Lifelong-Learning-Institute Course

Hybrid, Plug-in-Hybrid & Battery-Electric Cars

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http://tinyurl.com/RoperLDavid

1. **HEVs**: Hybrid-Electric Vehicles
   (Baby step to zero emissions)
   http://tinyurl.com/HEVsRoper
2. **PHEVs**: Plug-in Hybrid-Electric Vehicles
   (Juvenile step to zero emissions)
   http://tinyurl.com/PHEVsRoper
3. **BEVs**: Battery-Electric Vehicles
   (Zero emissions with renewable energy)
   http://tinyurl.com/BEVsRoper

Terminology

ICE = Internal Combustion Engine car (gasoline or diesel).

mHEV = mild Hybrid car: large ICE + **very small battery (~0.5 kWh)** + small inline electric **motor**. Battery usually 200-300 volts; some 48-volts.

HEV = hybrid car: medium ICE + **small battery (~1.5-kWh)** + 1 or 2 electric motors. Battery usually 200-300 volts. **SOC = State of Charge of battery.**

PHEV = Plug-in Hybrid car: small ICE + **larger battery (8/20-kWh)** + 1 or 2 electric motors **+ plug. SOC = State of Charge of battery.**

BEV = Battery Electric car: large battery (30/120-kWh) + 1 or 2 powerful electric motors + plug. Battery >300 volts. **SOC = State of Charge of battery.**

EV = Electric Vehicle = PHEV or BEV.

Electrified Vehicle = all of the above except ICE.

The definitions are often confused in news and car advertisements.

Energy: kilowatt-hours (kWh), Power = Energy/time = kilowatts (kW)

Hybrid Vehicles (HEVs)

http://tinyurl.com/HEVsRoper

- Toyota Prius (7 models), Prius C (4 models), Prius V (4 models)
- Toyota Camry Hybrid, Avalon Hybrid, RAV4 Hybrid, Highlander Hybrid
- Ford C-Max Hybrid, Fusion Hybrid, Mustang Hybrid (TBA), F-150 Hybrid (TBA)
- Honda Accord Hybrid
- Chevrolet Malibu Hybrid
- Hyundai Sonata Hybrid, Ioniq Hybrid
- Kia Optima Hybrid, Niro Hybrid
- Nissan Rogue Hybrid (limited availability)
- Lincoln MKZ Hybrid
- Lexus CT Hybrid, ES Hybrid, GS Hybrid, NX Hybrid, RX Hybrid, LC Hybrid
- Infiniti Q50 Hybrid
- Acura NSX Sport Hybrid, RLX Sport Hybrid, MDX Sport Hybrid
- More are very expensive or on the way.
- Some HEVs have been discontinued but are available on the used market.
- **Note that Toyota/Lexus lead the field with excellent engineering.**

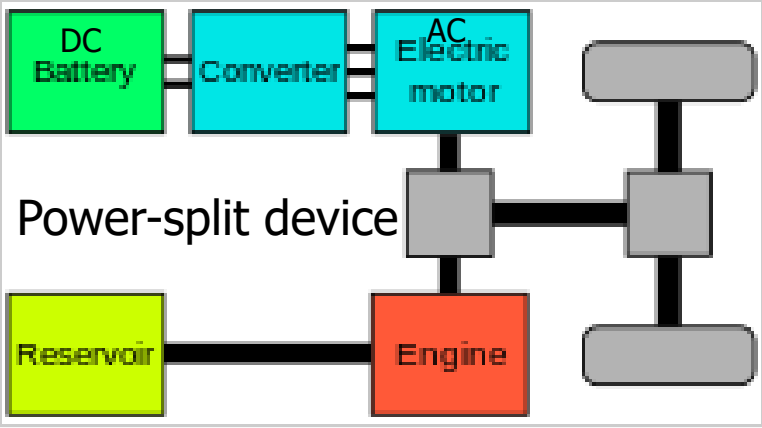
My Hybrid Experience

- 2005 Toyota Prius II
  - –2009 plug-in conversion
- 2006 Toyota AWD Highlander Hybrid
  - –2014 **attempted** plug-in conversion
- 2016 Toyota AWD RAV4 Hybrid
- The last two for my wife and long trips; I drive only BEVs since 2012!

Why Hybrid Vehicles?

- Emissions from vehicles are causing global warming and human sickness. HEVs produce much less emissions than ICEs.
- HEV use about 50% less liquid fuel than the average new vehicle in the same class because **electric motors are ~3 times ICE efficiency.**
- Oil extraction is peaking in the U.S.
- Natural-gas extraction will peak soon in the U.S.
- Oil extraction for the world will peak within two decades.
- Natural-gas extraction for the world will peak within two decades. It is expensive and dangerous to transport.

Types of Hybrid Vehicles



Structure of a parallel hybrid electric vehicle. The grey squares represent differential gears.

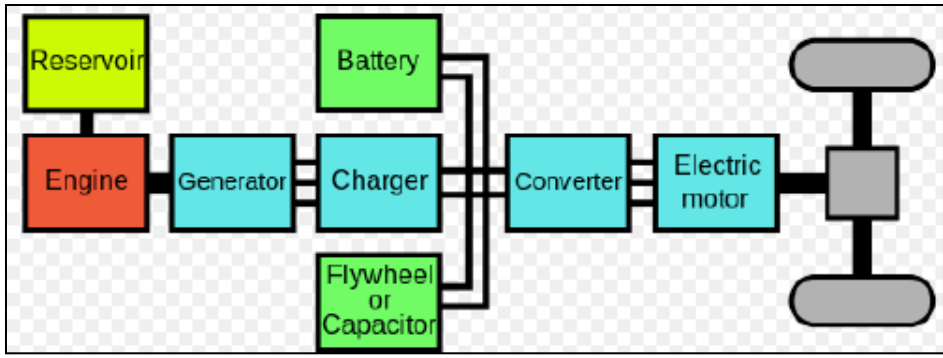
Parallel Hybrids
Motor & Engine turn wheels.

For example, the
Toyota Prius HEV

For both types the ICE, gravity and kinetic energy charge the battery. (Regeneration)

Series Hybrids

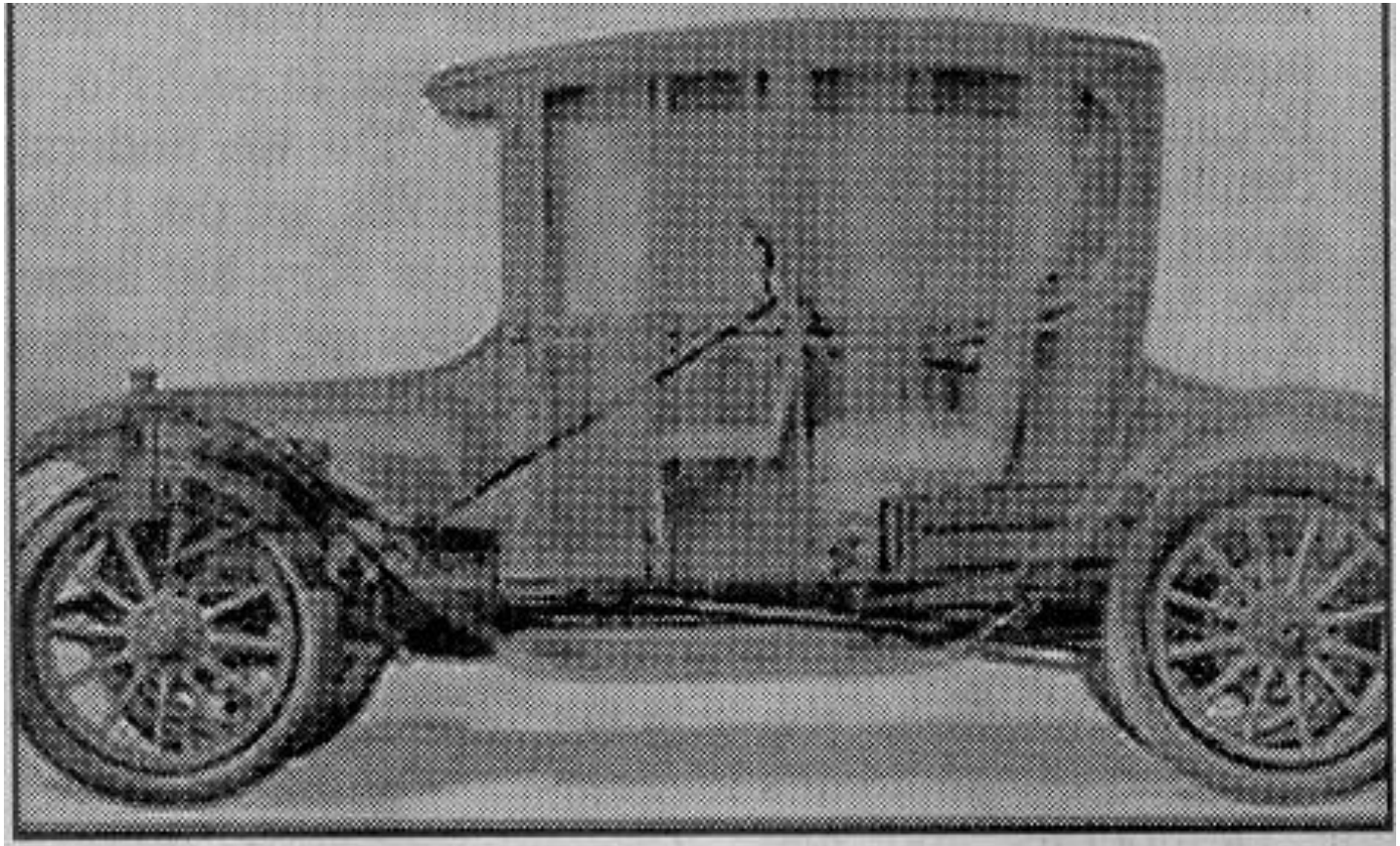
For example, the
Nissan Versa e-Power
Toyota Prius HEV



Only the electric motor turns the wheels.

Series/Parallel Hybrids

For example: **Toyota Prius HEV & most hybrids**



COURTESY OF PETERSEN AUTOMOTIVE MUSEUM IN LOS ANGELES

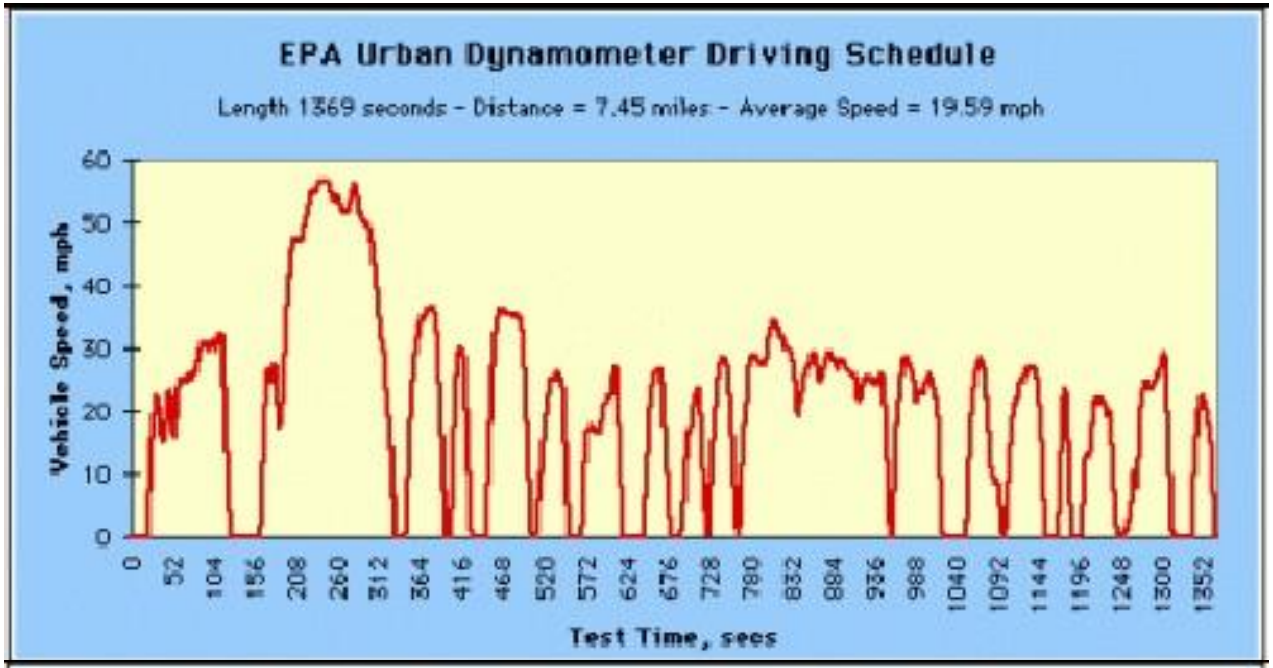
Everything but the name 'hybrid'

