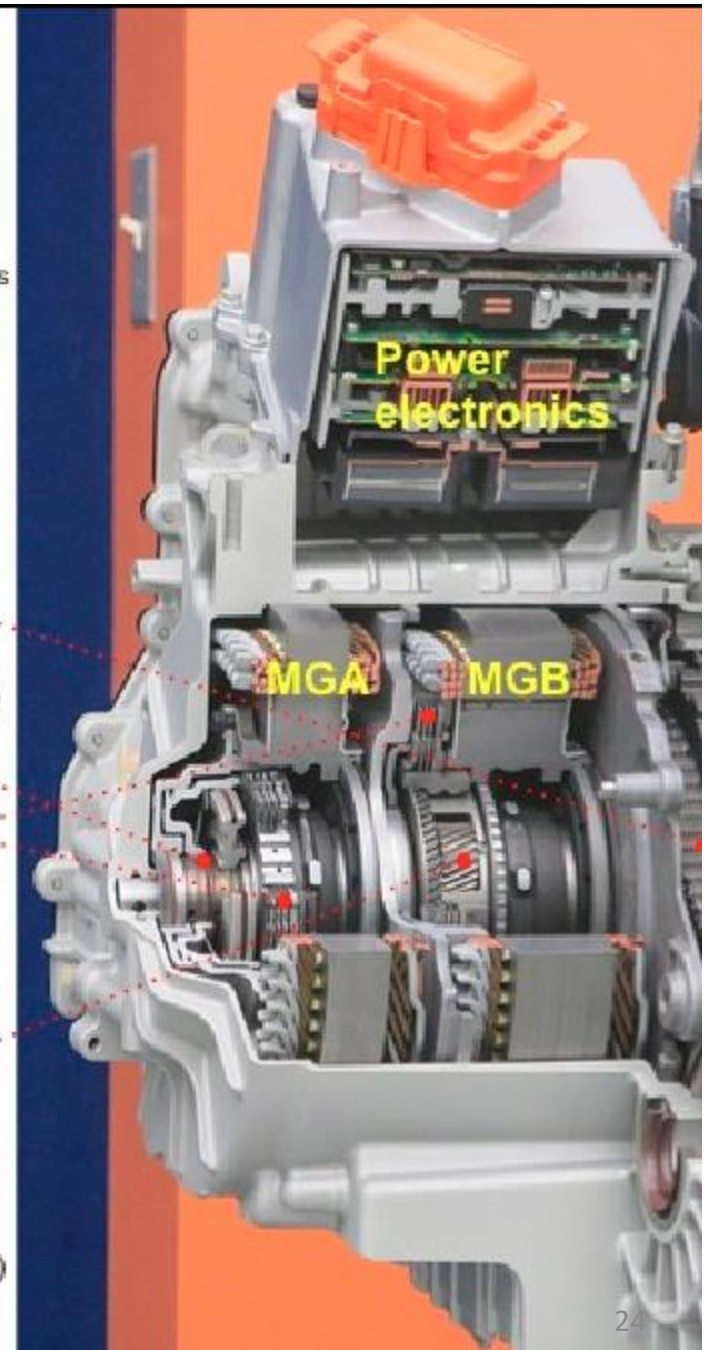
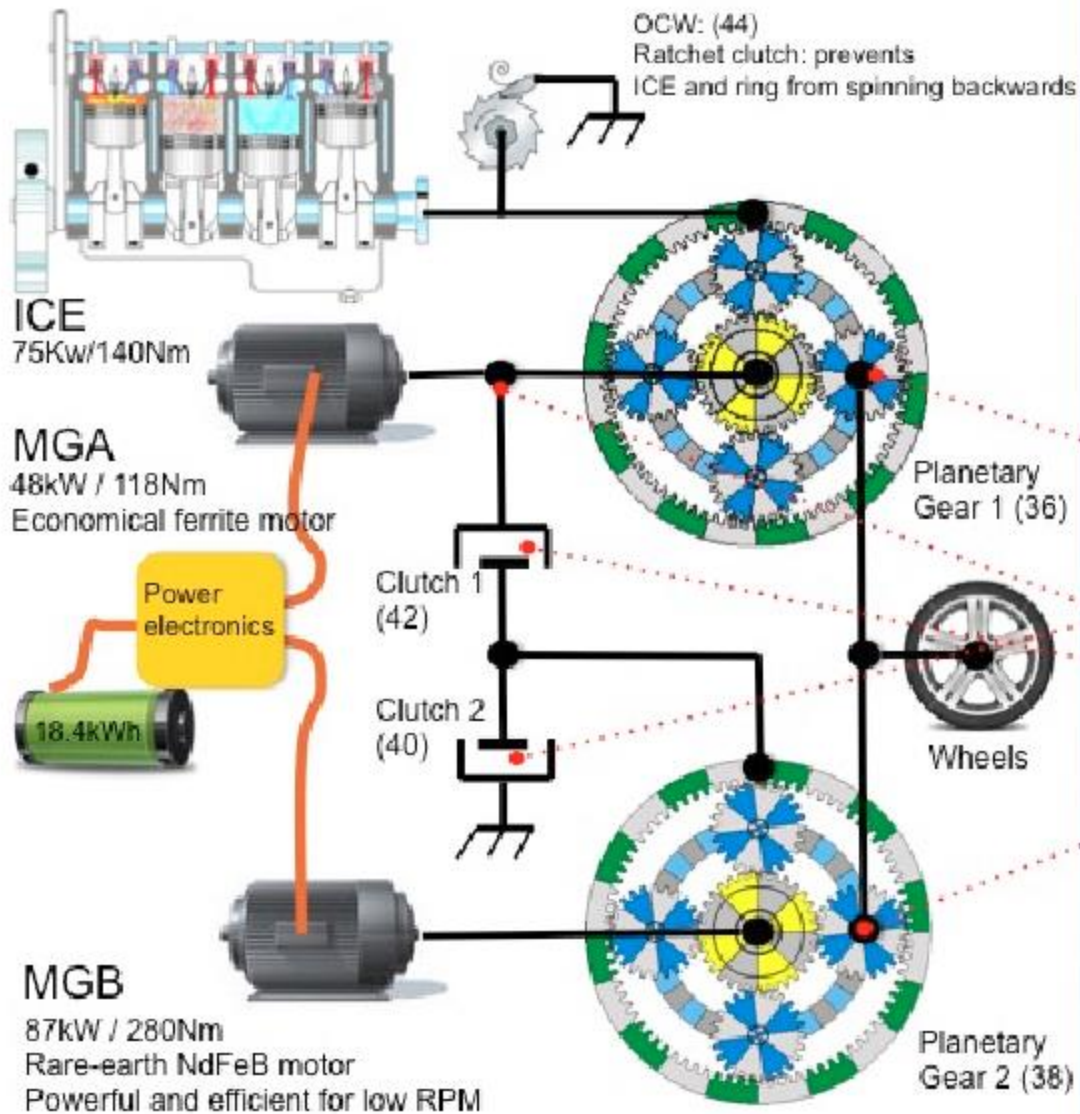
2 EV modes & 2 extended-range modes:

- EV1: C1 on, C2 off, C3 off
- EV2: C1 off, C2 on, C3 off
- ER1: C1 on, C2 off, C3 on
- ER2: C1 off, C2 on, C3 on



NEW 2016 VOLTEC

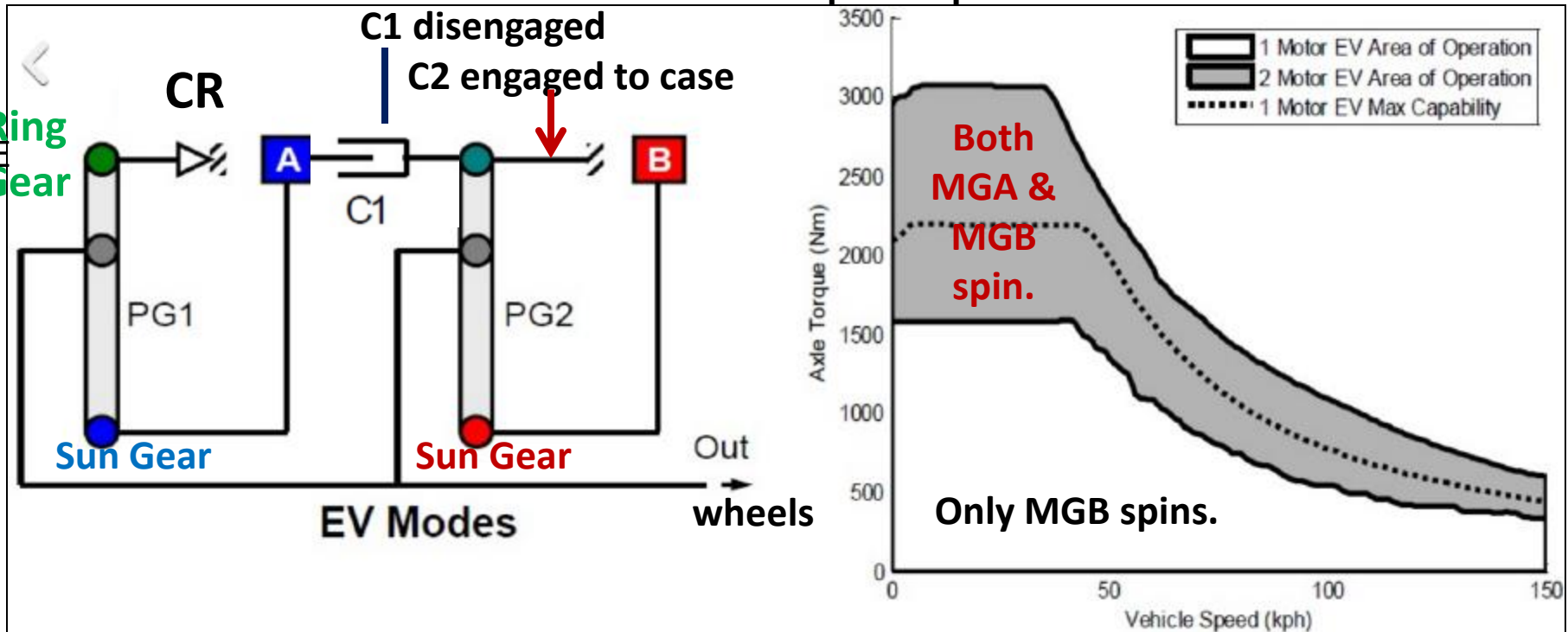
Based on US patent 8,602,938 + GM SAE paper 2015-01-1152



Chevrolet Volt 2017

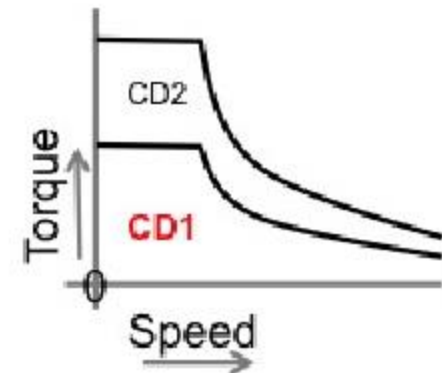
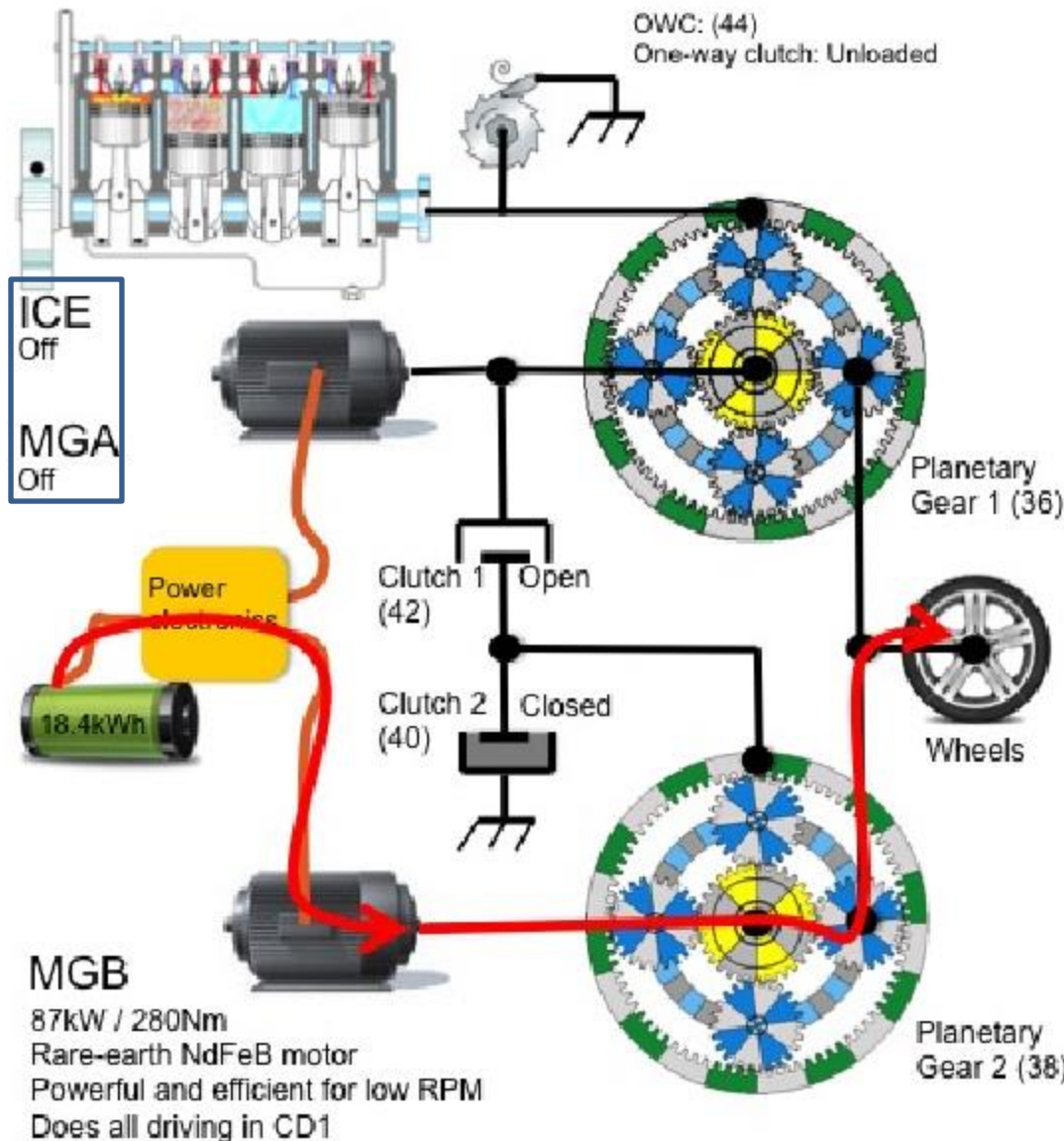
EV Motion

Torque vs speed



- Both motors, **MGA** & **MGB**, connected to the 2 sun gears, **PGA** & **PGB**.
- **PG1 ring gear** is ratcheted to only spin forward
- **PG2 ring gear** is fixed to not rotate.
- Both planet-carriers connect to the wheels through a fixed-gears box.