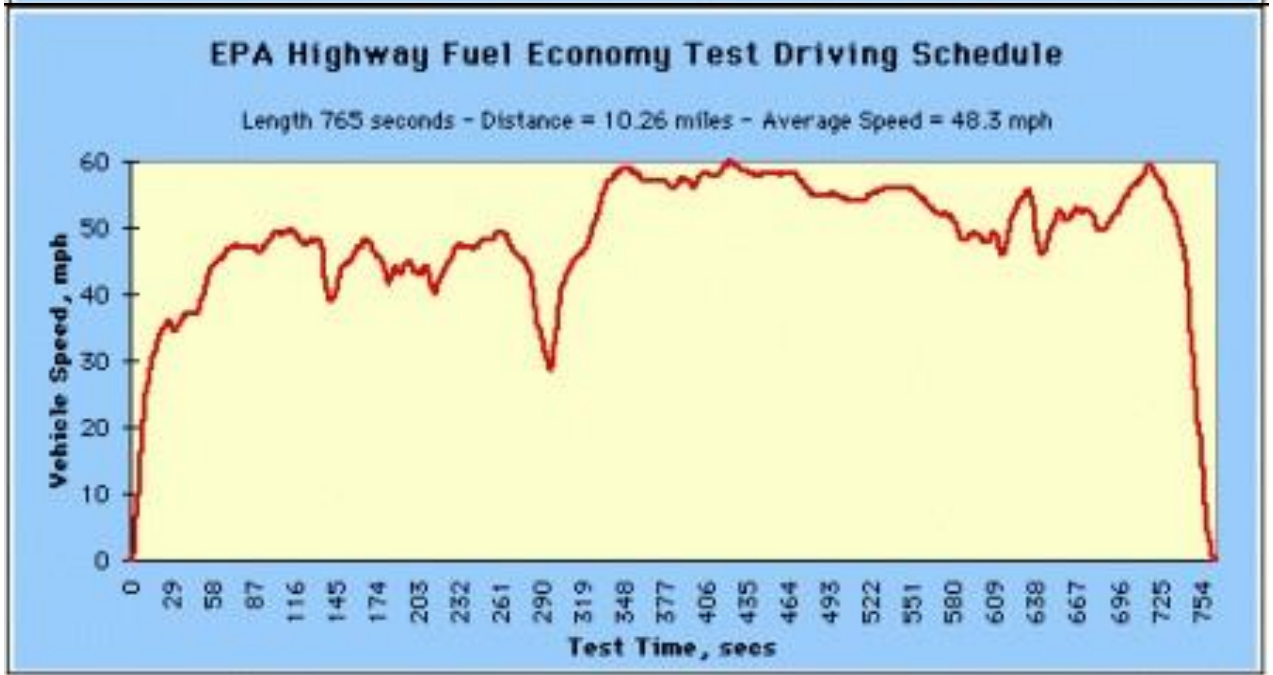
The Woods Motor Co., which produced this 1917 Woods dual-power car, was ahead of its time and introduced its product at a time when steam, electric and gasoline-powered cars vied with the horse and carriage on the nation's roads.

Electric Energy Regeneration for HEVs and EVs

- The electric motor(s) is(are) used as a generator to charge the battery.
- When “brake” pedal is pressed, except in emergencies and at very low speeds, due to kinetic energy decreasing. Therefore, mechanical brakes last longer!
- When going down a hill due to gravitational energy decreasing.
- When accelerator is not being depressed, due to kinetic energy decreasing.

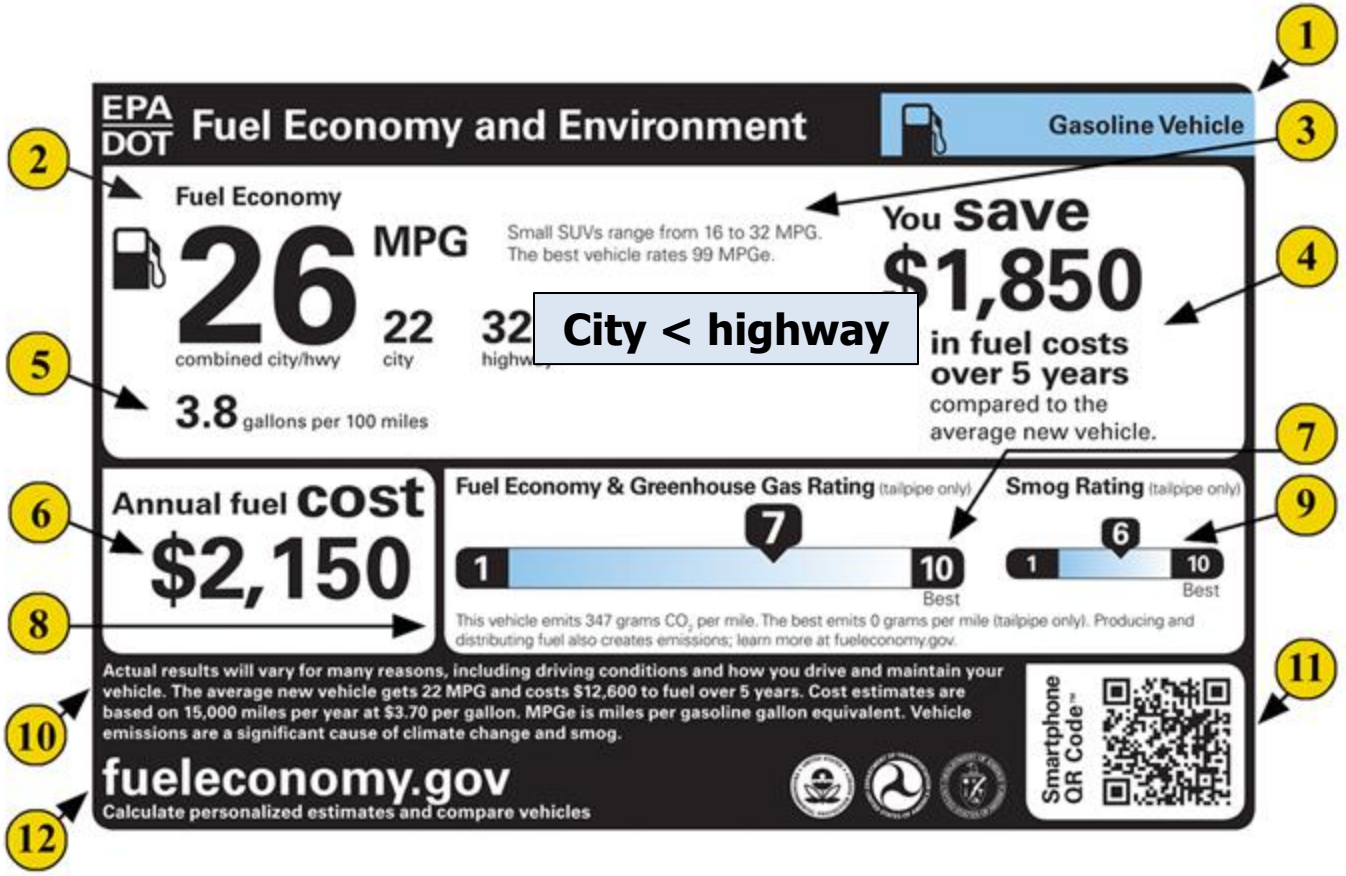
EPA Driving Cycles





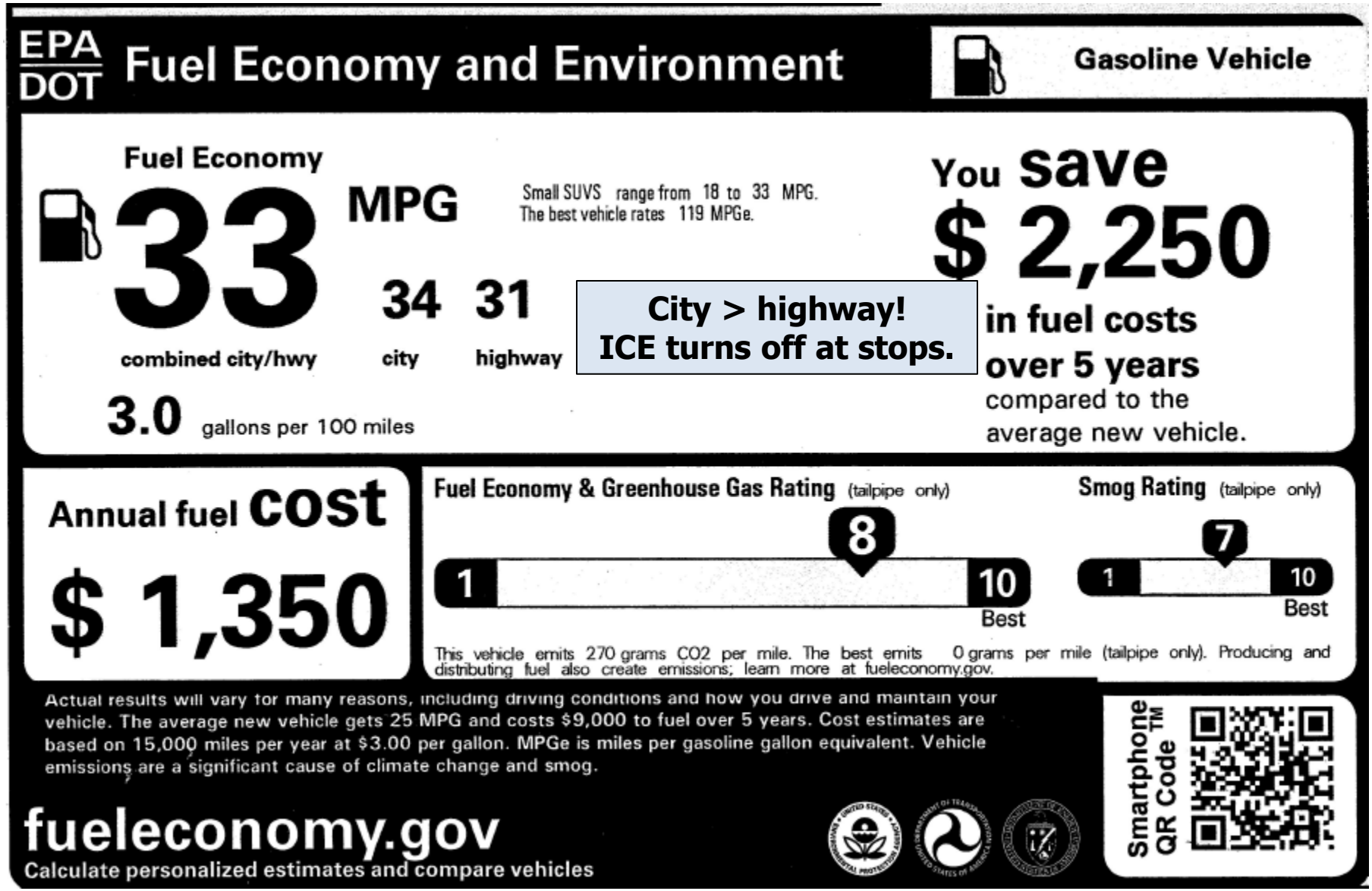
These cycles may not conform to the way you drive.

EPA Monroney Label for Cars



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: **CO_2** Emissions. 9: Smog Rating. 10: Details 11: QR Code. 12: Web page.

2016 RAV4 AWD-i Hybrid Monroney Label



Toyota Prius I 1999-2003

City: 42 mpg
Hwy: 41 mpg

A serial-parallel hybrid car

A few are being driven around Blacksburg.

Toyota Prius II 2004-9

A serial-parallel hybrid car

City: 48 mpg
Hwy: 45 mpg

Toyota Prius III 2009-15

City: 51 mpg
Hwy: 48 mpg

Toyota Prius IV 2016-?

2017 Prius Quick Reference Guide

121 hp
City: 54 mpg
Hwy: 50 mpg

Eco Model:
City: 58 mpg
Hwy: 53 mpg

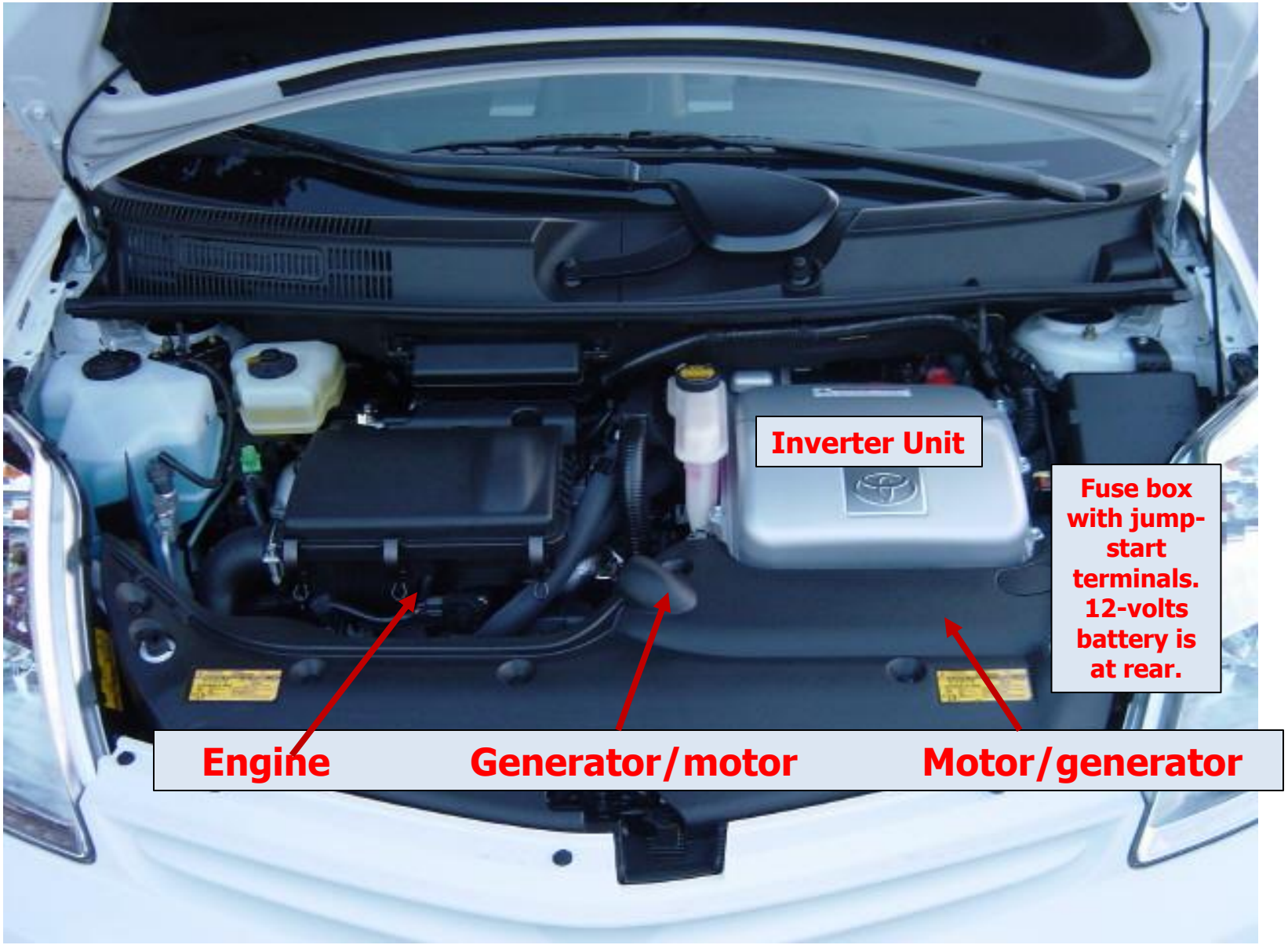
2017 Prius Owner's Manual

Toyota Prius C & V 2016-?

compact: 99 hp
City: 53 mpg
Hwy: 46 mpg

Versatile: 234 hp
City: 43 mpg
Hwy: 39 mpg

Prius 2004-9 Under the Hood



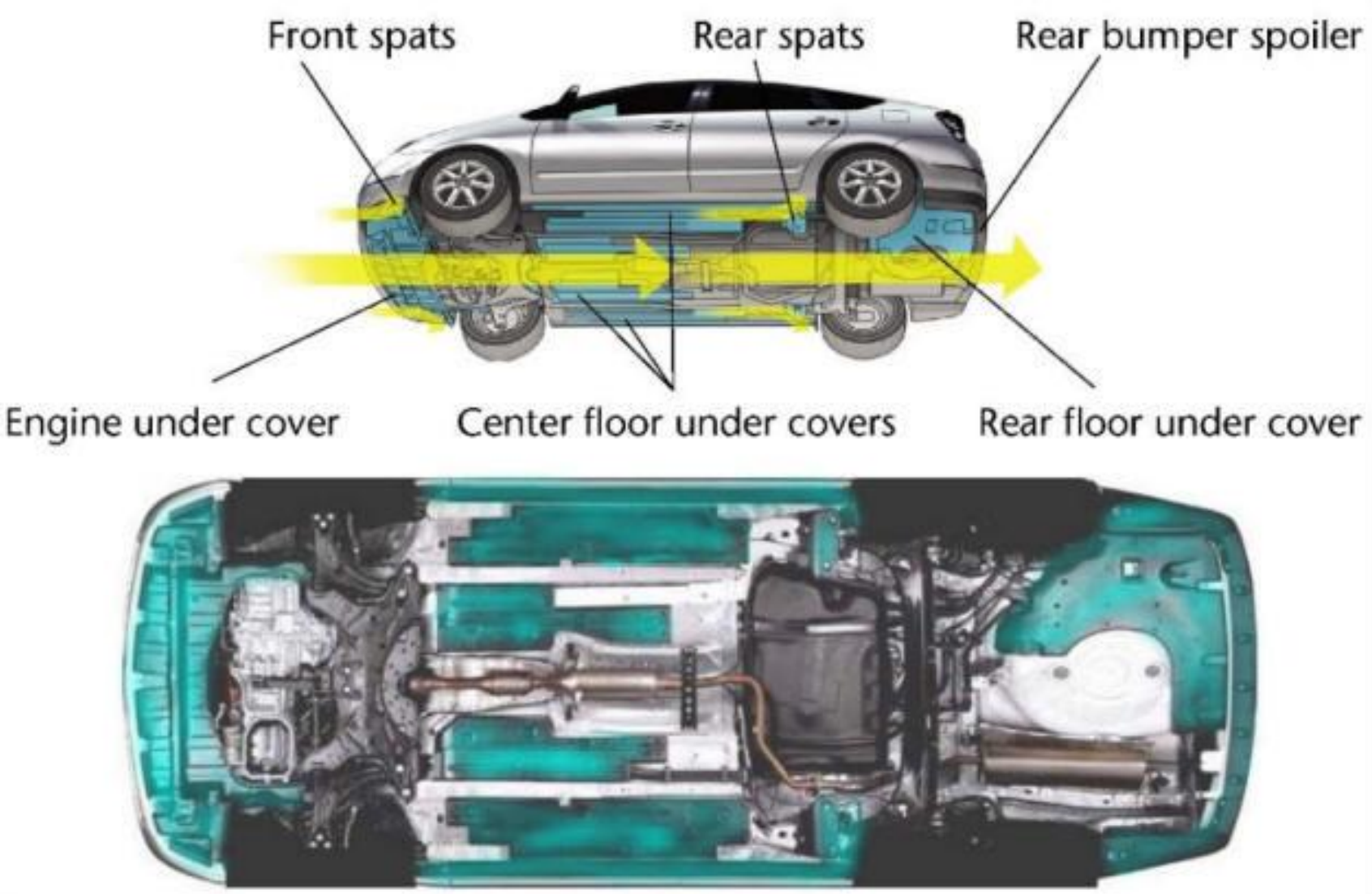
4-cylinder ICE + 2 electric motors = 6-cylinder engine performance.

Prius 2015 Battery Under the Back Seat

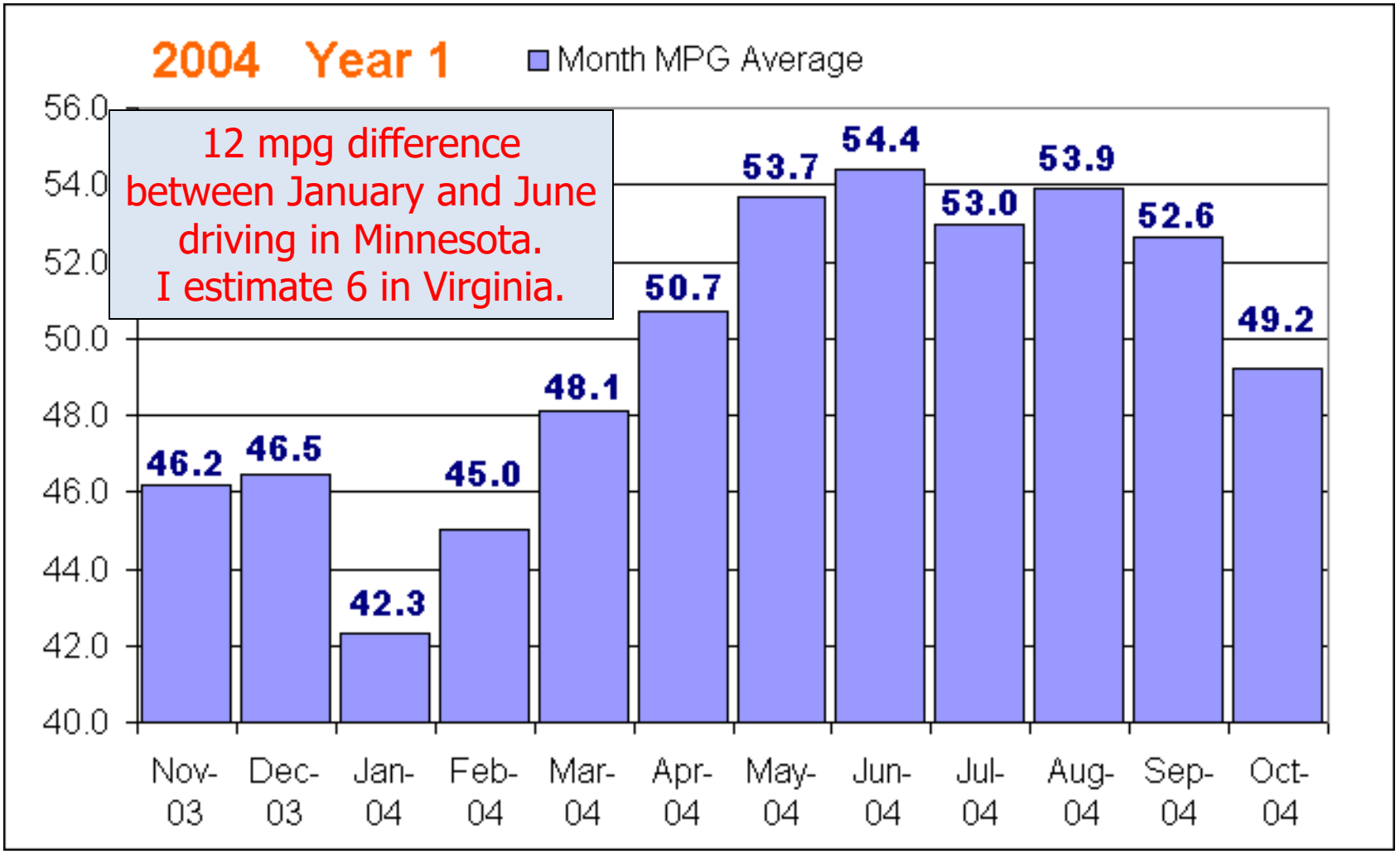
How Does a Hybrid Achieve Fuel Efficiency?

- Because of electric motor assistance, the engine can run at peak efficiency more often.
- Electric motors are more efficient than gasoline engines over a larger range of rpm.
- The high voltage (500 V) for the motors/generators cuts down resistance loss.
- Deceleration, braking & elevation reduction recharge the battery.
- The engine shuts off when not needed; for example, at stops and down hill. It then instantly restarts when needed.
- The engine receives hot coolant before starting, which enhances efficiency. Starts at 1000 rpm by means of the MG1 generator/motor.
- The body is aerodynamically designed for low drag (typically ~0.26 drag coefficient).

Aerodynamics Underneath



2004 Prius mpg Versus Month of Year



Location: Minnesota. Mix of city, suburban & highway driving

Total Cost of a Prius

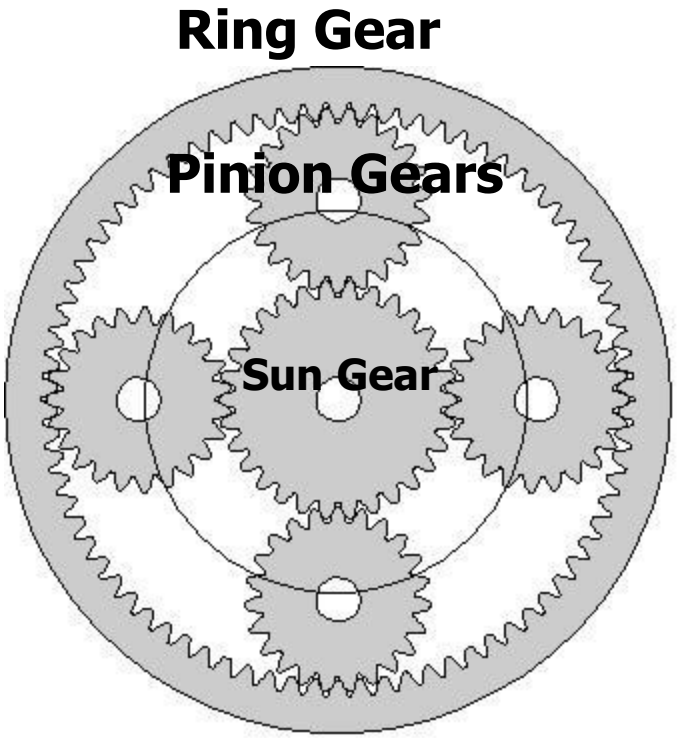
- The Prius hybrid system has no clutches or friction bands to wear out, contrary to the case for a gasoline car. There is nothing in the hybrid system to wear out except gears and bearings. The hybrid system should last for at least 500,000 miles if properly maintained.
- The engine is not stressed nearly as much as one is in a gasoline car. So, the engine should last for over 200,000 miles if properly maintained.
- The electric motors are brushless designs, so they should last for 500,000 miles if properly maintained.
- Regenerative braking greatly delays brake pad and rotor wear. So, the brakes should last for more than 100,000 miles.
- So, cost effectiveness of driving a Prius is as much due to the longevity of the hybrid system, the gasoline engine, the electric motors and the brakes as it is due to higher mpg.
- More important than mpg is the low emissions of a Prius compared to any gasoline car. High mpg for a gasoline car does not equate to low emissions. A gasoline car optimized for low emissions usually has high mpg, but it sacrifices performance. **Performance is not sacrificed in a Prius.**