CD1: ONE MOTOR EV MODE



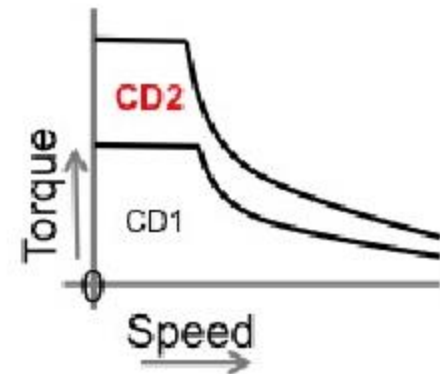
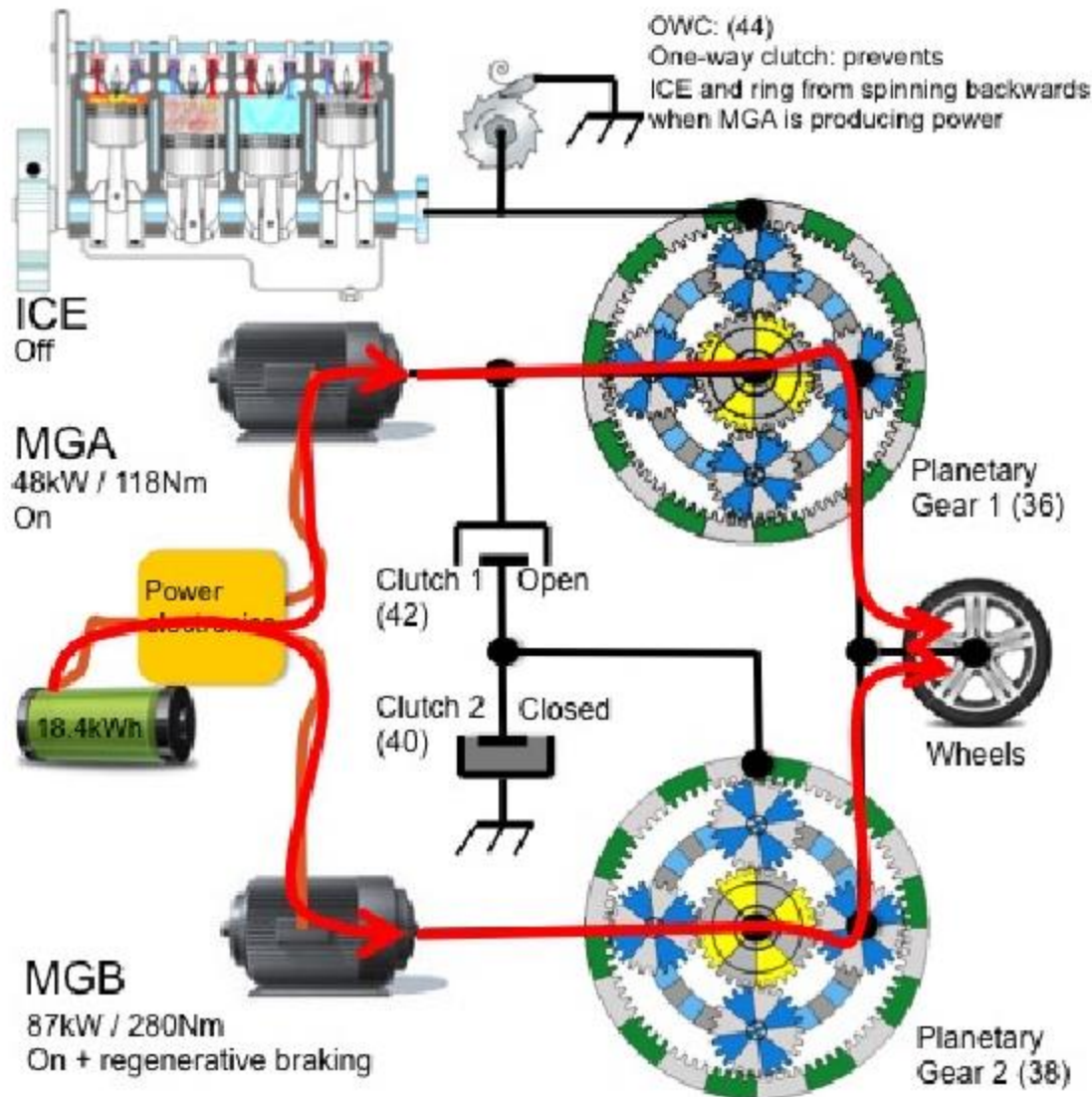
Mode **CD1**: (74) *One Motor EV*

When: Electric drive CD
Low & medium torque demand.
Any speed including reverse.
+ CS mode low speed & low torque.

How: MGB is on. MGA & ICE are off
Clutch 1 is open, Clutch 2 is closed.
MGB also does regenerative braking.

Why: Most efficient since MGB is
efficient for low torque.

CD2: TWO MOTOR EV MODE



Mode **CD2**: (74)
Two Motor EV

When: Electric drive CD
High torque demand, any speed

How: MGB+MGA are on. ICE is off
Clutch 1 is open, Clutch 2 is closed

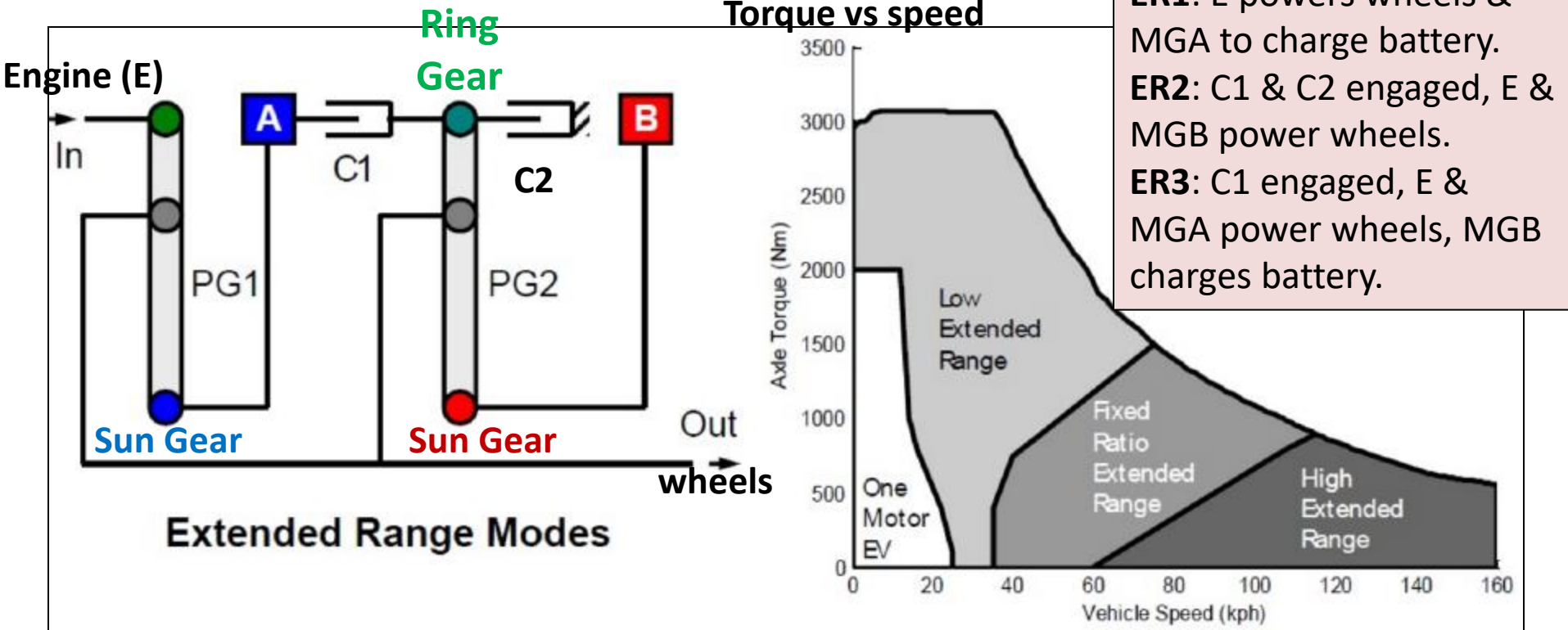
Only MGB does regenerative braking.
Fast, seamless transition between CD1 & CD2 or regen braking.

Why: Both motors work in parallel.
More peak output from smaller motors.

Different gear ratios give a wider torque band.

Chevrolet Volt 2017

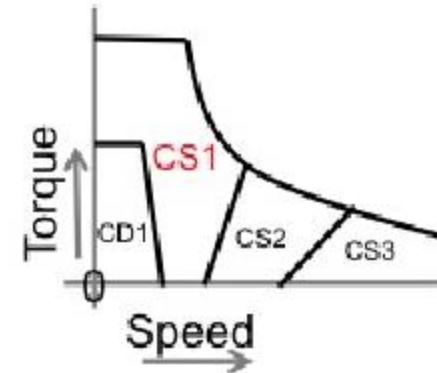
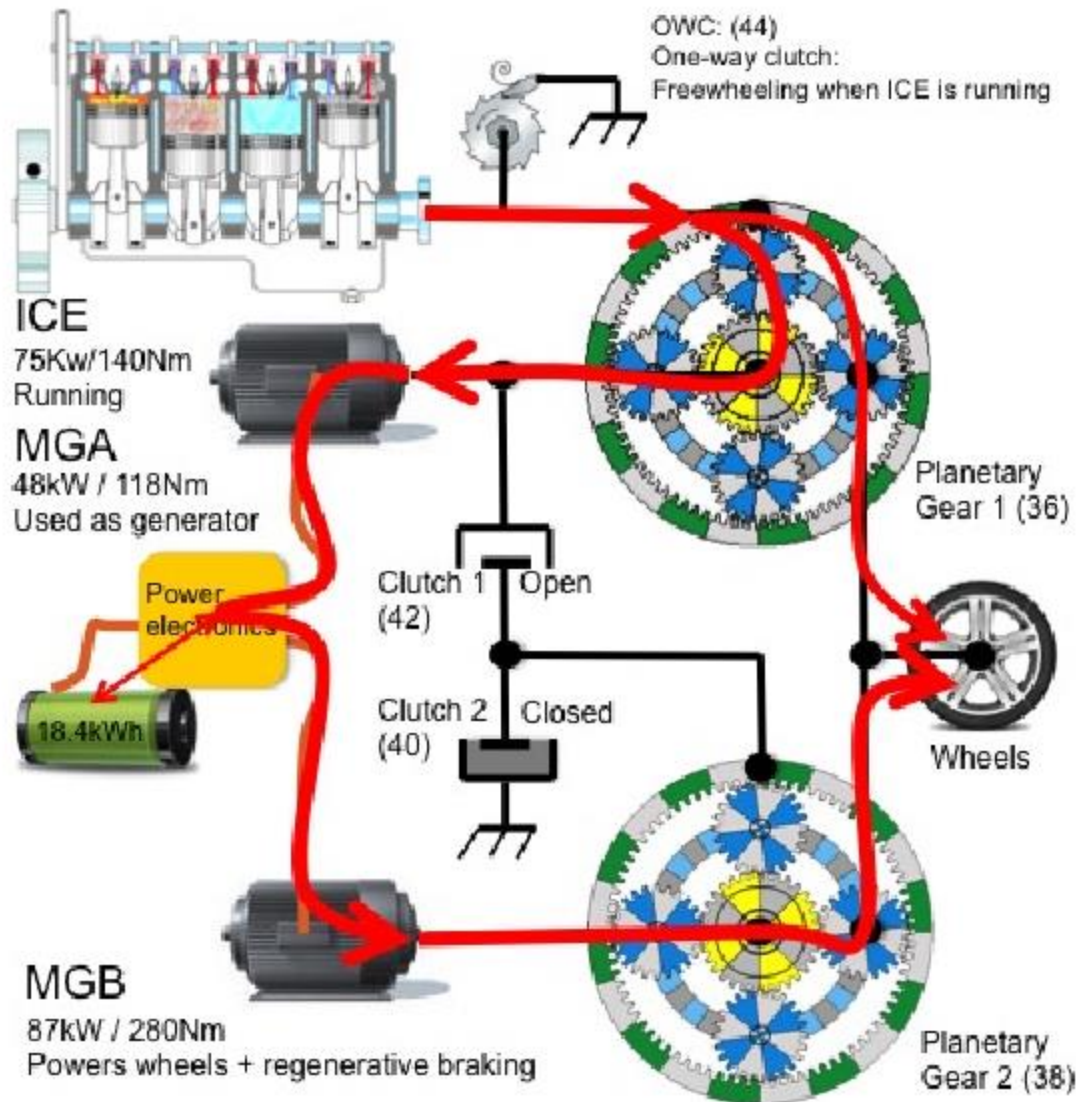
Extended-Range Motion



- Both motors, **MGA** & **MGB**, connect to the 2 sun gears, **PGA** & **PGB**.
- **MGA** connects to **PG2** ring gear through clutch C1.
- Engine connects to **PG1** ring gear.
- Both planet-carriers connect to the wheels through a fixed-gears box.

CS1: LOW EXTENDED RANGE MODE

Mixed Mode

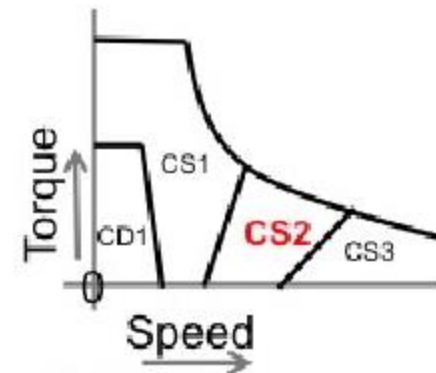
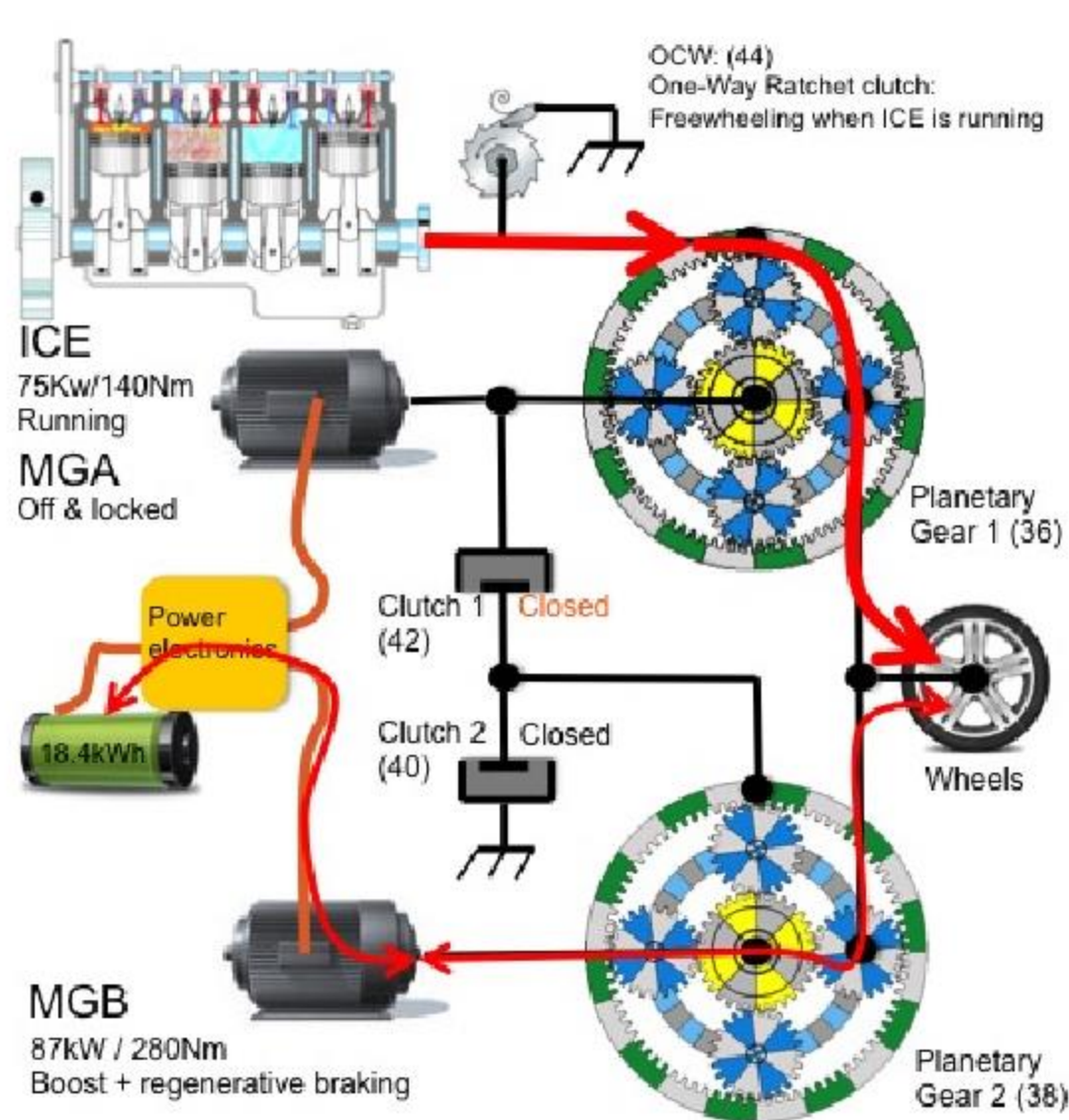


Mode **CS1**: (54)
Low Extended Range or
Input Split

When: Hybrid drive CS
High torque demand: 0-60km/h
Low torque demand: 20-40km/h

How: ICE power is split between wheels and generator MGA. MGA's electric output is sent down to MGB to power the wheels. At low speed & torque ICE is off and vehicle temporarily drives in CD1. Engine starts at CD1->CD2 by spinning up MGA.

CS2: FIXED RATIO EXTENDED RANGE



Mode **CS2**: (56)
Fixed Ratio Extended Range

When:

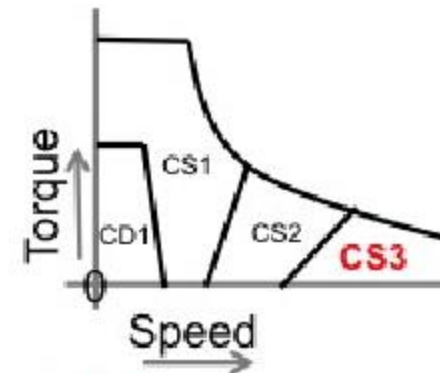
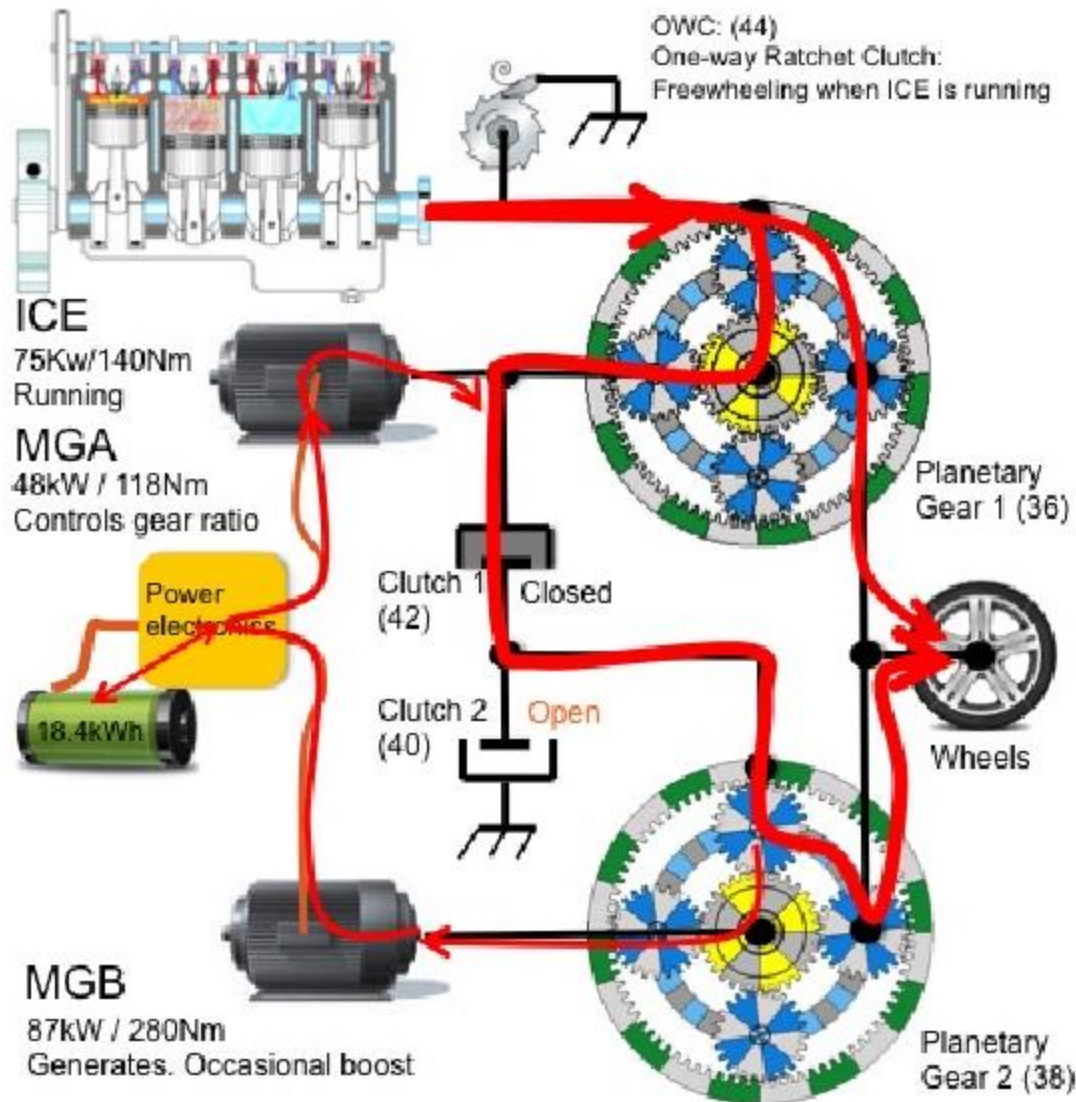
High torque demand: 70-110km/h
Low torque demand: 40-60km/h

How: Full ICE output power is sent to wheels. ICE RPM is tied to vehicle speed (fixed ratio). MGA is off and locked via clutches 1&2. MGB may drive wheels using battery power to give extra boost for overtake sprints. MGB does regenerative braking. At low output torque demand MGB recharges battery to keep ICE at efficient BFC by increasing ICE torque. Between CS1->CS2 modes MGA spins down and Clutch 2 closes.

Why: Most efficient as it avoids most electric conversion losses.

CS3: HIGH EXTENDED RANGE MODE

Mixed Mode



Mode **CS3**: (56)
*High Extended Range or
Compound Split*

When:

High torque demand: above 110km/h
Low torque demand: above 60km/h

How: ICE output power is mechanically split between wheels and the ring of PG2. This effectively gives a higher gear ratio. By controlling the RPM of MGA and by turning MGB slowly or backwards the ICE RPM and torque can be controlled. The energy siphoned off by MGB is sent up to MGA or to the battery during regenerative braking. Between CS2->CS3 modes MGB powers off allowing Clutch 2 to open with no torque.

Voltec Gen-2 eCVT

- The new transmission is lighter and has lower cost.
- Lower cost is achieved by using a smaller traction motor with fewer rare earth materials along with using an integrated inverter.
- Linking the 2 motors provides more torque (higher acceleration) than for Voltec Gen-1.
- We may see this new transmission, or slightly modified variants of it, in other General Motors plugin and non-plugin hybrids in the future.
- This new transmission is great engineering!

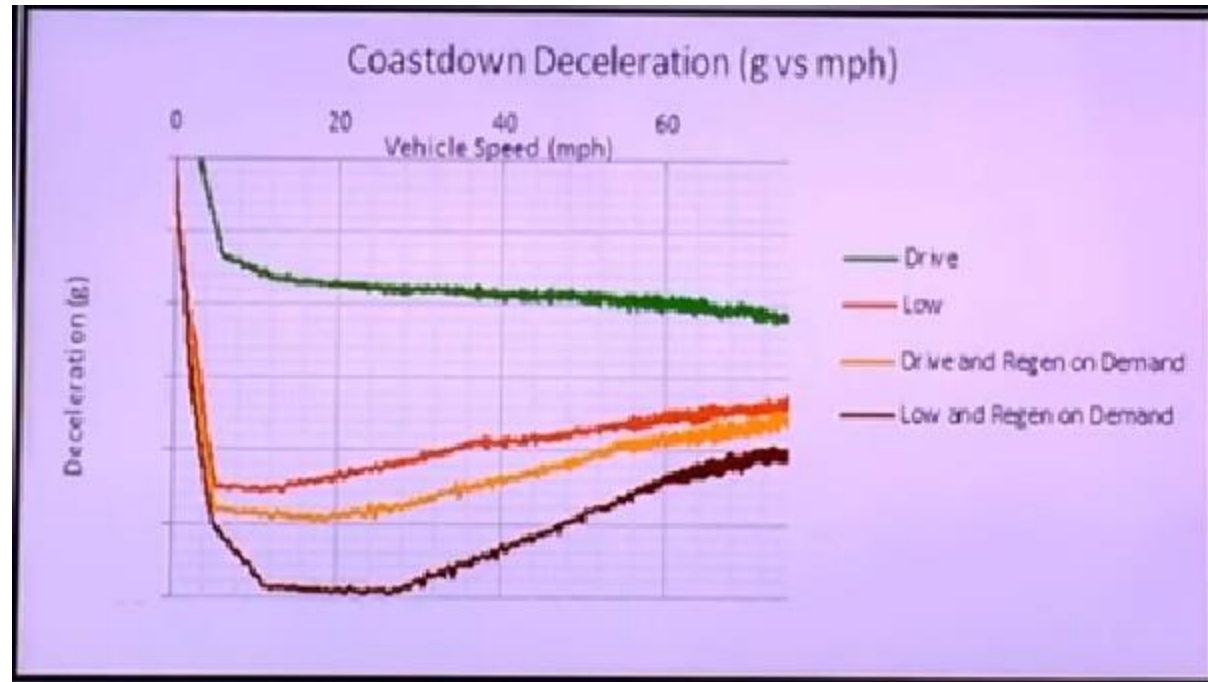
Volt Driving Modes

- **Normal:** Linear map the accelerator pedal.
- **Sport:** Remaps accelerator pedal to nearer top.
- **Mountain:** Holds the battery at 45% SOC.
- **Hold:** Holds battery at % SOC when switched on.
- **L on shift knob:** Increased regeneration to allow 1-pedal driving.



Volt Regeneration Increase

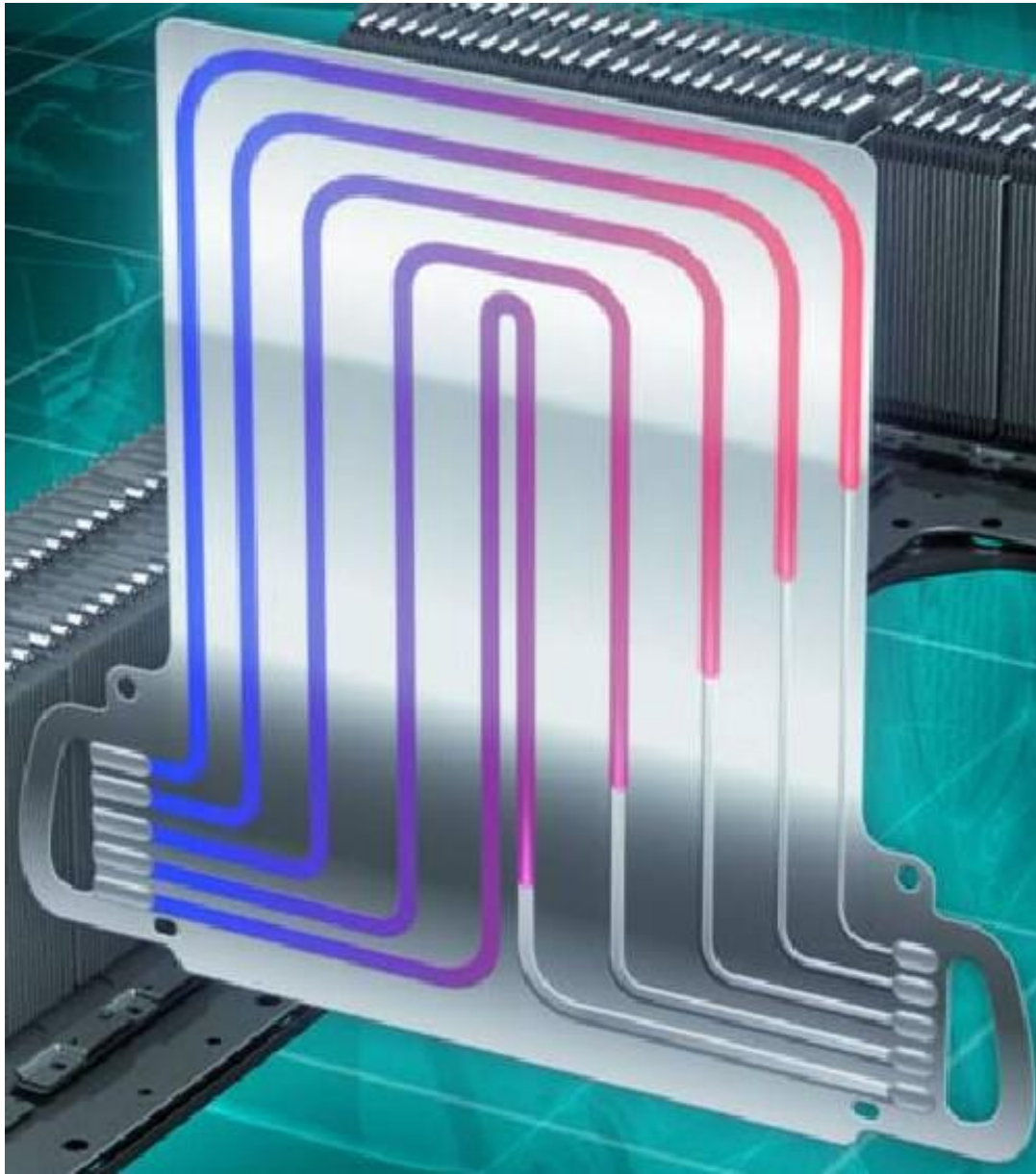
- L driving mode allows 1-pedal driving.
- Paddle behind left side of steering wheel increases regeneration (on demand).



Same as for Chevrolet Bolt EV

Battery Thermal Management

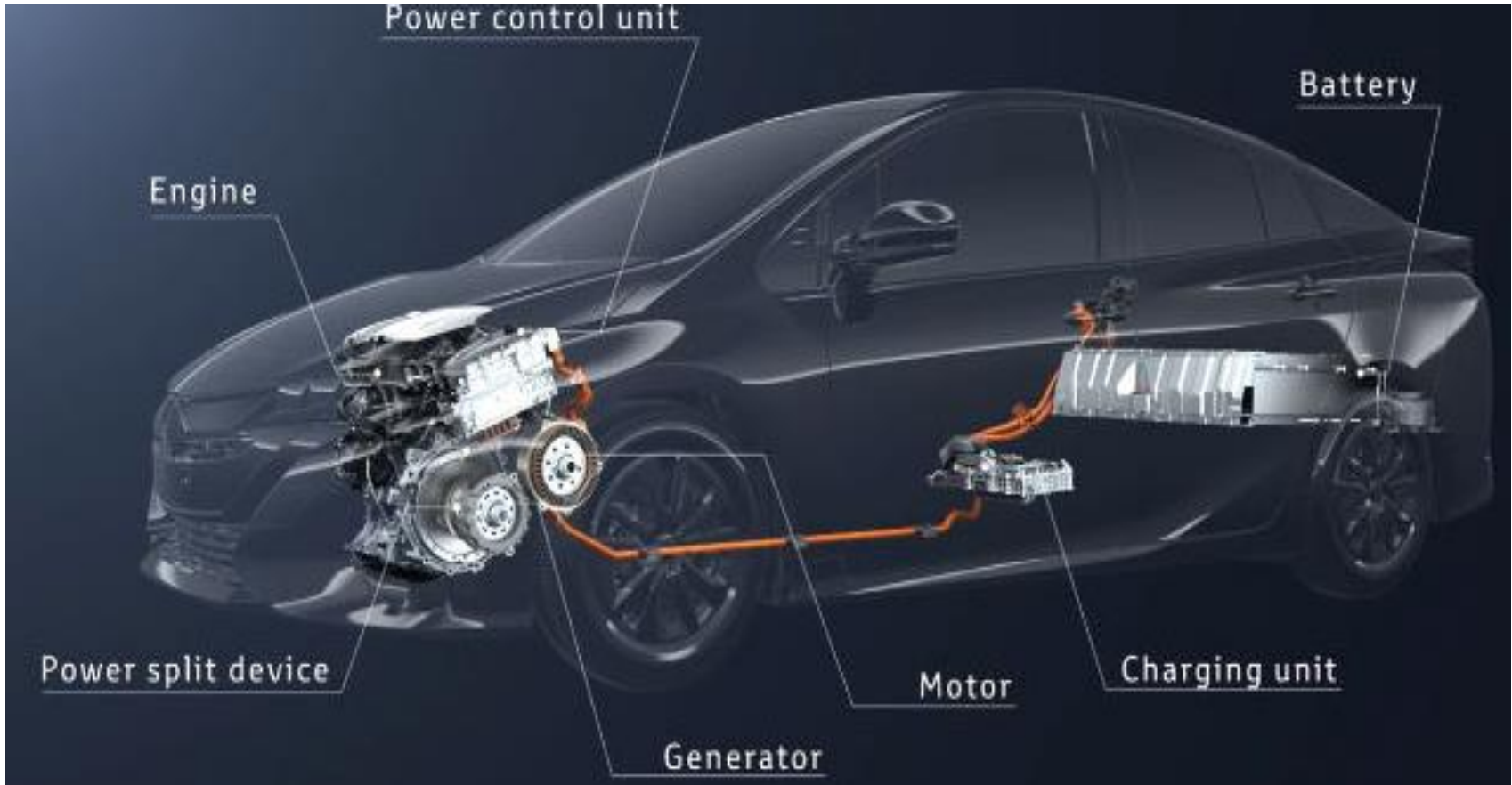
Chevrolet Volt/Bolt-EV Method



**Refrigeration
for cooling and
resistance
heating for
glycol in warm
weather.**

**Keep battery
plugged in
after charging
in cold or hot
weather.**

Toyota Prius Prime 2017



[Many details about Toyota Prius Prime PHEV](#)
[Brochure](#)
[Quick Reference Guide](#)
[Owner's Manual](#)

Battery = 8.8 kWh

Toyota Prius Prime PHEV

- Electric Range: **25 miles**
- Total Range: **640 miles**
- Battery Capacity: **8.8 kWh**
- Hybrid Efficiency: **54 MPG**
- Electric Efficiency: **133 MPGe**
- MSRP: **\$27,100**
- Federal Tax Credit: **\$4,500**

Uses a similar ratchet or one-way clutch as for the Chevy Volt, so both motors can drive the wheels in EV mode at higher speeds. It can use EV mode up to 84 mph.