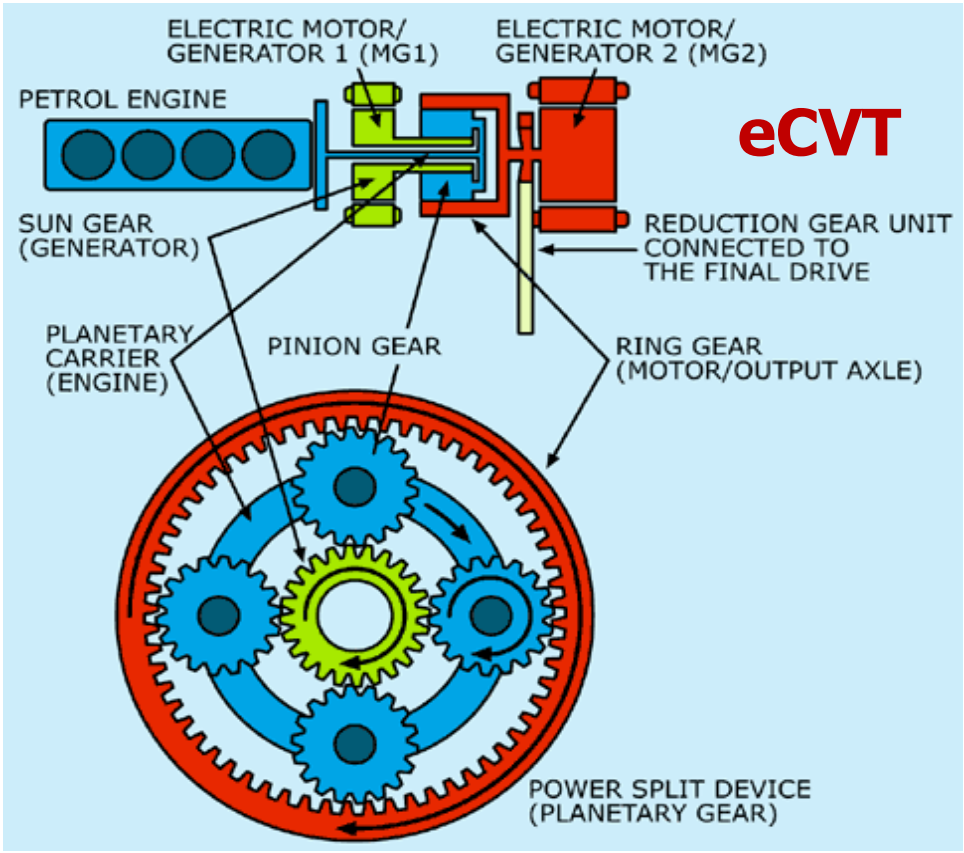
Vehicle Emissions (red=mpg related)

- Tailpipe emissions:
  - Hydrocarbons: urban smog, toxic
  - NO_x: $N_2 + xO_2 \rightarrow 2NO_x$ at high temperature and pressure: smog, acid rain (air=78% nitrogen)
  - CO: incomplete combustion; suffocates
  - CO_2: greenhouse gas
- Evaporative emissions: hydrocarbons
  - Gasoline tank venting
  - Running loses
  - Refueling loses
- A gasoline vehicle has to provide low speed power and low NO_x emissions. A hybrid vehicle can concentrate on just reducing NO_x .

http://en.wikipedia.org/wiki/Automobile_emissions_control

Toyota Prius 2004-5 **Power Split Device (PSD)** or **Planetary Gear Set (PGS)**

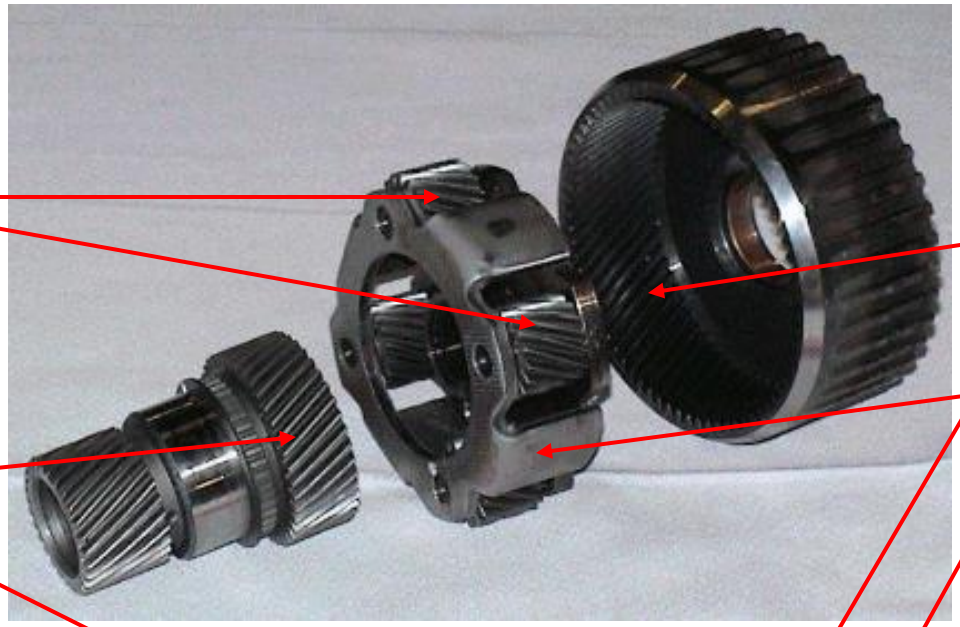


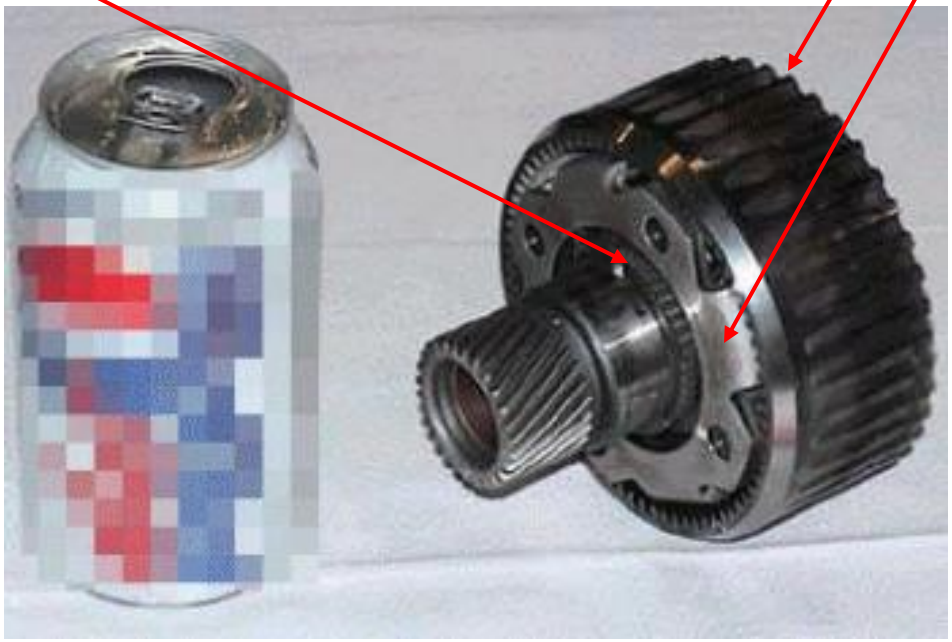


Power Split Device: 78 teeth in ring gear, 30 teeth in sun gear, 23 teeth in each planet/pinion gear.

eCVT = electronic Continuous Variable Transmission

Prius Power Split Device (PSD)





Planet/pinion gears

Ring gear

Planetary carrier

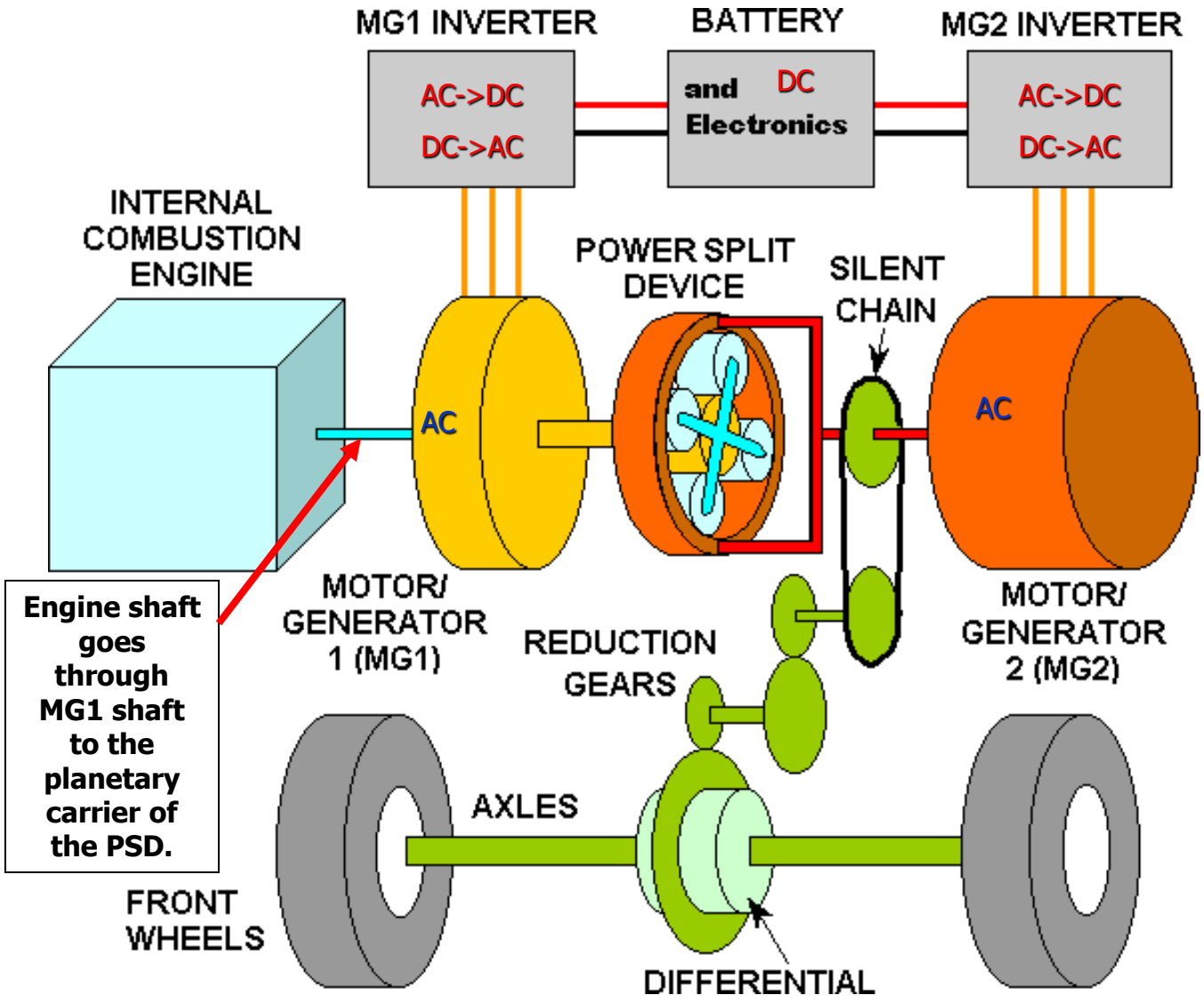
Sun gear

Effectively, this and the electronics comprise the continuously variable "transmission" (eCVT) of the Toyota Hybrid Synergy Drive.

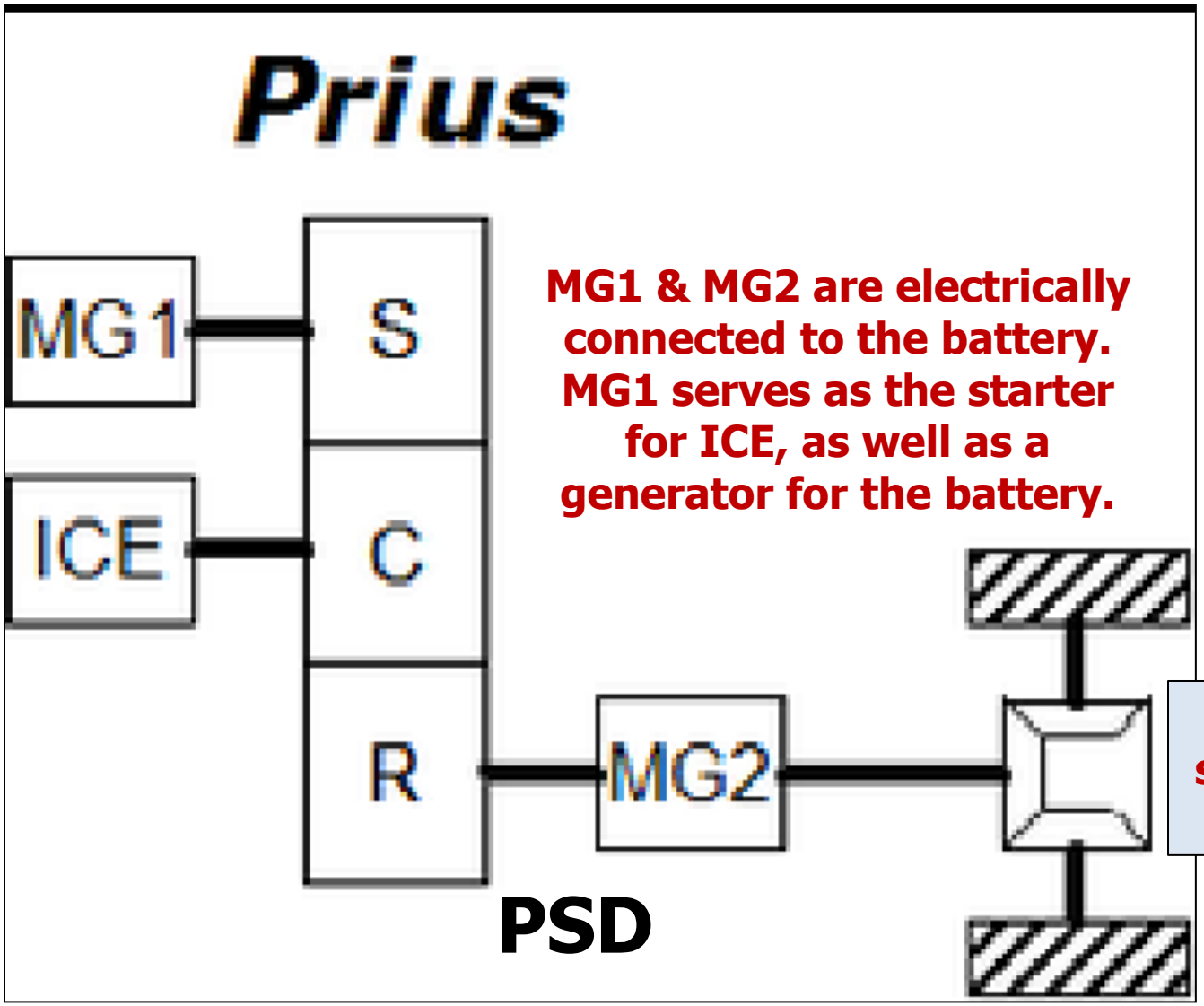
Notice how small it is!

Toyota Prius 2004-2005

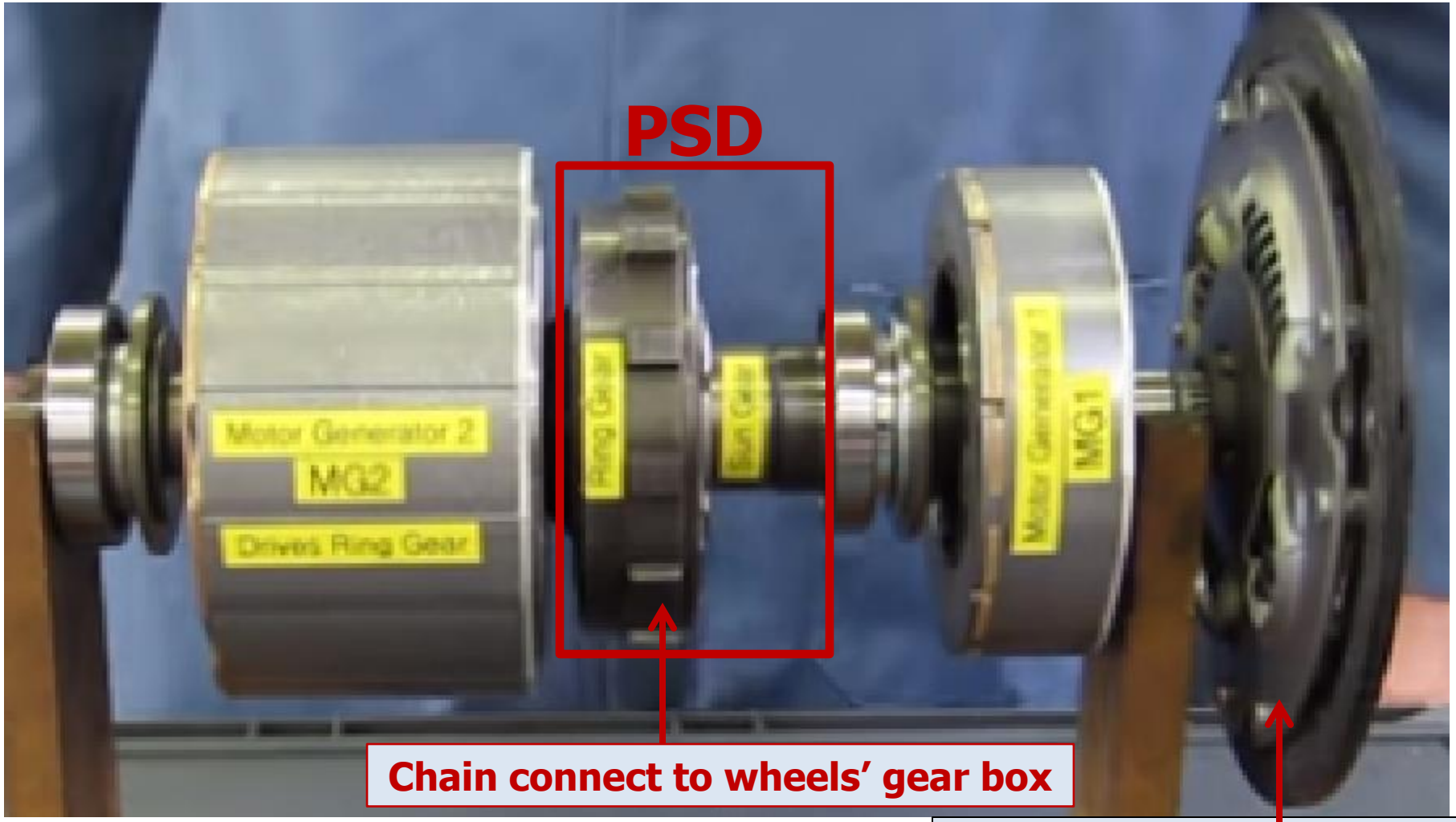
A series-parallel full hybrid (gasoline + electric) car



Prius I/II Power-Split Device Transaxle



Prius I/II Transaxle (eCVT)

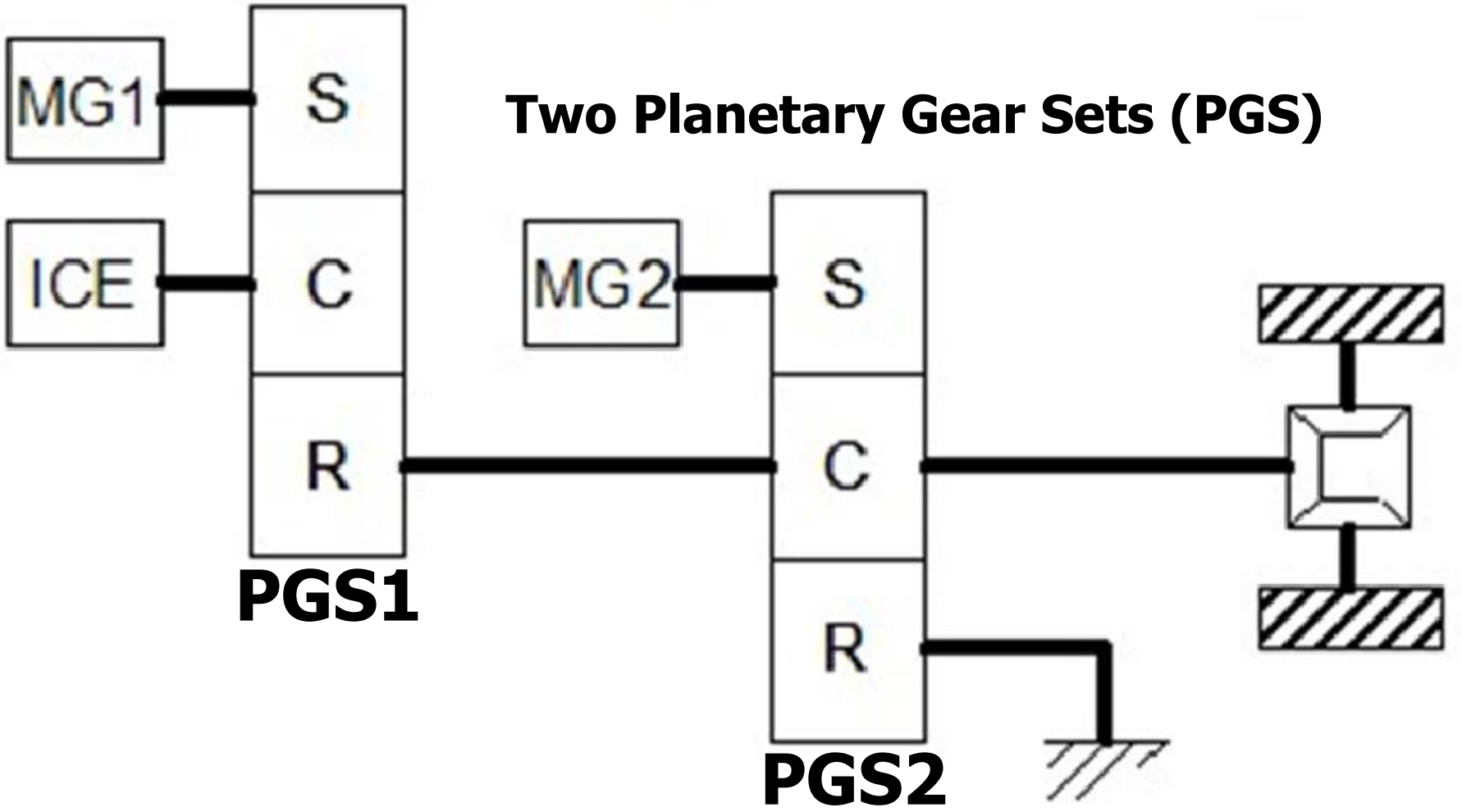


For detail video

Hybrid electric-Continuous-Variable-Transmission (**eCVT**)

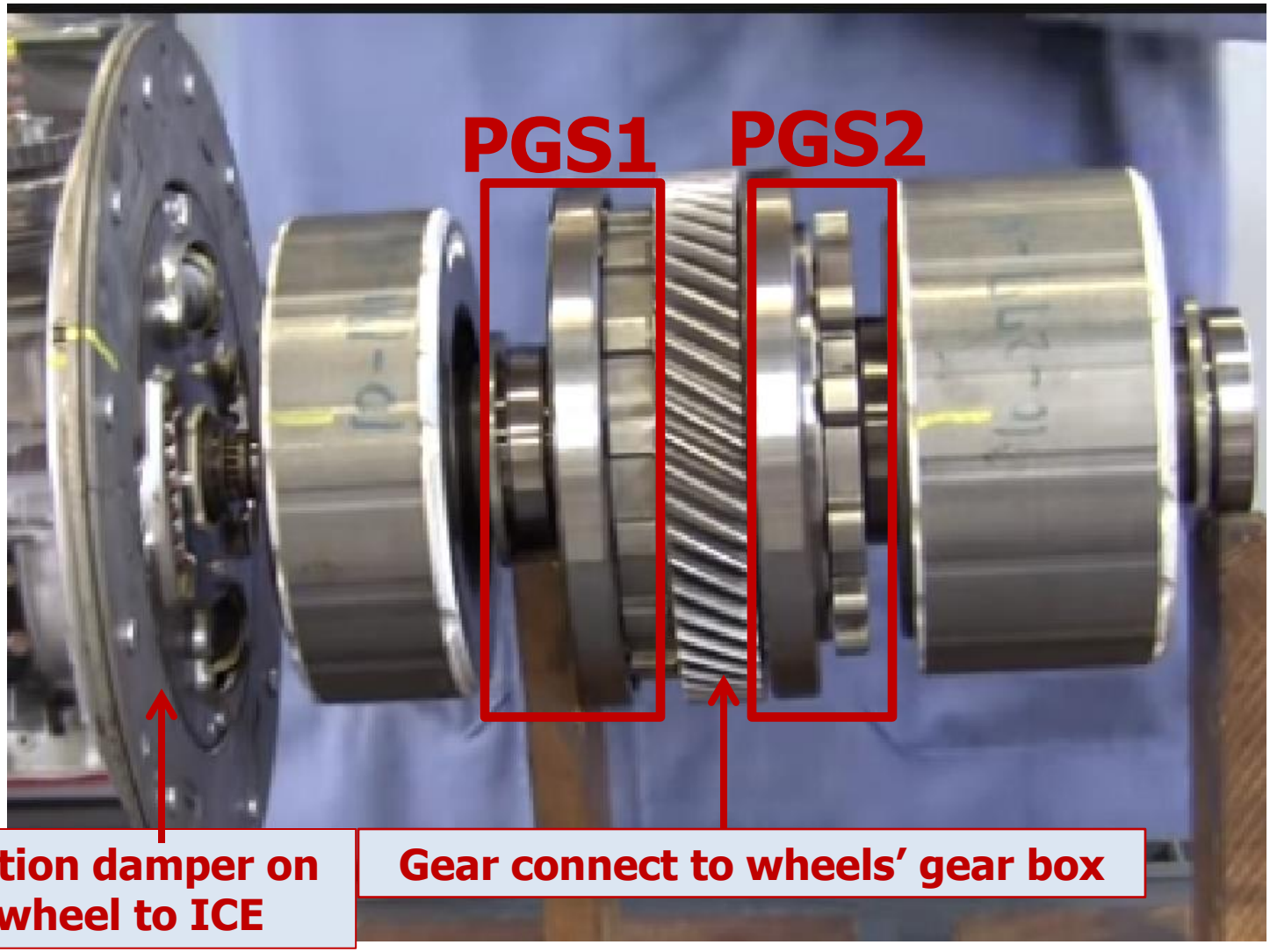
- The Prius does not have a "true" transmission, instead the gear ratio is fixed. One can accelerate from zero to the maximum speed in one gear; however engine torque is not multiplied by a transmission. This lack of low-end engine torque is replaced by lan electric motor/generator and a smaller generator/motor, which are connected to the engine in a planetary gear arrangement (Power Split Device).
- The onboard computer shifts power from the engine and to and from (using the traction battery's power) the motor/generators, determining the most efficient use of the engine and/or the electric motor/generators based on driving conditions, accessories in use and when to charge the battery.