ICE has 40% efficiency!



Prius Prime Lilon 2017



Prius Prime Lilon Battery



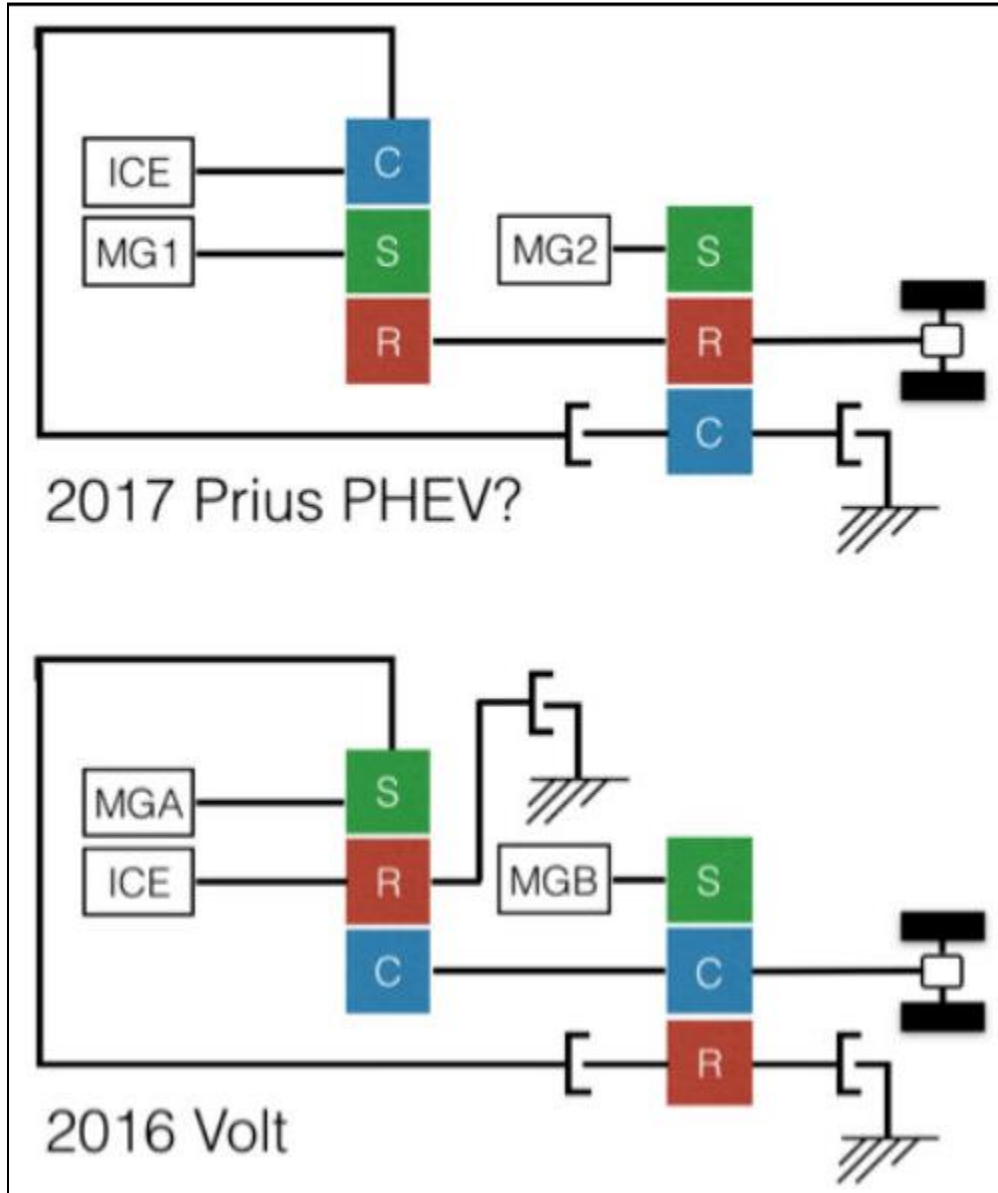
Prius Prime Console



Premium: 11.6" portrait screen

Advanced: [Heads-Up Display at bottom of windshield](#)

Volt vs Prius Prime Comparison



This is not correct. Only MG1 connects to a PGS. MG2 connects to an other gears arrangement.

[Detailed breakdown of Prius Prime eCVT](#)

Prius Prime Driving Modes

- Drive: Default HEV mode with linear map of accelerator.
- ECO: Maps accelerator toward bottom.
- PWR: Maps accelerator toward top; reduces AC.
- HV EV: “Electric Vehicle” mode, EV up to 84 mph or low battery.
- EV AUTO: Electric mode unless battery low or high acceleration.
- B: Uses ICE braking, for going down hills.



Ford C-Max Energi PHEV

- Electric Range: 20 miles
- Total Range: 670 miles
- Battery Capacity: 7.9 kWh
- Hybrid Efficiency: 38 MPG
- Electric Efficiency: 88 MPGe
- MSRP: \$27,120
- Federal Tax Credit: \$4,007



Ford Fusion Energi PHEV

- Electric Range: 21 miles
- Total Range: 670 miles
- Battery Capacity: 7.9 kWh
- Hybrid Efficiency: 42 MPG
- Electric Efficiency: 97 MPGe
- MSRP: \$33,900
- Federal Tax Credit: \$4,007



Honda Clarity PHEV

- Electric Range: 47 miles
- Total Range: 330 miles
- Battery Capacity: 17 kWh
- Hybrid Efficiency: 48 MPG
- Electric Efficiency: 110 MPGe
- MSRP: <\$40,000
- Federal Tax Credit: \$7,500



Other PHEVs

- Chrysler Pacifica Hybrid

- Electric Range: 33 miles
- Total Range: 570 miles
- Hybrid Efficiency: 32 MPG
- Electric Efficiency: 84 MPGe
- Battery Capacity: 16 kWh
- MSRP: \$41,995
- Federal Tax Credit: \$7,500



World's first plug-in-hybrid minivan

- Audi A3 Sportback e-tron

- Electric Range: 16/17 miles
- Total Range: 380/430 miles
- Hybrid Efficiency: 35/39 MPG
- Electric Efficiency: 83/86 MPGe
- Battery Capacity: 8.8 kWh
- MSRP: \$39,500
- US Tax Credit: \$4,502



Other PHEVs

- [Volvo XC90 T8 AWD PHEV](#)

- Electric Range: ~16 miles
- Total Range: 350 miles
- Hybrid Efficiency: 25 MPG
- Electric Efficiency: 53 MPGe
- Battery Capacity: 10.4 kWh
- MSRP: \$67,800
- US Tax Credit: \$ 4,585



- [BMW i3/i3s REx \(Range Extender\)](#)

- Electric Range: **97 miles**
- Total Range: **180 miles (2.4-gallons gas tank!)**
- Hybrid Efficiency: 35 MPG
- Electric Efficiency: 111 MPGe
- Battery Capacity: **33.2 kWh**
- Gasoline Capacity: **2.4 gallons**
- Generator: 33.5 hp
- MSRP: \$48,300
- US Tax Credit: \$7,500



Other PHEVs

- [BMW 740e xDrive AWD](#)

- Electric Range: 14 miles
- Total Range: 340 miles
- Hybrid Efficiency: 27 MPG
- Electric Efficiency: 64 MPGe
- Battery Capacity: 9.2 kWh
- MSRP: \$90,700
- US Tax Credit: \$4,668



- [BMW 530e](#)

- Electric Range: 15 miles
- Total Range: 370
- Hybrid Efficiency: 31 MPG
- Electric Efficiency: 72 MPGe
- Battery Capacity: 9.2 kWh
- MSRP: \$52,400
- US Tax Credit: \$4,668



Other PHEVs

- [BMW 330e](#)

- Electric Range: 14 miles
- Total Range: 350 miles
- Hybrid Efficiency: 31 MPG
- Electric Efficiency: 71 MPGe
- Battery Capacity: 7.6 kWh
- MSRP: \$44,100
- US Tax Credit: \$4,001



- [BMW X5 xDrive40e](#)

- Electric Range: 14 miles
- Total Range: 540 miles
- Hybrid Efficiency: 24 MPG
- Electric Efficiency: 56 MPGe
- Battery Capacity: 9.2 kWh
- MSRP: \$63,200
- US Tax Credit: \$4668



Other PHEVs

- BMW i8

- Electric Range: 15 miles
- Total Range: 330 miles
- Electric Efficiency: 76 MPGe
- Battery Capacity: 7.1 kWh
- MSRP: \$143,400
- US Tax Credit: \$3793



- Kia Niro PHEV

- Battery Capacity: 8.9 kWh
- Electric Efficiency: 76 MPGe
- US Tax Credit: \$4,502



Other PHEVs

- [Mercedes E350e](#)

- Electric Range: 10 miles
- Total Range: 410
- Electric Efficiency: 93 MPGe
- Battery Capacity: 6.2 kWh
- MSRP: \$39,900
- US Tax Credit: \$4043



- [Mercedes GLC 350e](#)

- Electric Range: 12 miles
- Total Range: 450
- Electric Efficiency: 109 MPGe
- Battery Capacity: 8.7 kWh
- US Tax Credit: \$4,085



Other PHEVs

- Mercedes GLE 550e

- Electric Range: 10 miles
- Total Range: 460 miles
- Hybrid Efficiency: 21 MPG
- Electric Efficiency: 43 MPGe
- Battery Capacity: 8.7 kWh
- MSRP: \$66,300
- US Tax Credit: \$4,085



- Mitsubishi Outlander PHEV AWD

- Electric Range: 22 miles
- Electric Efficiency: 131 MPGe
- Battery Capacity: 12 kWh
- US Tax Credit: \$5,836
- MSRP: \$35,500/\$42,235



World's first plug-in-hybrid SUV⁵²

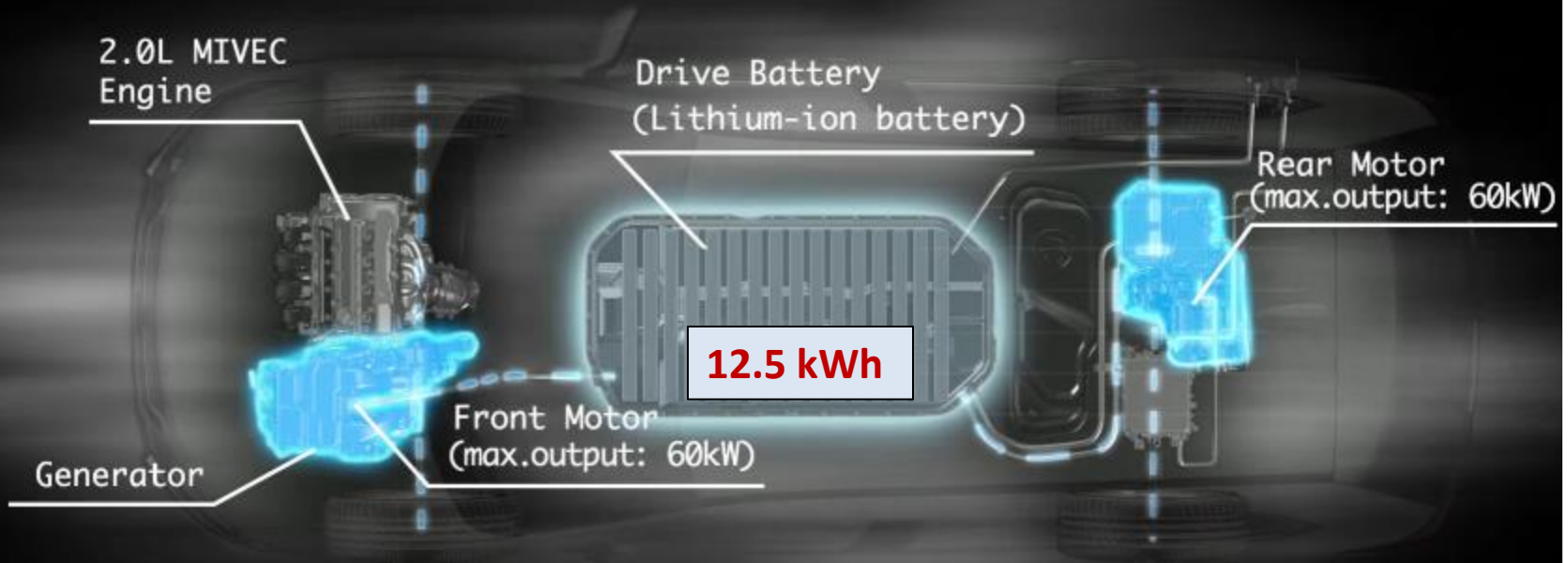
Mitsubishi Outlander PHEV AWD

Mitsubishi Outlander PHEV Technology

kuh

0 of 0

TWIN MOTOR 4WD



World's first plug-in-hybrid SUV
CHAdeMO fast-charging port
Two 120-volts outlets (1.5-kW AC)
Lowest price PHEV SUV in U.S.



Other PHEVs

- [Kia Optima PHEV](#)
 - Electric Range: 27 miles
 - Hybrid Efficiency: 40 MPG
 - Electric Efficiency: 103 MPGe
 - Battery Capacity: 9.8 kWh
 - US Tax Credit: \$4,919
- [Volkswagen Golf GTE PHEV](#)
 - Electric Range: 22 miles
 - Hybrid Efficiency: 45 MPG
 - Electric Efficiency: 95 MPGe
 - Battery Capacity: 8.7 kWh
 - US Tax Credit: \$4,085



Other PHEVs

- [Hyundai Sonata Plug-In Hybrid](#)

- Electric Range: 27 miles
- Total Range: 600 miles
- Hybrid Efficiency: 40 MPG
- Electric Efficiency: 99 MPGe
- Battery Capacity: 9.8 kWh
- US Tax Credit: \$4,919



- [Hyundai Ioniq Plug-In Hybrid](#)

- Electric Range: 27 miles
- Hybrid Efficiency: 50 MPG
- Electric Efficiency: 105 MPGe
- Battery Capacity: 8.9 kWh
- US Tax Credit: \$4,085



Other PHEVs

- [Porsche Cayenne S E-Hybrid](#)

- Electric Range: 14 miles
- Total Range: miles
- Hybrid Efficiency: 47 MPG
- Electric Efficiency: 27 MPGe
- Battery Capacity: 10.8 kWh
- US Tax Credit: \$5,300
- MSRP: \$86,995



- [Porsche Panamera S E-Hybrid](#)

- Electric Range: 23 miles
- Hybrid Efficiency: 27 MPG
- Electric Efficiency: 51 MPGe
- Battery Capacity: 14.1 kWh
- US Tax Credit: \$7,500
- MSRP: \$185,450



Other PHEVs

- [MINI Cooper AWD PHEV](#)
 - Electric Range: 17 miles
 - Total Range: miles
 - Hybrid Efficiency: MPG
 - Electric Efficiency: 135 MPGe
 - Battery Capacity: 7.6 kWh
 - US Tax Credit: \$3793
 - MSRP: \$37,650



- [Range Rover Sport P400e](#)
 - Electric Range: ~31 miles
 - Battery Capacity: 13.1 kWh
 - US Tax Credit: \$5880



Other PHEVs

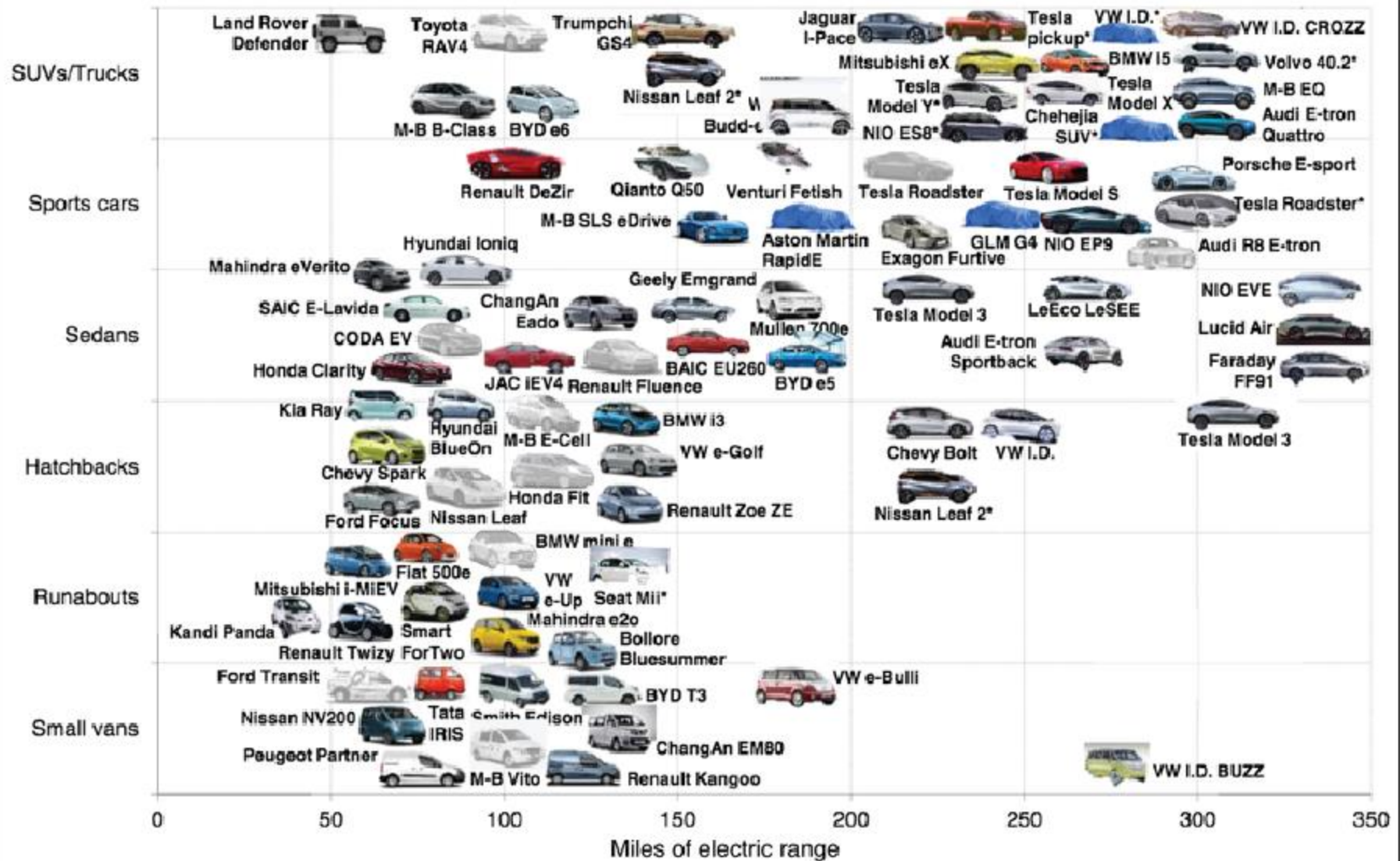
- [Volvo XC40 SUV PHEV](#)
 - Electric Range: 25 miles
 - Battery Capacity: 9.7 kwh
 - US Tax Credit: \$4,919



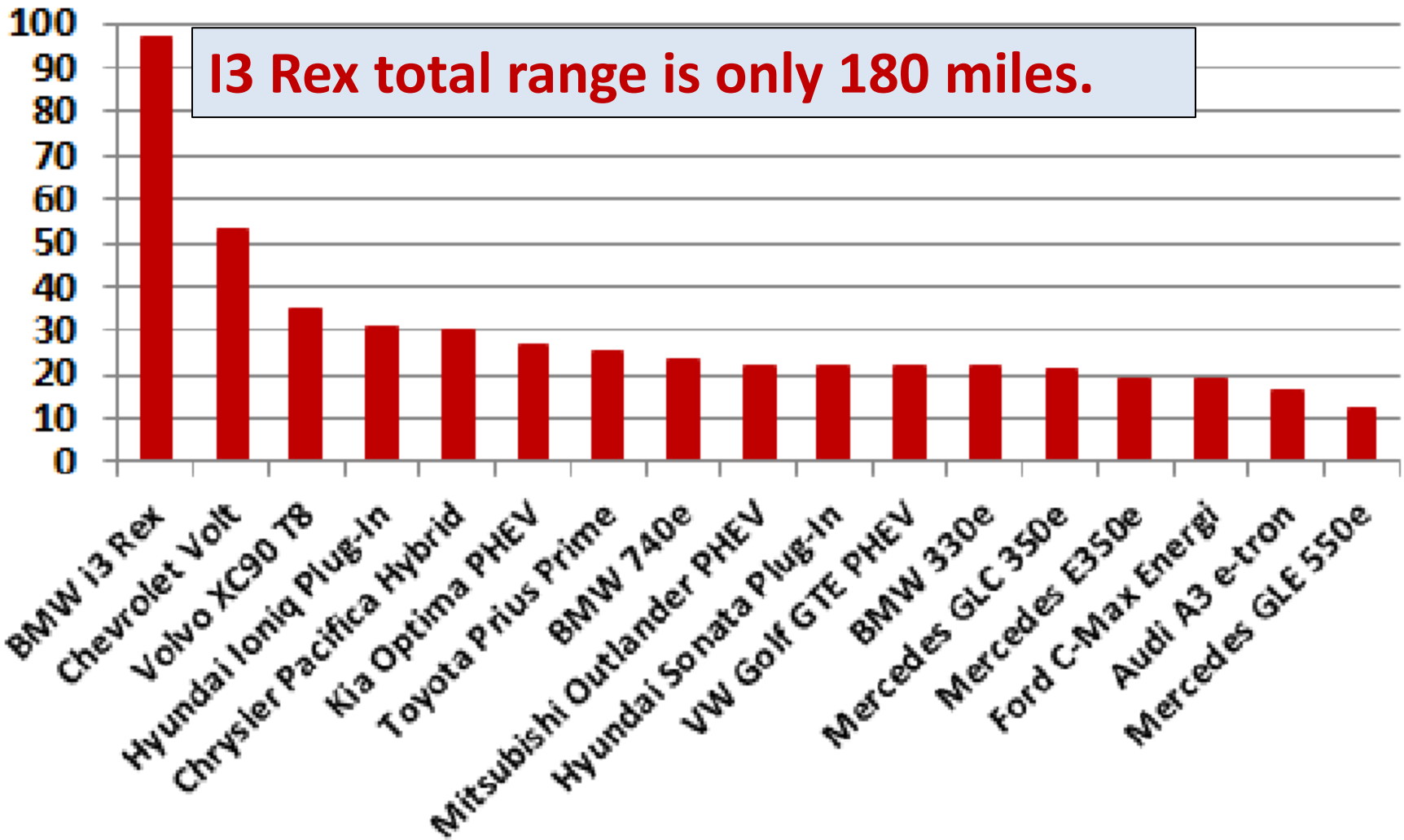
- [Ford F-150 pickup HEV, PHEV or BEV?](#)
 - [XL-Hybrids F-150 PHEV Conversion](#)

Electric-Car Boom

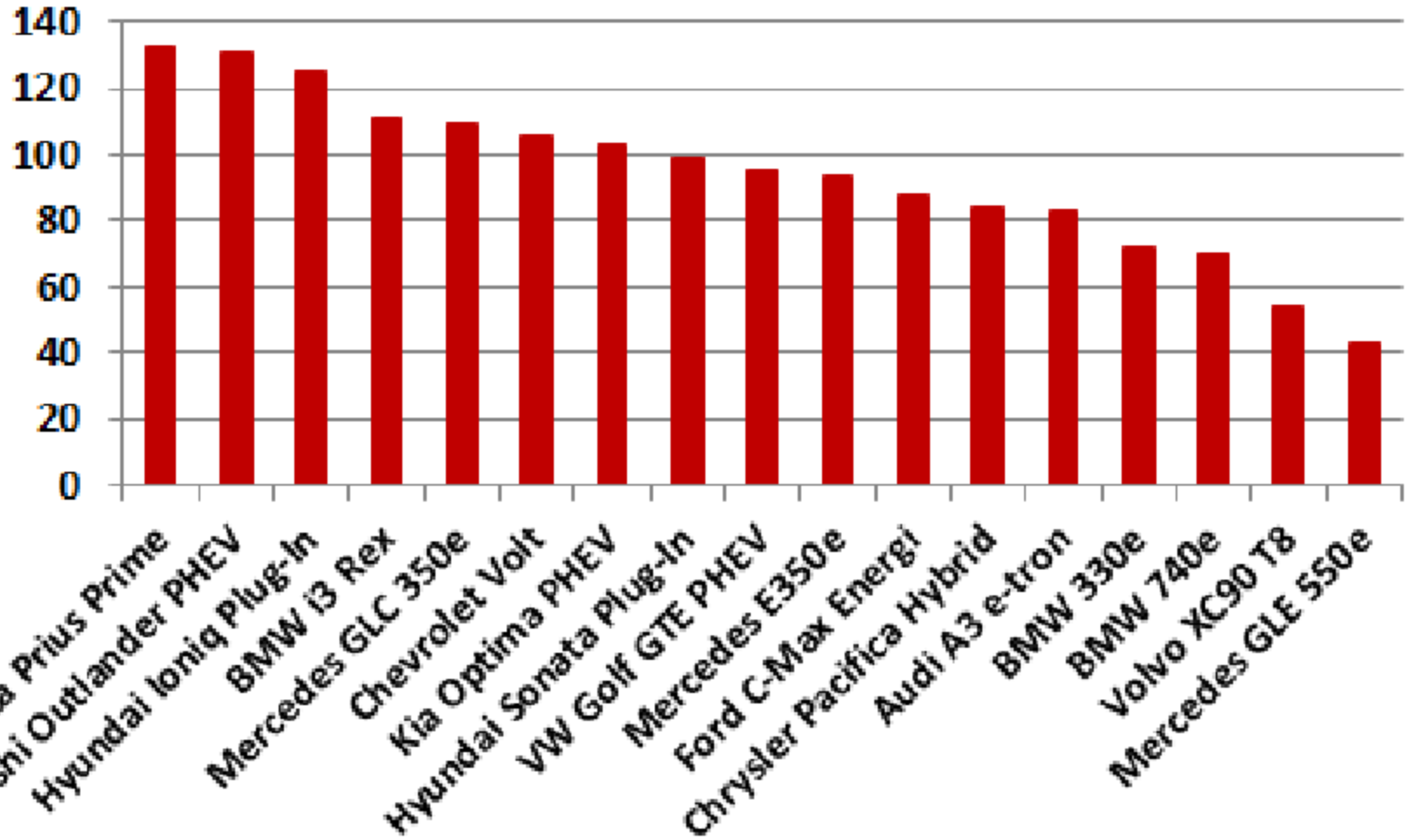
Models by style and range available through 2020