Prius III/IV/Prime, Camry, Avalon Highlander, RAV4 & Lexus eCVT

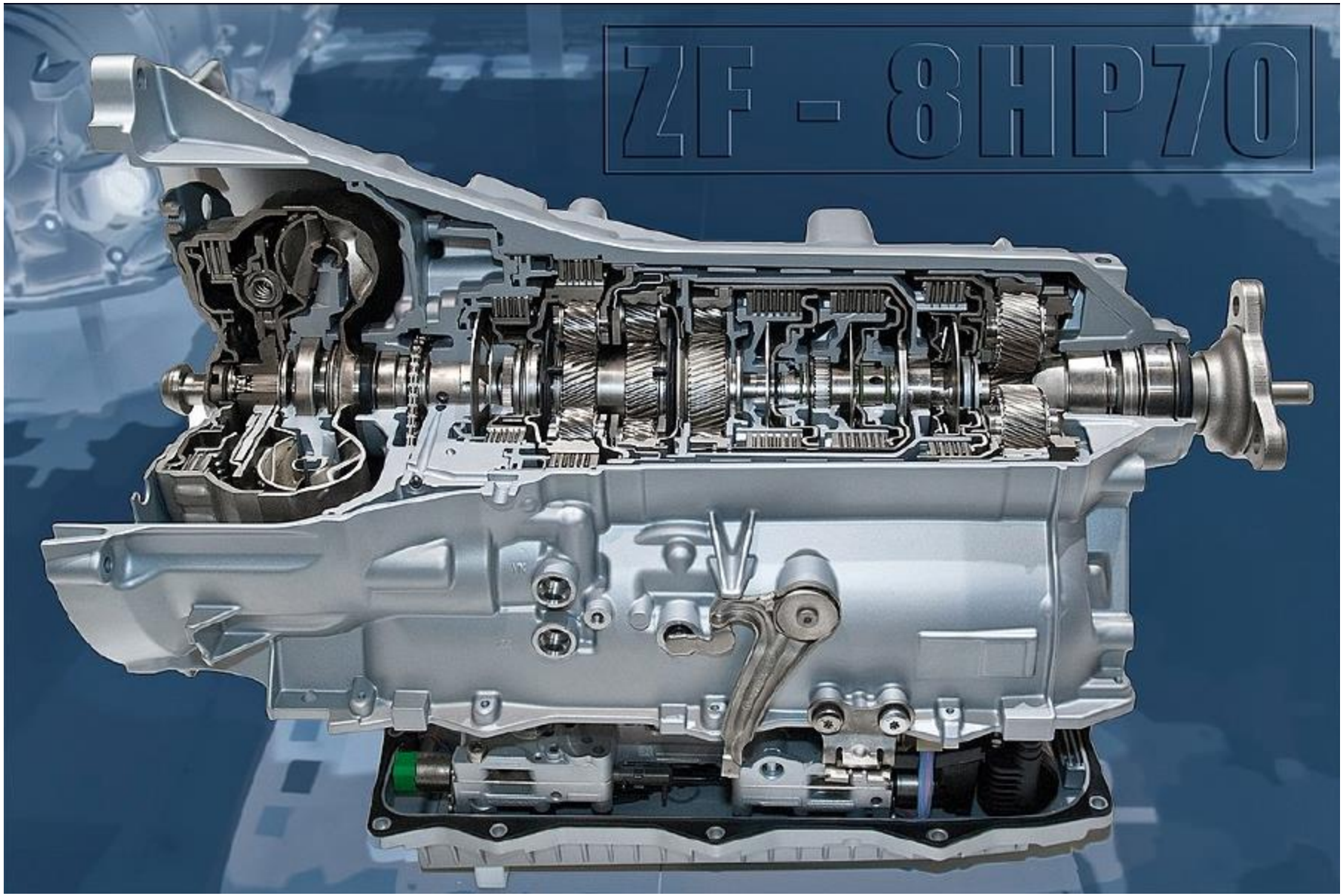


PGS2 is for motor-speed-reduction to increase maximum speed for battery power only.

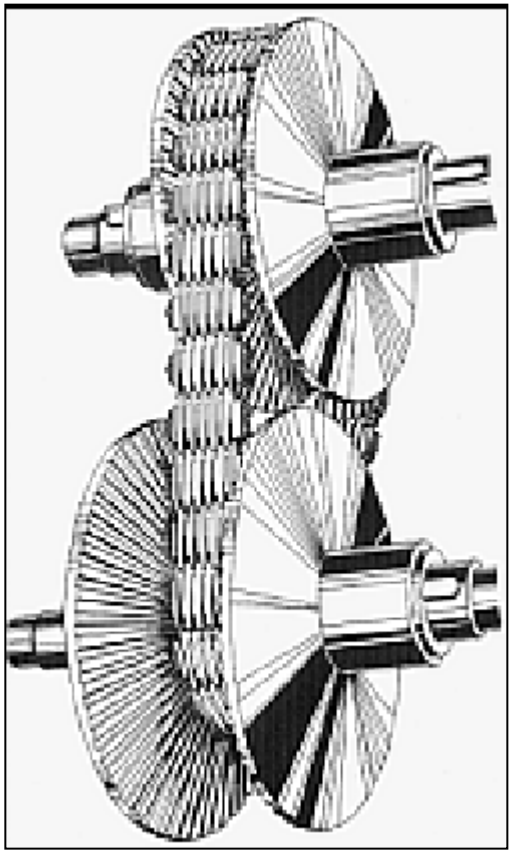
Prius III/IV/Prime, Camry, Avalon, Highlander, RAV4 & Lexus Transaxle (eCVT)

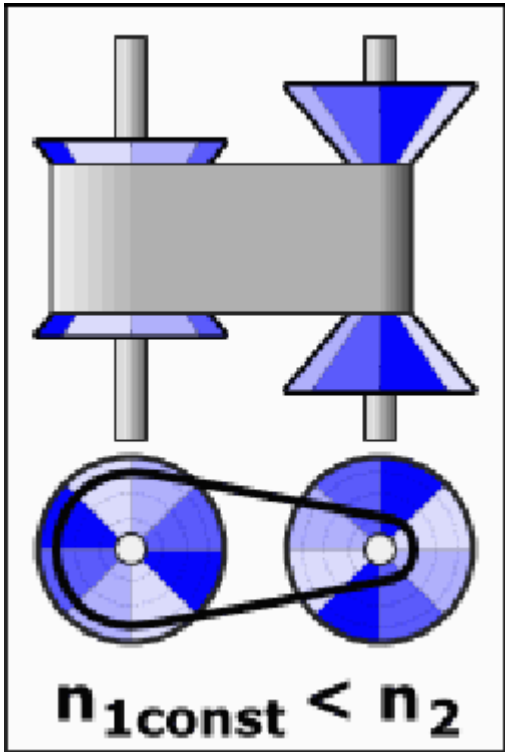


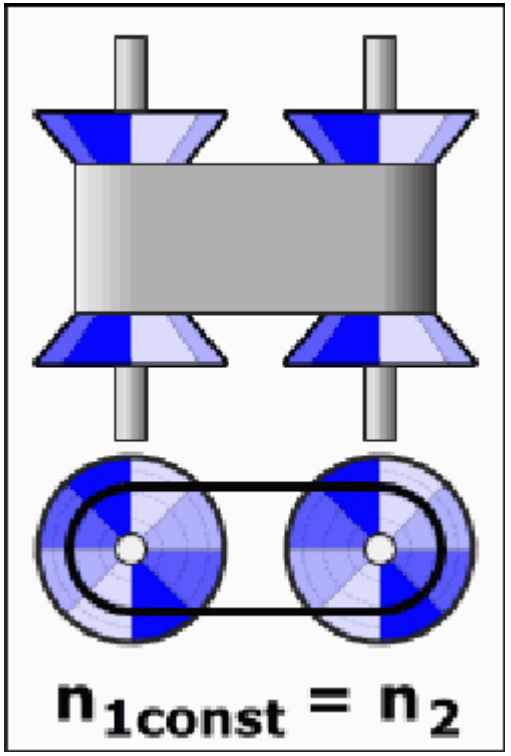
8-Speed Automatic Transmission



Continuous Variable Transmission







The 4 plates are cones whose 2 separations are variable.
It is much more complicated than shown here.

Prius 12-Volts Battery

- Turns the hybrid system on by actuating contact relays.
- Provides power for the five computers and the networks in the car.
- Provides power for the accessories.
- Charged by the traction battery. Can be jump-started by other 12-Volts batteries by using terminals in the fuse box under hood. If the 12-Volts battery becomes discharged, you cannot move the Prius with its front wheels on the ground, because it is in PARK.
- Will gradually discharge when car is dormant. Decrease the discharge by turning off the smart-key switch under the steering wheel. For longer dormancy periods use a BatteryMINDer (https://www.batteryweb.com/batteryminder.cfm) or disconnect the cable from the positive jump-start terminal in the fuse box on the right under the hood (and lose memory settings).
- Batteries maintenance: http://www.vfaq.net/docs/TSBs/PG007-03.pdf

Prius IV Gasoline Engine

- 1.8 cc, 95 hp, 105 lb-ft, 4 cyl, 16 valves, VVT-i=Variable Valve Timing-intelligent, ETCS-i=Electronic Throttle Control-intelligent, compression ratio 13.0/1 (ICE + motors = 121 hp)
- Aluminum alloy
- Atkinson/Miller cycle: short compression stroke (Valves do not close until after the end of expansion stroke.)
- Offset crank shaft allows straight down power stroke.
- 3 liters of Heated coolant stored near boiling point for 3 days used to preheat the engine before starting.
- Engine stopped at precise point in cycle to minimize stress when restarted.
- Engine is cranked to 1000 rpm and oil pressure established before spark is applied first to 2 of the 4 cylinders. This takes about ½ second.
- Variable valve timing to optimize efficiency.
- Unique air intake system to reduce manifold friction.