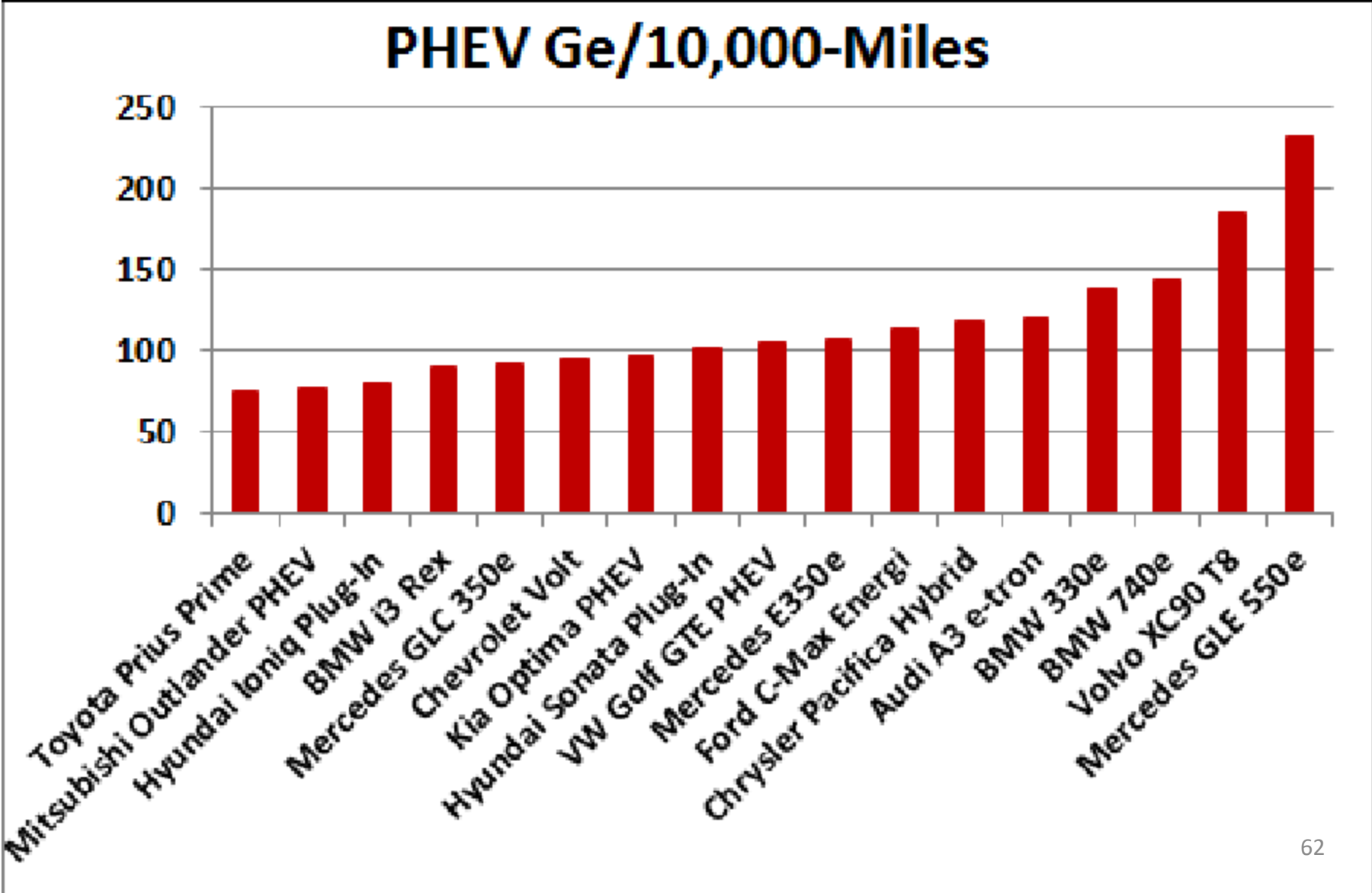
PHEV eRange



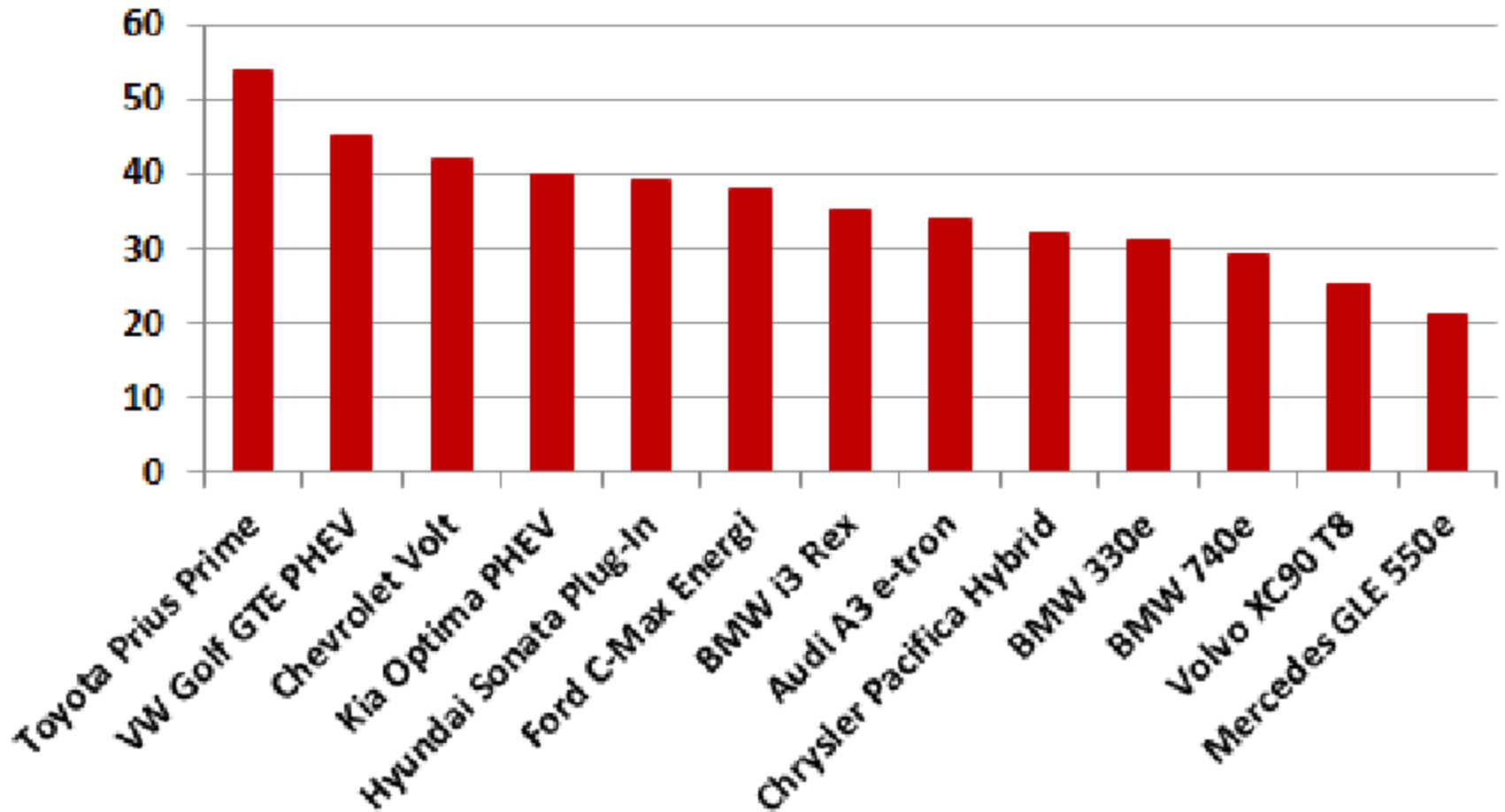
PHEV MPGe



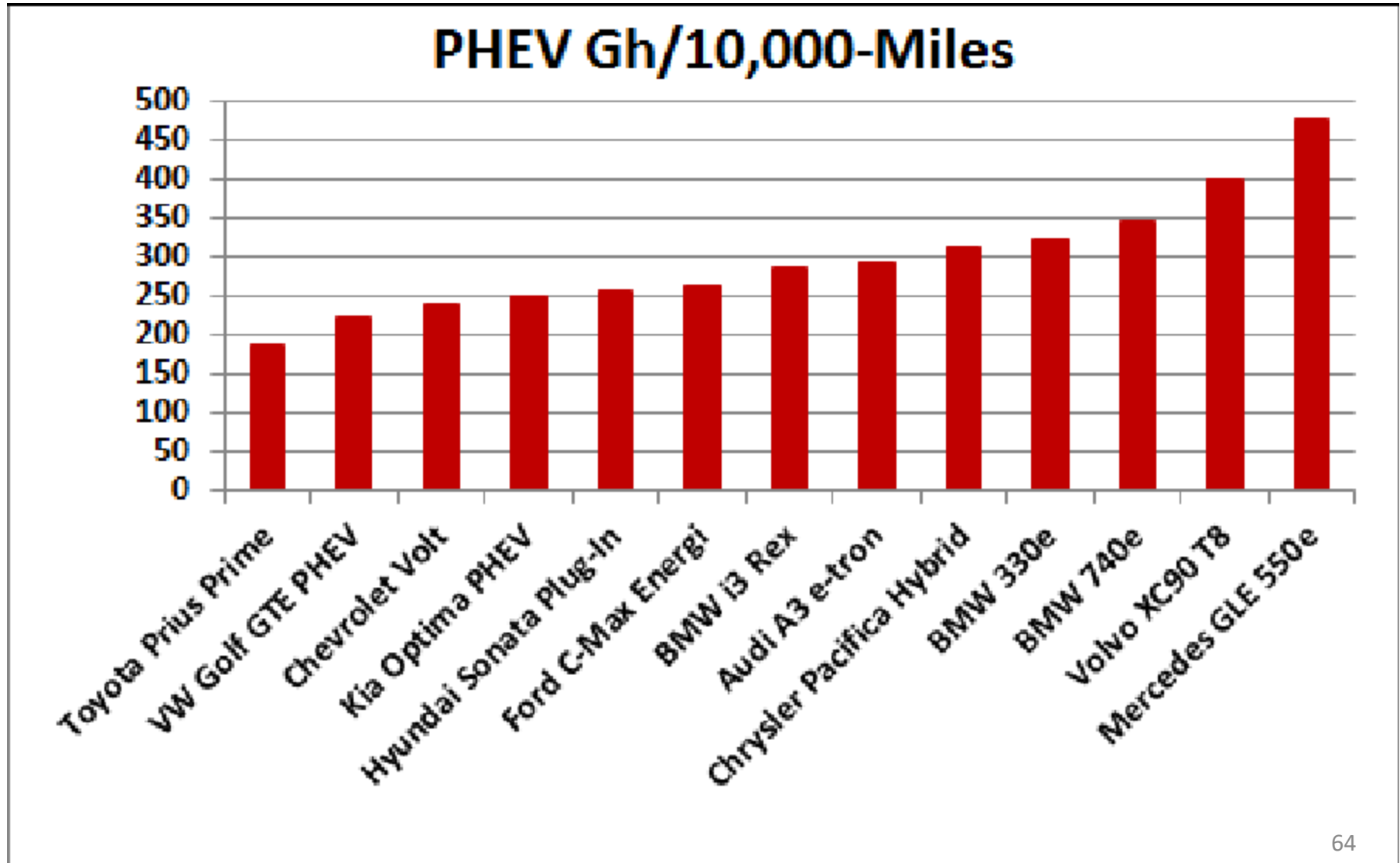
Better metric to compare PHEVs: **Gallons/10,000-Miles** is about how much gasoline would be used in one year. Multiply by \$/Gallon to get an estimate of the yearly fuel cost.



PHEV MPGh



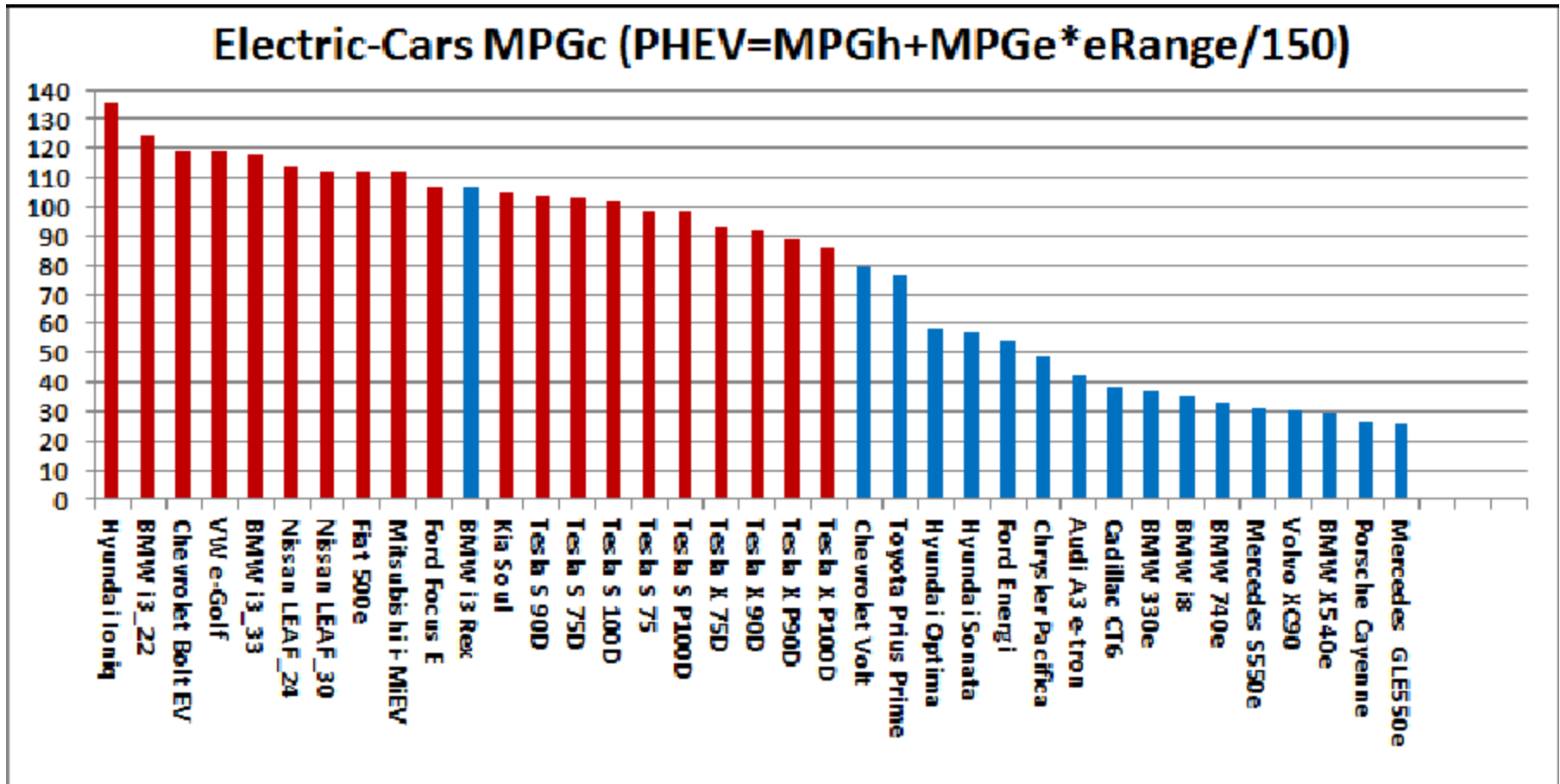
Better metric to compare PHEVs: **Gallons/10,000-Miles** is about how much gasoline would be used in one year. Multiply by \$/Gallon to get an estimate of the yearly fuel cost.



BEV MPGe

&

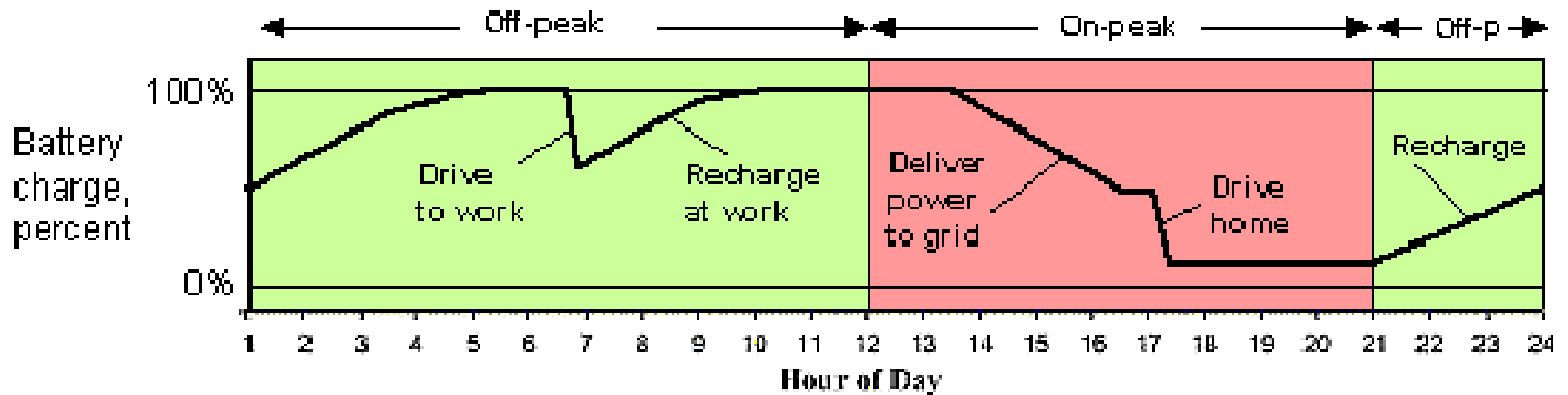
Calculated $MPG_c(PHEV) = MPG_h + MPGe * eRange / 150$



Electricity as Backup for Transportation when Fuel Gasoline becomes Scarce

- Gasoline will become scarce as world oil extraction rate decreases.
- Plug-in hybrid vehicles can travel 20-55 miles without gasoline, which should be sufficient for getting necessities for living.
- Electricity to charge the vehicles' batteries can be obtained from many sources: national grid, local electric storage, local photoelectric panels, local wind generators and local fuel cells using many different fuels.

State of Charge of a Battery of a Plug-in Hybrid over a Day.

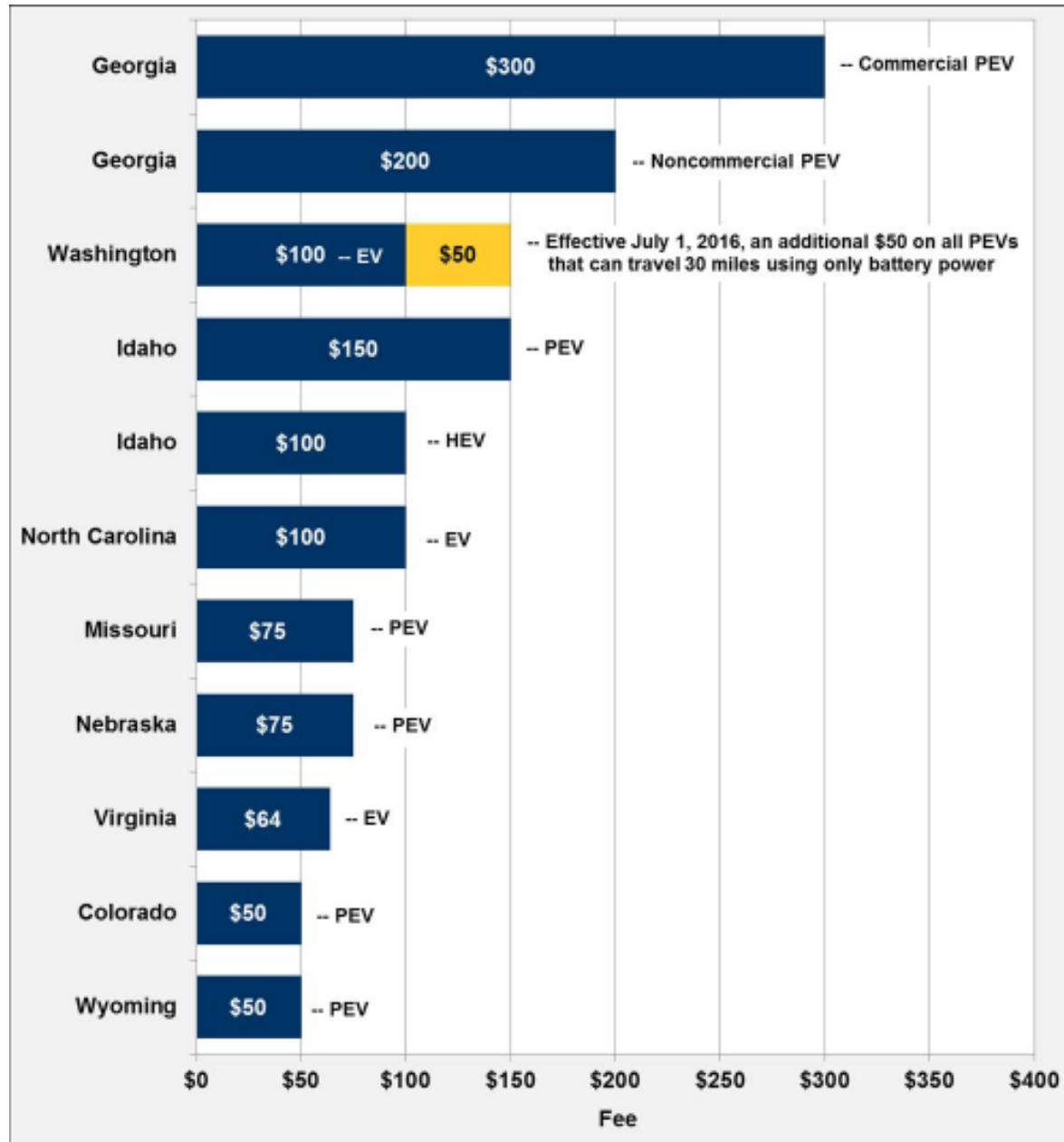


<https://en.wikipedia.org/wiki/Vehicle-to-grid>

Politics of Plug-In Hybrids?

- How to pay for roads with no gas taxes?
- Will there be different rates for “traction electricity” and “house electricity” and, thus, different meters to register the amount used?
- Will there be special state and federal taxes on “traction electricity”?
- 17 states charge fees for EVs.

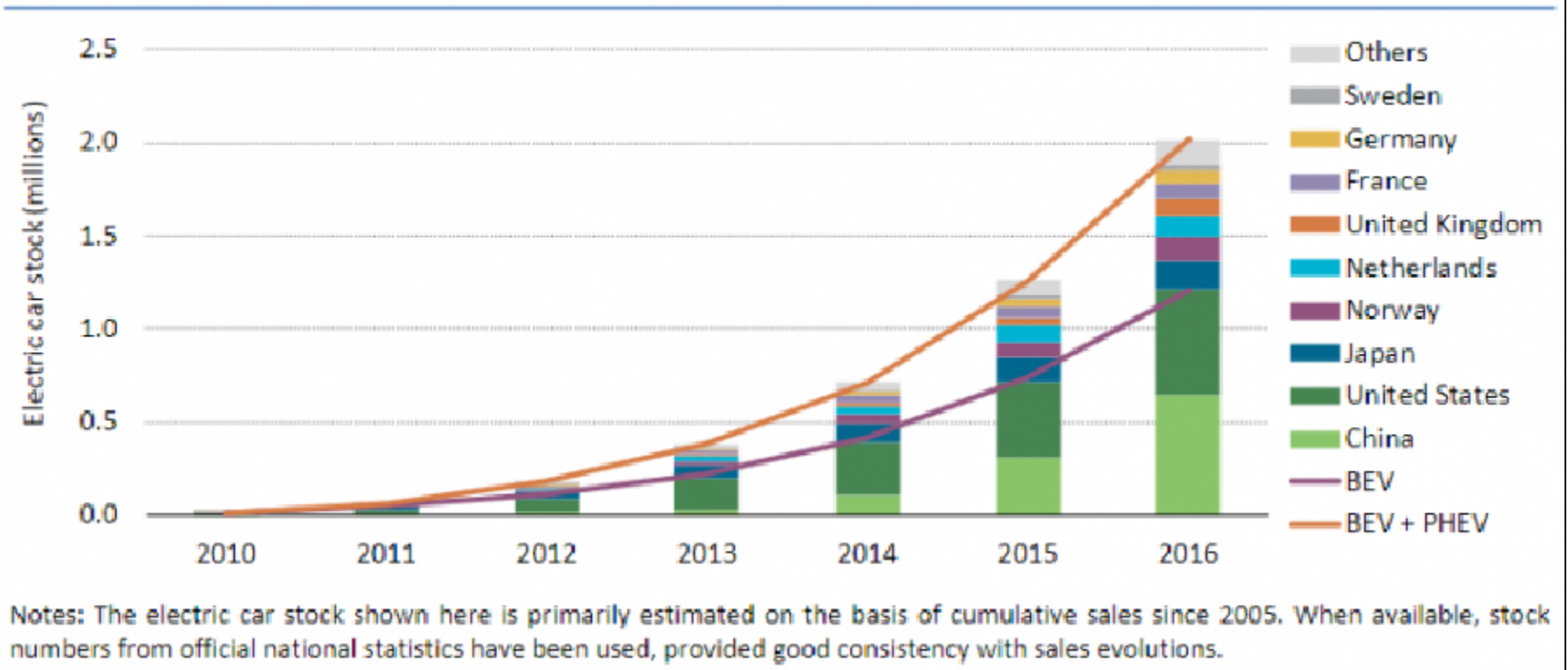
Annual State Fees 2015 (PHEVs & BEVs)



**West Virginia,
Michigan,
Minnesota,
Indiana,
Oklahoma,
Tennessee,
California and
South Carolina
by 2017.**

Global Electric Cars (PHEVs & BEVs)

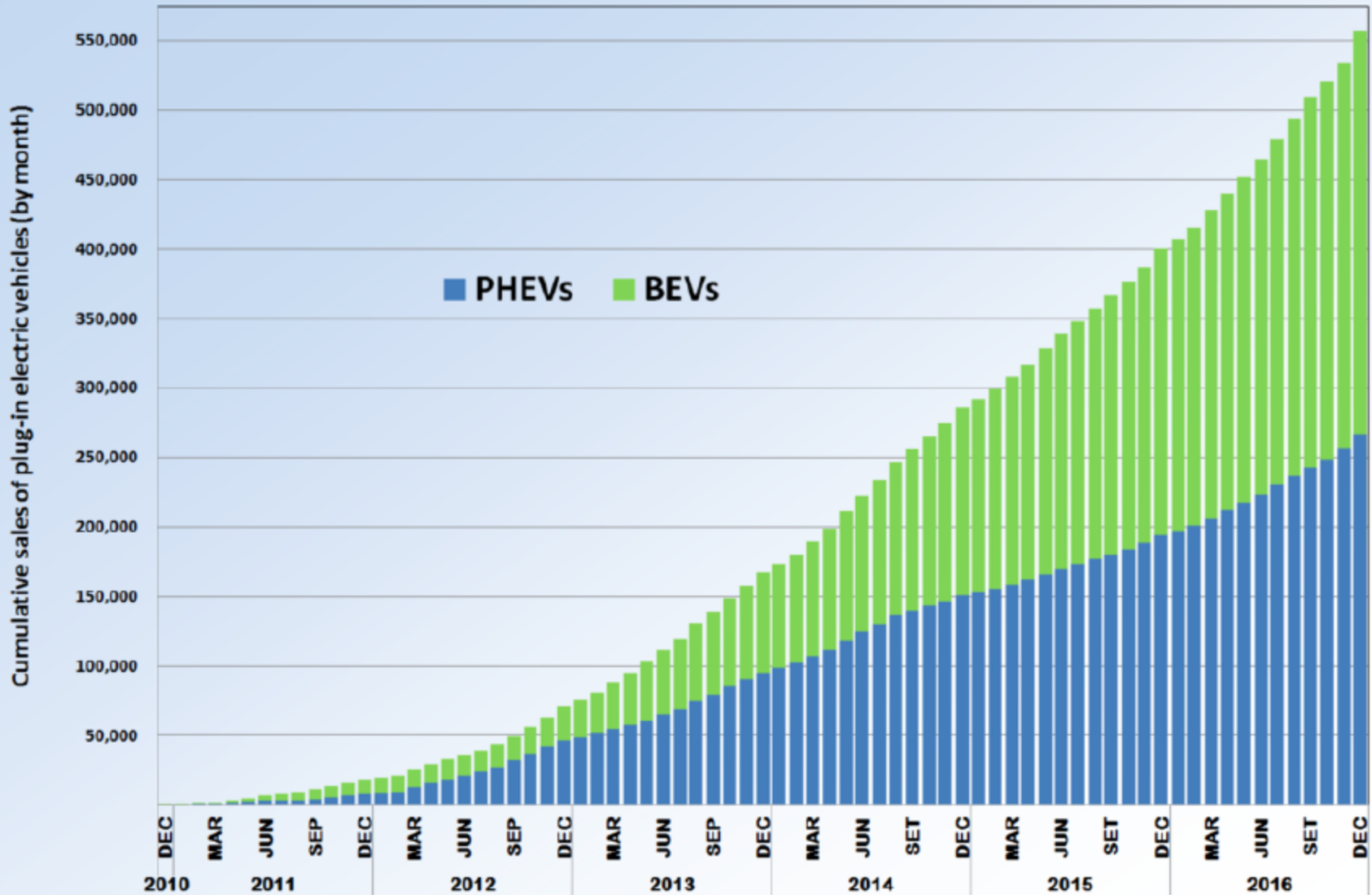
Figure 1 • Evolution of the global electric car stock, 2010-16



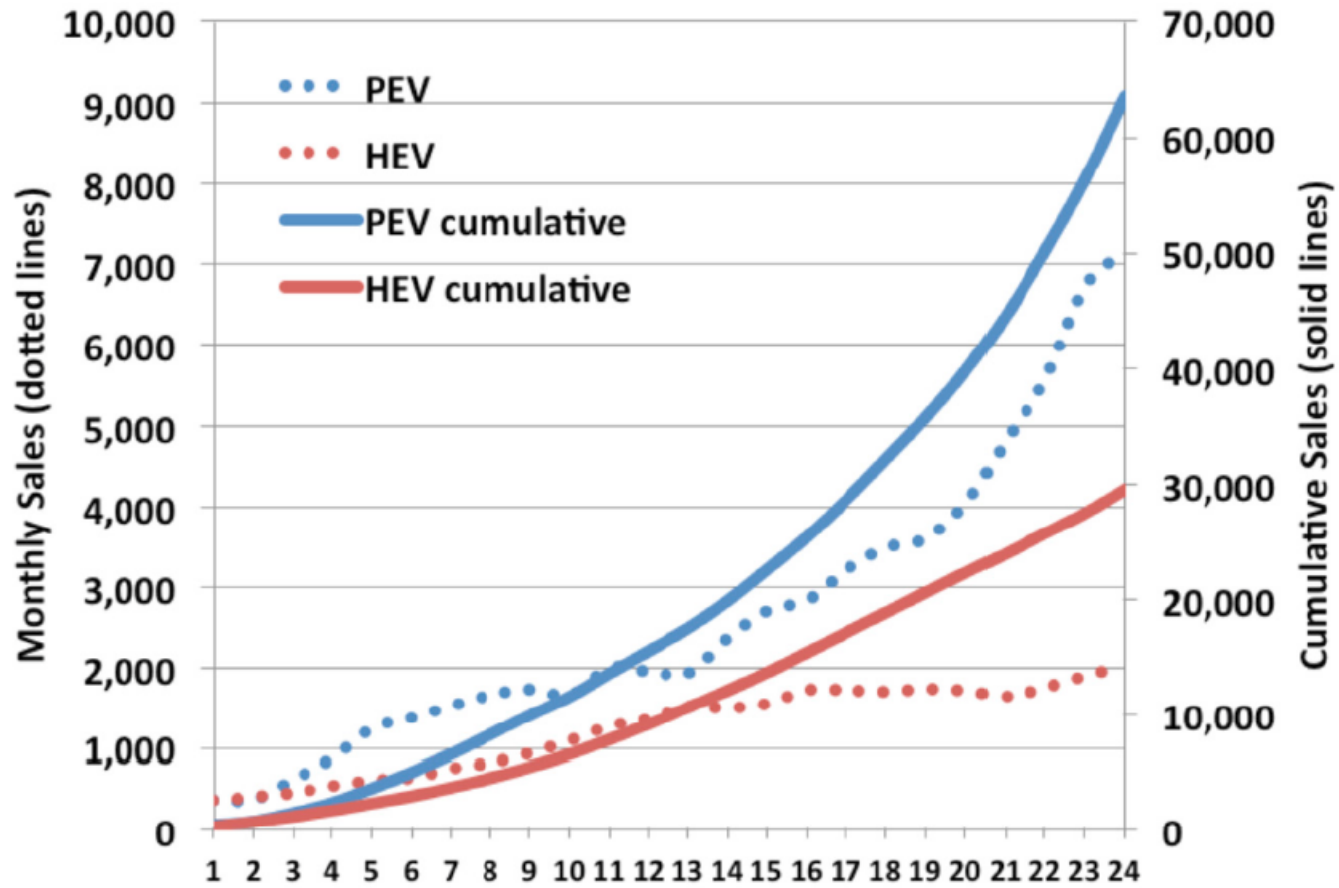
Cumulative U.S. sales of plug-in electric vehicles

by monthly sales of all-electric cars (BEVs) and plug-in hybrids (PHEVs)

(Dec 2010 - Dec 2016)

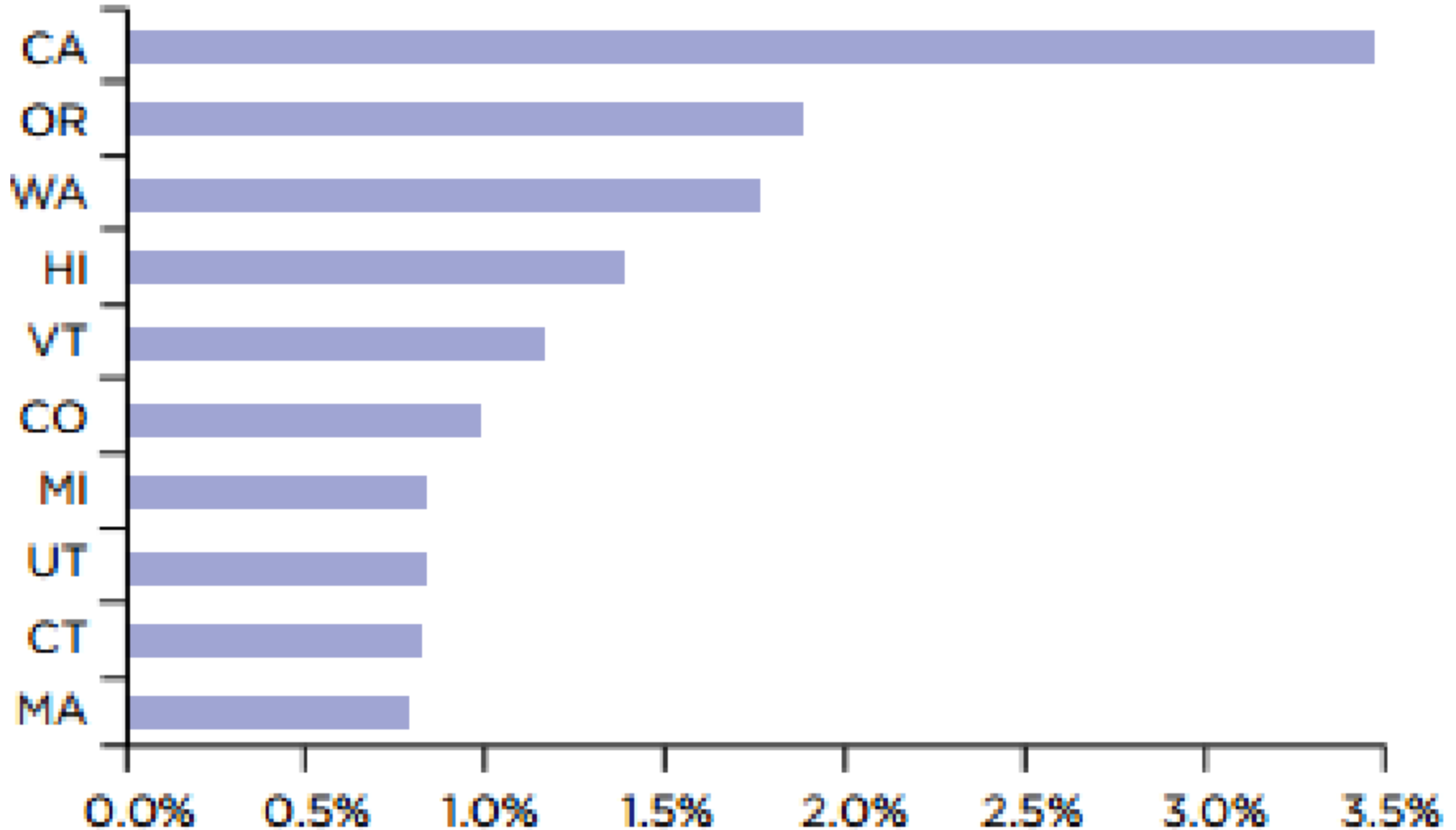


New PEV sales compared to HEV sales over their respective 24 month introductory periods



PEV sales 12/2010 through 11/2012, HEV sales 12/1999 through 11/2001

U.S. Electric Cars (PHEVs & BEVs)