Prius IV Large Motor (MG2)

- Permanent-Magnet Synchronous
- Maximum voltage: 600-volts
- Power: 71 hp (53 kW)
- Torque: 120 lb-ft

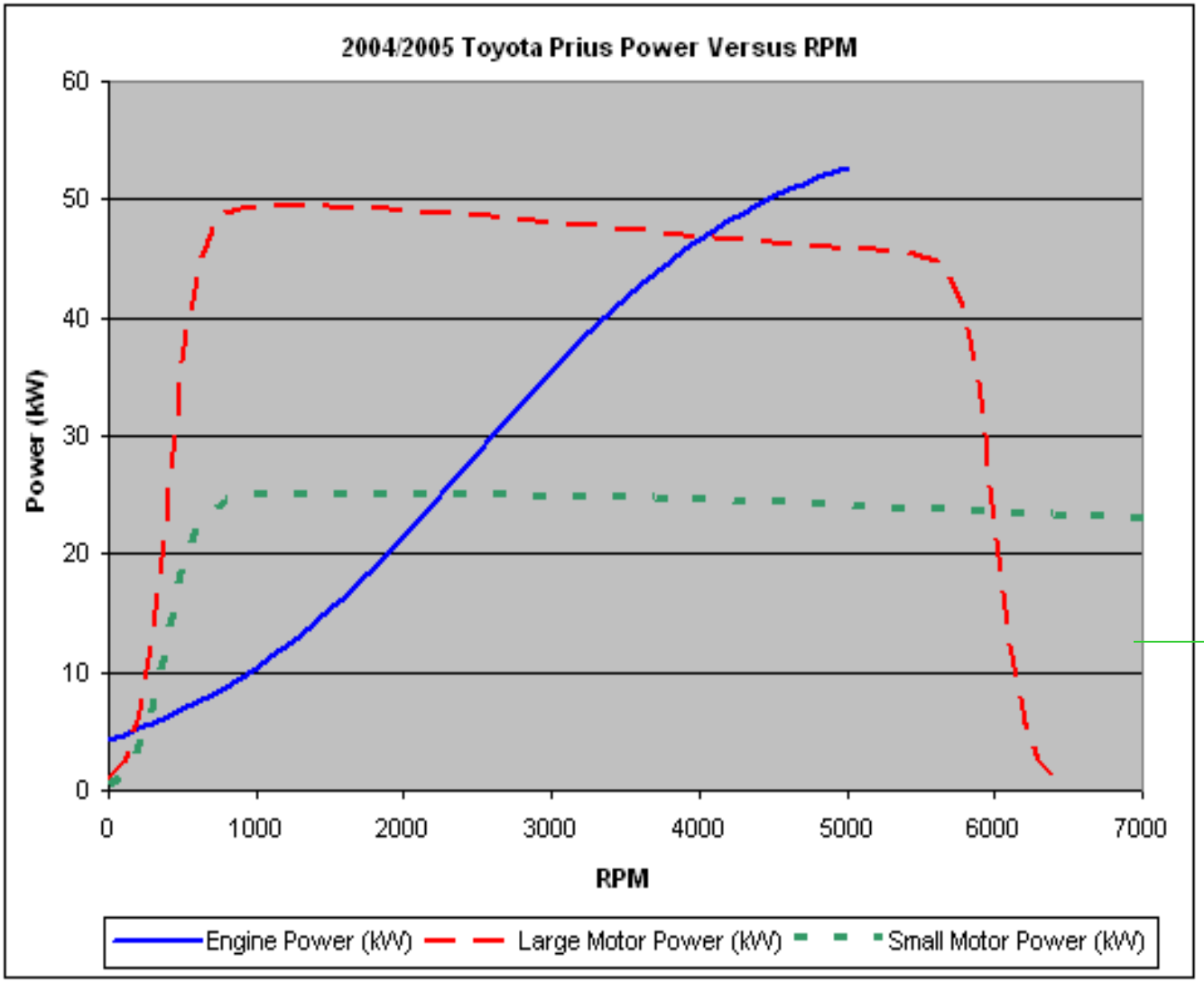
Prius-IV Batteries

- Nickel-Metal-Hydride (NiMH) or Lithium-ion (LiIon)
- NiMH: 207.2 volts, **1.31 kWh**
  only in base Prius Two model
- LiIon: 201.6 volts, 16-kg lighter than NiMH, 4.9-liters smaller than NiMH, **0.75 kWh**
  Charges faster than and has about same usable capacity as the NiMH battery.
- Mounted under back seat
- "The older NiMH battery operates in a very narrow charge band, while the LiIon pack can use considerably more of its state-of-charge range."

Toyota Hybrid Battery Replacement Costs

- 2001-2003 Toyota Prius (1st generation) - **$3,649**
- 2004-2009 Toyota Prius (2nd generation) - **$3,939**
- 2010-2011 Toyota Prius (3rd generation) - **$4,080**
- 2012-2015 Toyota Prius Liftback - **$3,939**
- 2012-2016 Toyota Prius V - **$3,939**
- 2012-2016 Toyota Prius C - **$3,807**
- 2007-2011 Toyota Camry Hybrid - **$4,892**
- 2012-2015 Toyota Camry Hybrid - **$4,892**
- 2013-2015 Toyota Avalon Hybrid - **$4,892**
- 2006-2010 Toyota Highlander Hybrid - **$6,198**
- 2011-2015 Toyota Highlander Hybrid - **$6,353**

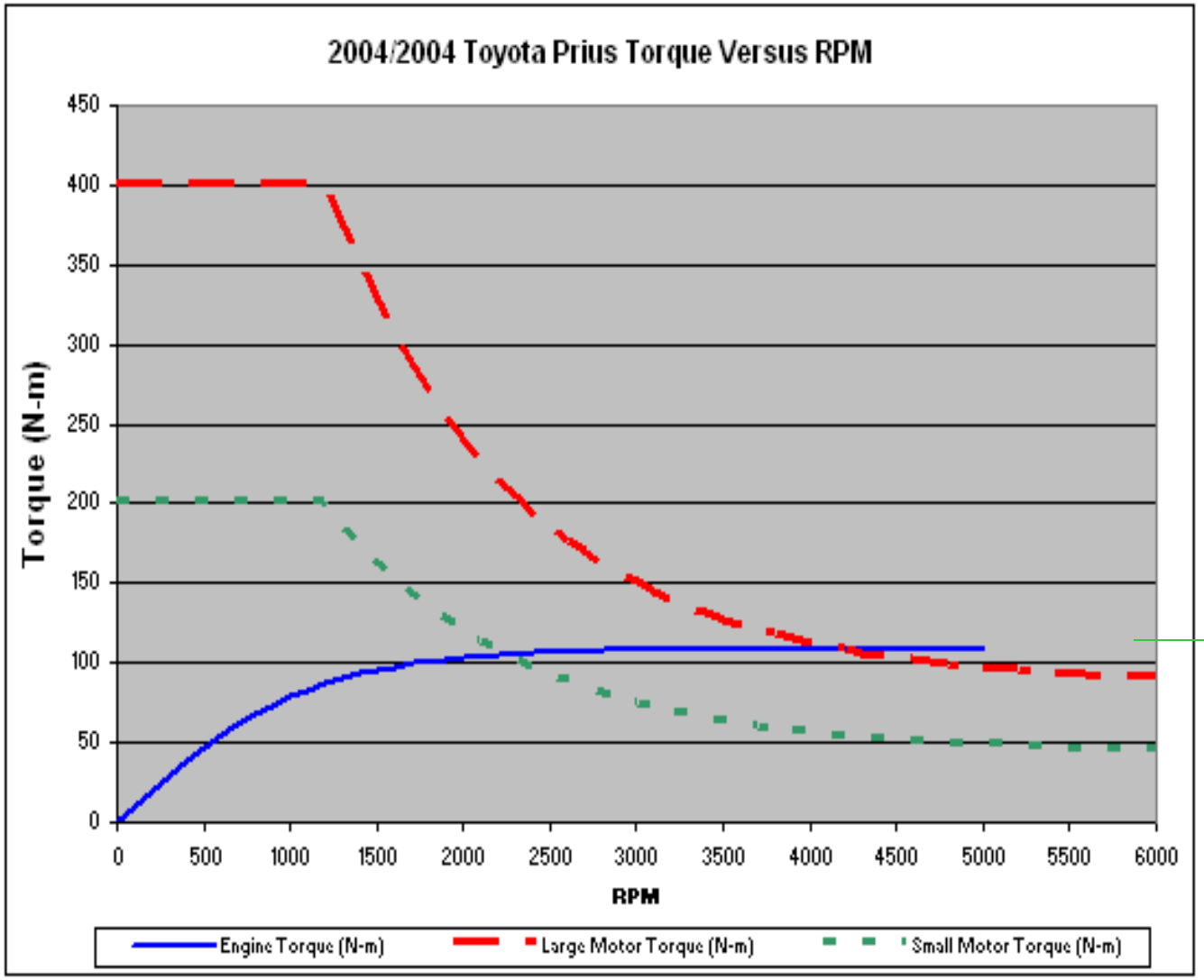
Prius Power vs rpm



One can see why the electric motor is important for power at all, but especially low, rpm.

Small motor extends to 10,000 rpm.

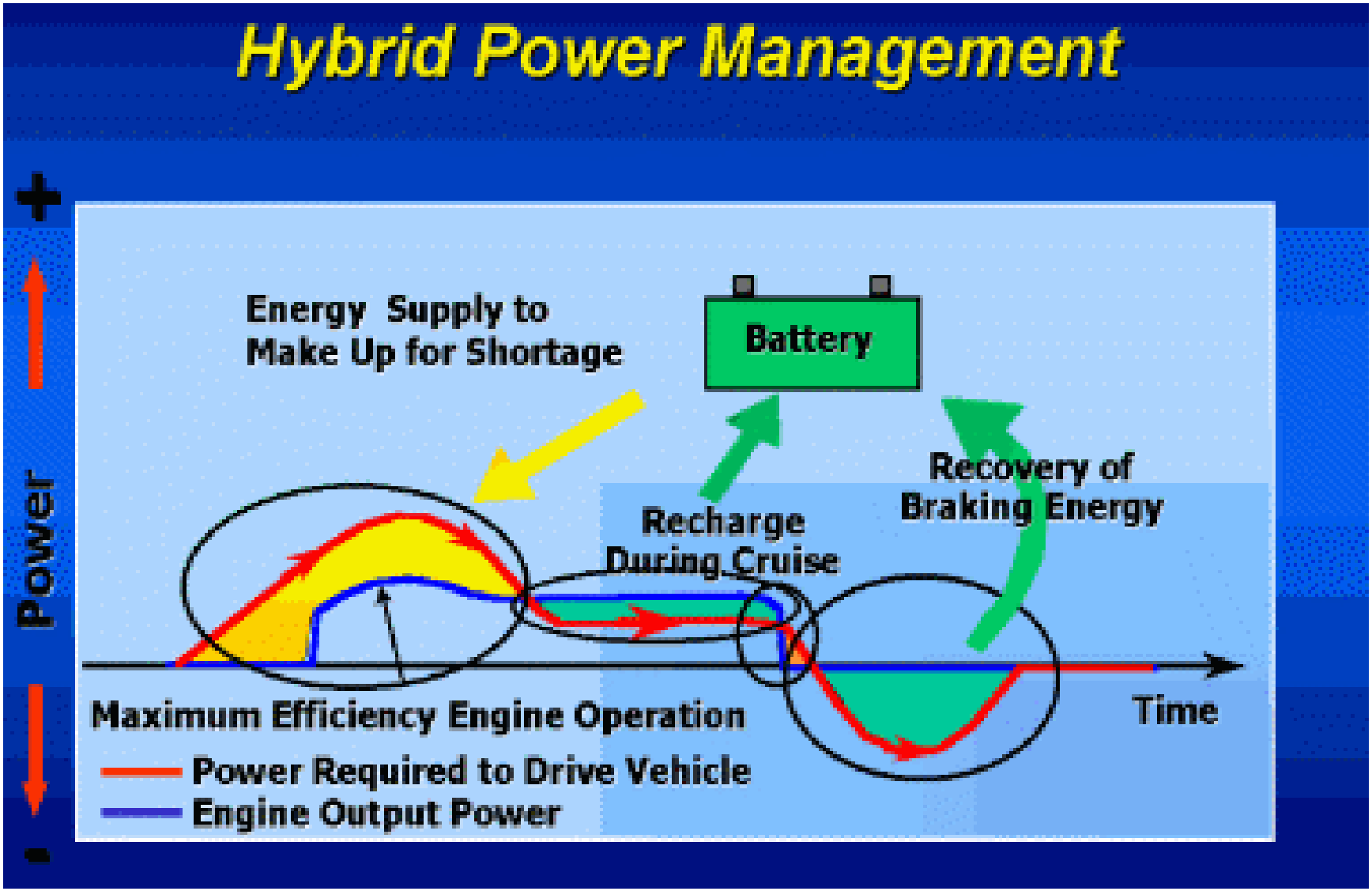
Prius Torque vs rpm



One can see why the electric motor is important for torque at all, but especially low, rpm.

Small motor torque extends to 10,000 rpm.