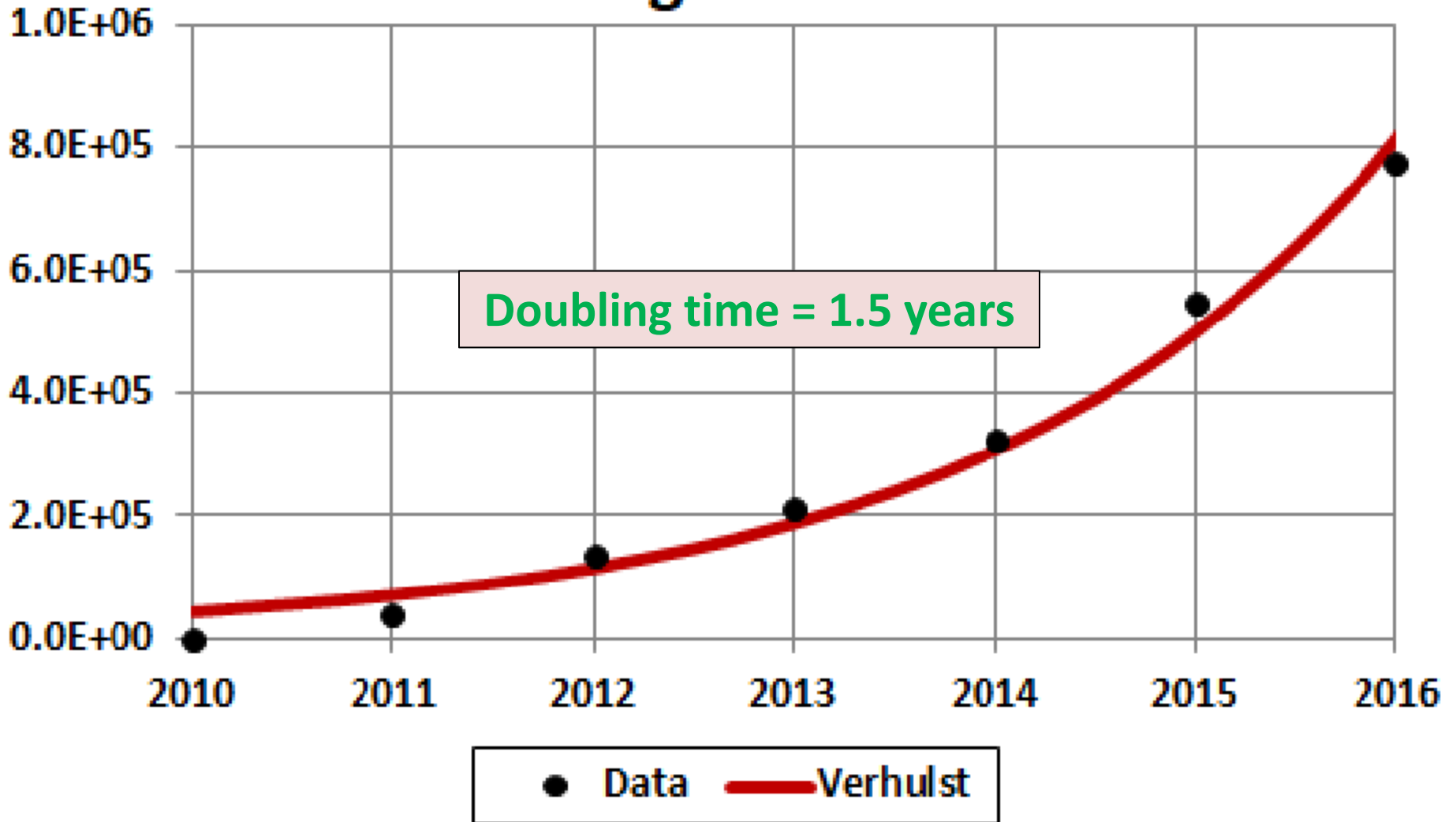
EVs as Portion of New Car Sales, 2016

When will all cars be electric?

- **Norway:** All new cars electric by **2025**
- **Germany, India:** All new cars electric by **2030**
- **Britain, France:** All new cars electric by **2040**
- **China, California:** Studying all new cars electric
- **U.S.:** Over half of cars will be electric by **2030**.
- **Audi:** 40% of luxury cars will be electric by **2030**; BEVs will soon have 400-miles range, and eventually 500 miles.
- **VW:** 50 new BEVs from VW group by 2025
- **GM:** 20 new BEVs by 2023
- **Ford:** Plans a 400-miles BEV by 2020

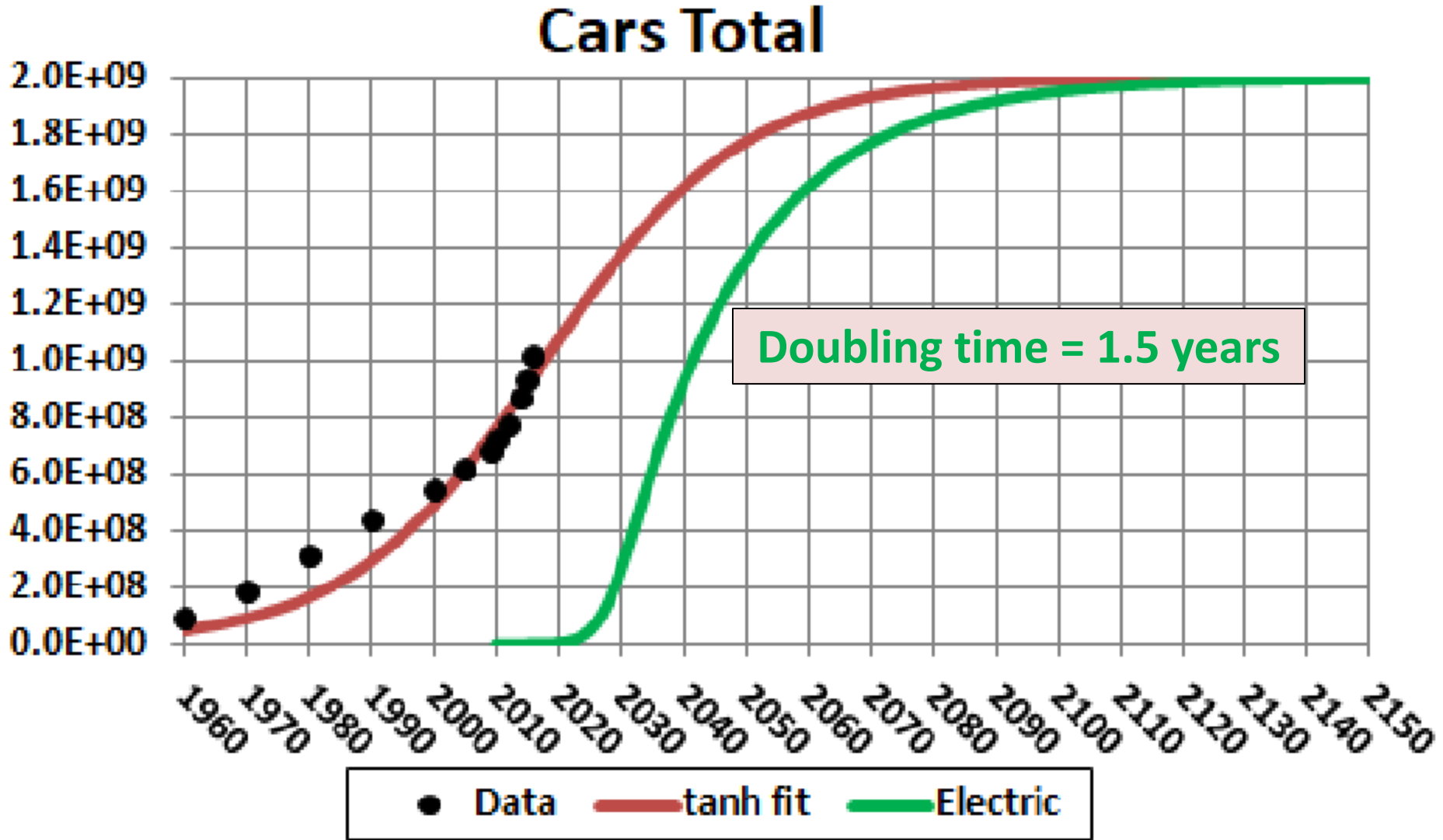
Exponential Rise of World Electric Cars

Plug-In Cars



When will all cars be electric?

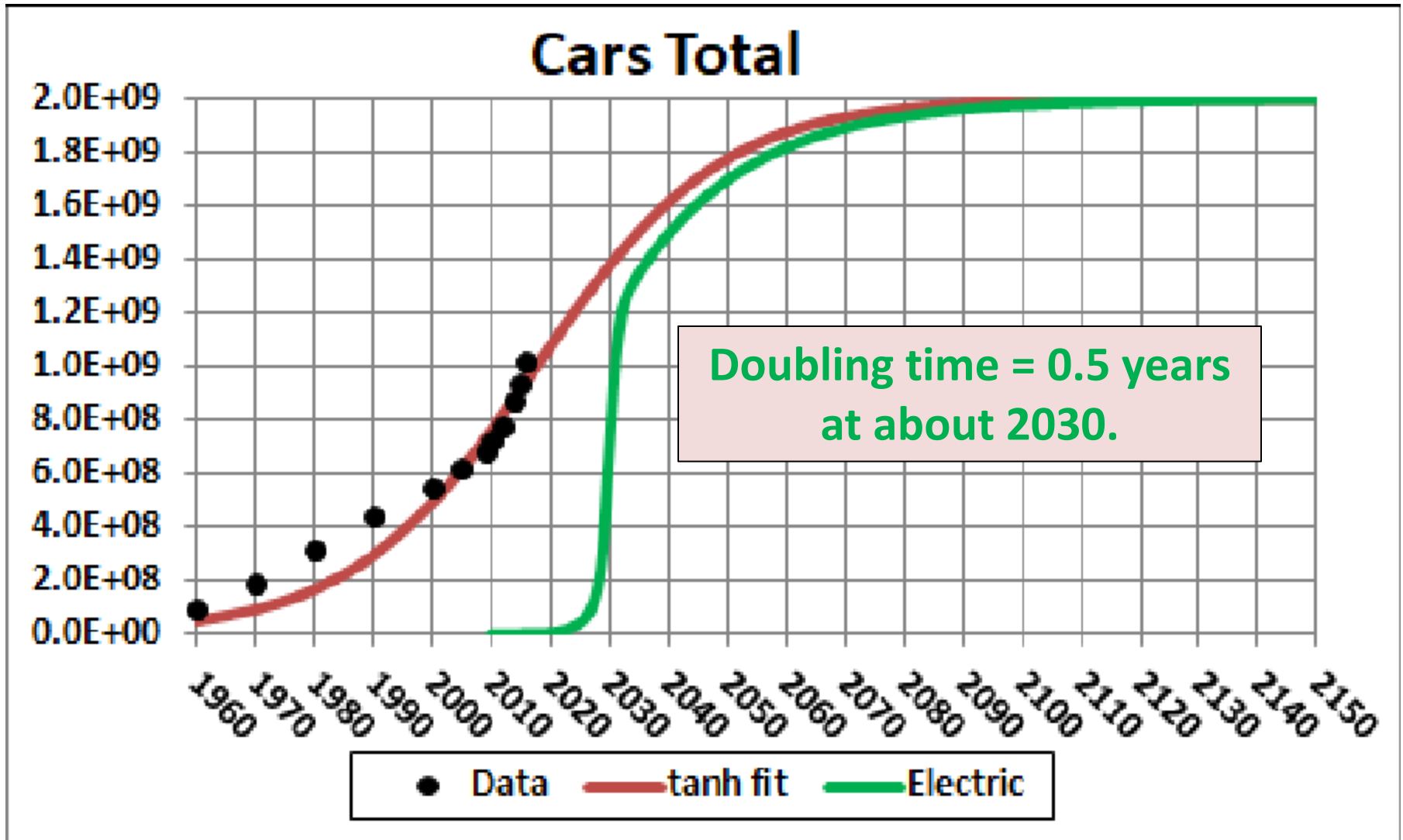
(BEV & PHEV)



Once autonomous cars take over, it will probably happen faster.

When will all cars be electric?

(BEV & PHEV)



Charging PHEVs

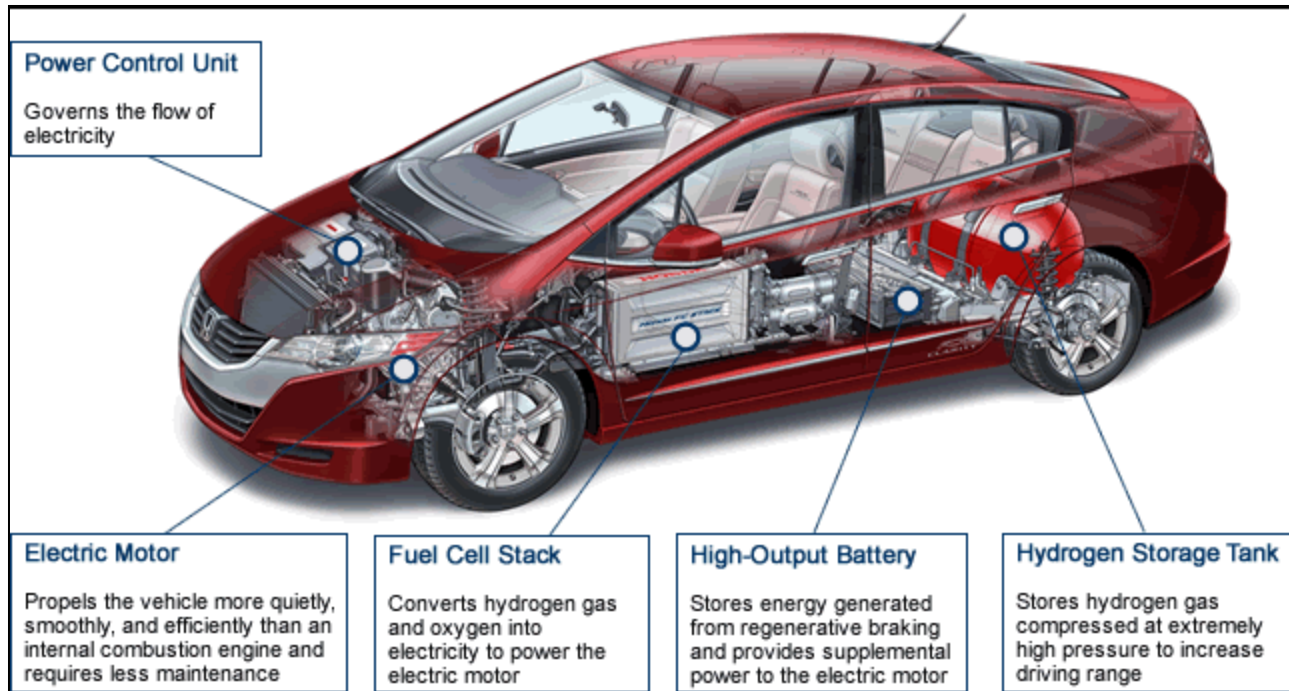
- **Most charging will occur at home in a garage, driveway or parking space.**
- **Level-1: 120-volts AC, 1.12-kW**, for all BEVs & PHEVs (Everywhere!) (**SAE-J1772 cord that comes with the PHEV**)
- **Level-2: 240-volts AC, 3.3-kW & 6.6-kW charging station** with SAE-J1772 plug for all BEVs & PHEVs (Your parking space, Kroger, InnVT, Campus Automotive)
- **SAE-J1772 cord that comes with the PHEV** can have a [pigtail that allows level-2 charging](#) with a standard 240-volts outlet.
- The Mitsubishi Outlander PHEV allows fast charging (CHAdeMO).

Light-Pole Charging Stations



Why Not Fuel-Cell (FCEV) Cars?

- They are very complicated:



- Requires a 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 & ships.

We Need a Rational **National Energy System Design**

- Fuel cells, solar photoelectric panels, hydropower, wind, geothermal and biofuel electricity generators at homes, work sites and parking garages to charge electric and hybrid vehicles' batteries and feed energy into the national electric grid. All possible fuels are used for the fuel cells. That is, **create a distributed multi-source energy system** to supplement, and eventually replace, huge coal, natural gas and nuclear electric power plants.
- Electric and plug-in hybrid vehicles that **automatically connect to the national grid and local energy sources** when parked at homes, work sites and parking garages.
- Plugged-in vehicles serve as **national/local grid energy storage devices when at rest** and drive away as **fully charged vehicles for travel**. They also serve as **electric power backup at the home location**.
- Use **biodiesel made from new and recycled vegetable/animal oils and other wastes** as fuels for long-distance hybrid-vehicle travel between recharging sites. Also, made from algae and bacteria?
- Use the remaining fossil fuels to **develop the infrastructure** needed to accomplish the items given above on a large scale, instead of merely as fuel for transportation.