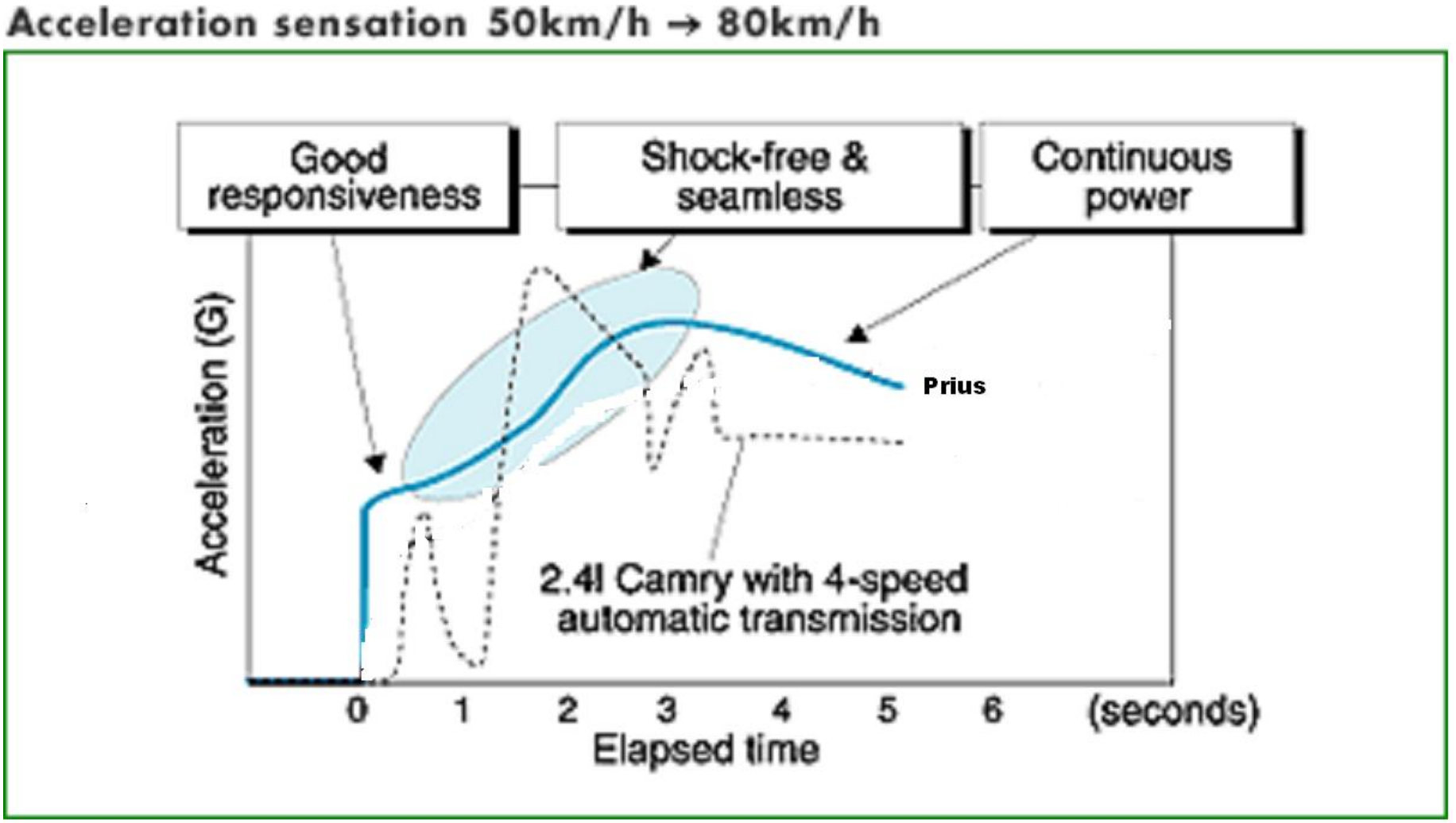
Prius Power-Train Performance



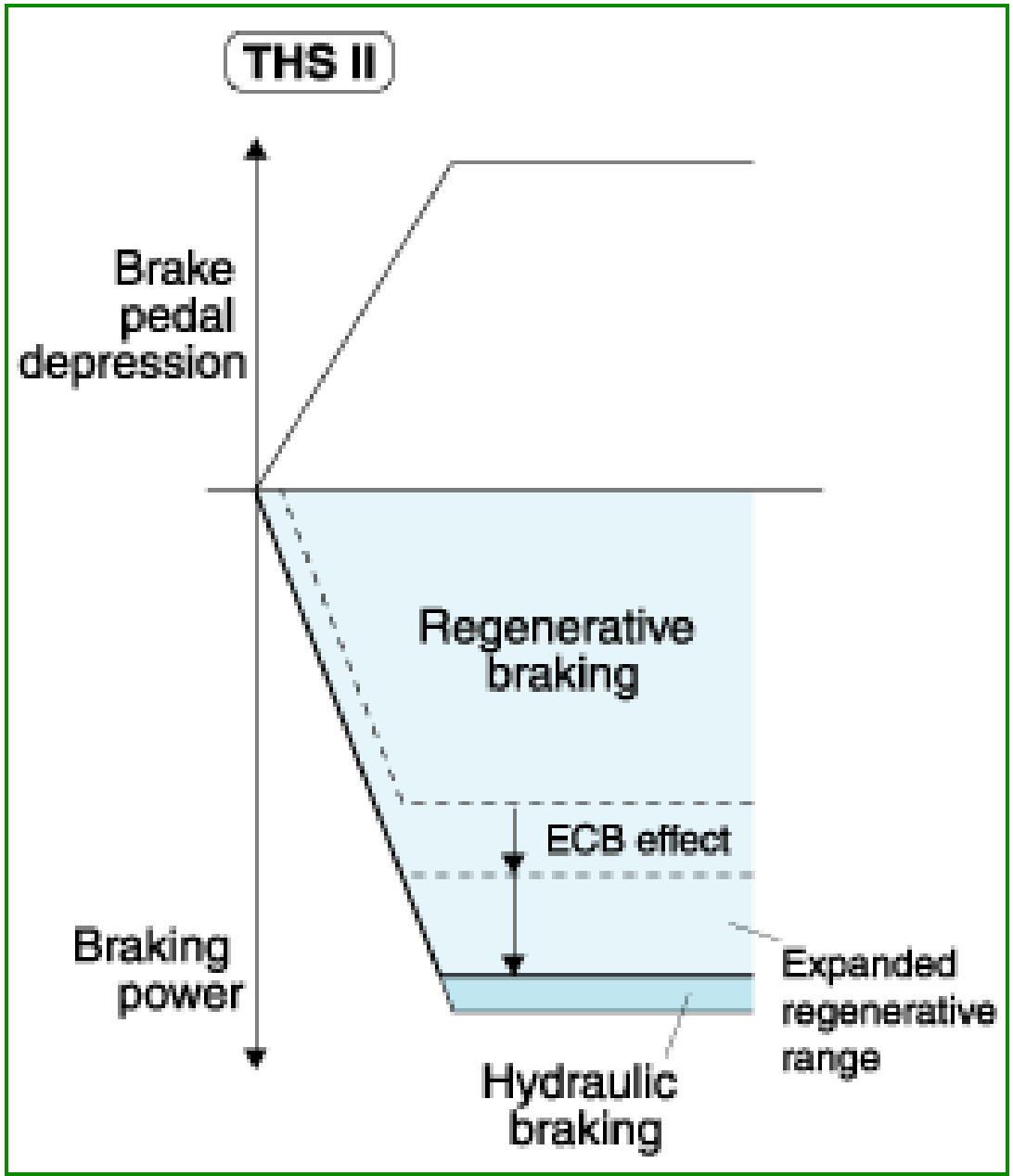
When Does The Engine Run?

- To move the vehicle.
- To charge the traction battery.
- To warm up for lowest emissions.
- To provide heat for passengers.
- To power the air-conditioner compressor.
- To run hybrid-system diagnostics.
- Prius misconceptions:
  http://john1701a.com/prius/prius-misconceptions.htm

Smooth Acceleration

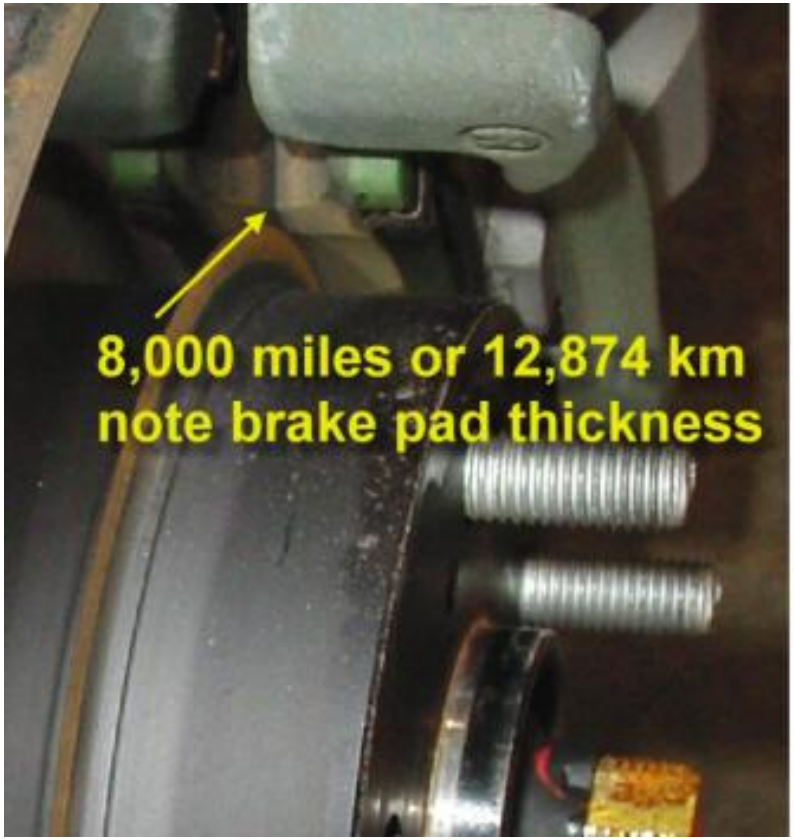


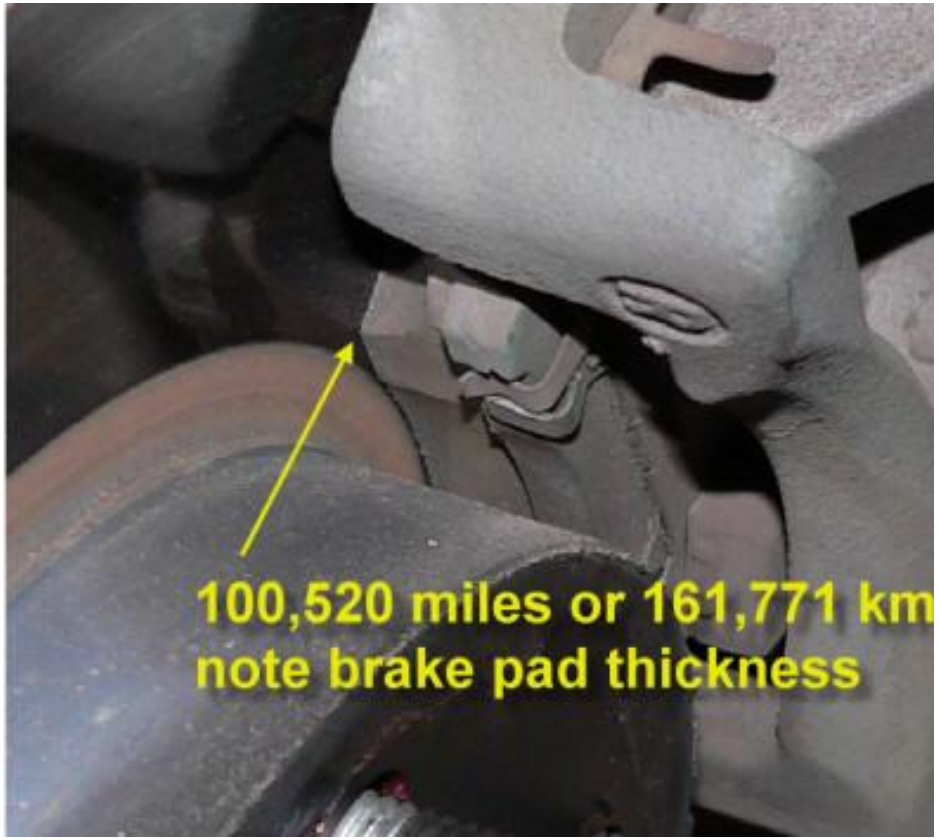
Regenerative Braking



ECB = Electronically Controlled Braking System which controls the coordination between friction braking and regenerative braking, which preferentially uses regenerative braking. Recovers up to 30% of the possible recoverable energy down to 7 mph. Each wheel's brake is independently controlled electronically.

Brake Pads after 8,000 & 100,520 Miles





Prius as a Powerful Computer Network

- There are many Local Area Networks (LANs) connecting 5 computers in the vehicle. (All new vehicles have powerful computers and networks; hybrids take that one giant step further.)
- The LANs communicate through super networks. E.g., the climate-control network and the braking network communicate with the power-train network.
- For the keyless entry & start option, the vehicle's main computer powers up using the 12-Volts battery when you approach the vehicle. When you press the Power button the other computers and LANs are turned on, powered by the 500-Volts traction battery.
- Pressing on the accelerator activates the motive networks according to the movement selection.

Prius Electric Safety

- Battery is placed between the frame rails and in front of the axle where it is least likely to be damaged in an accident.
- High-voltage cables are metal shielded, orange colored and placed away from possible damage in collisions.
- Battery power is cut off when an air bag deploys and other collision sensors activate.
- Vehicle does an electric system check when powered up.
- Toyota provides special pamphlets for emergency personnel.

Prius III/IV 5 Driving Modes

Prius III/IV Driving Modes

- **Normal Mode**: Active when neither the EV, ECO, PWR or B modes are active; the acceleration is linear in pedal depression; normal A/C-heater functioning.
- **ECO Mode**: Accelerator pedal is mapped to **reduce** acceleration for a given depression. Heater is optimized for low fuel consumption.
- **PWR Mode**: Accelerator pedal is mapped to **increase** acceleration for a given depression.
- **EV Mode**: Only electric motor drives car until a given low battery charge or a given high speed.

To "B" or not to "B"

The "B" selection on the motion selector causes the engine to turn without firing, using air compression and engine friction to turn some of the vehicle's motion energy into heat. Some of the motion energy may go into charging the battery. (After using "B" you will need to reset the cruise control.) When might one use "B"?:

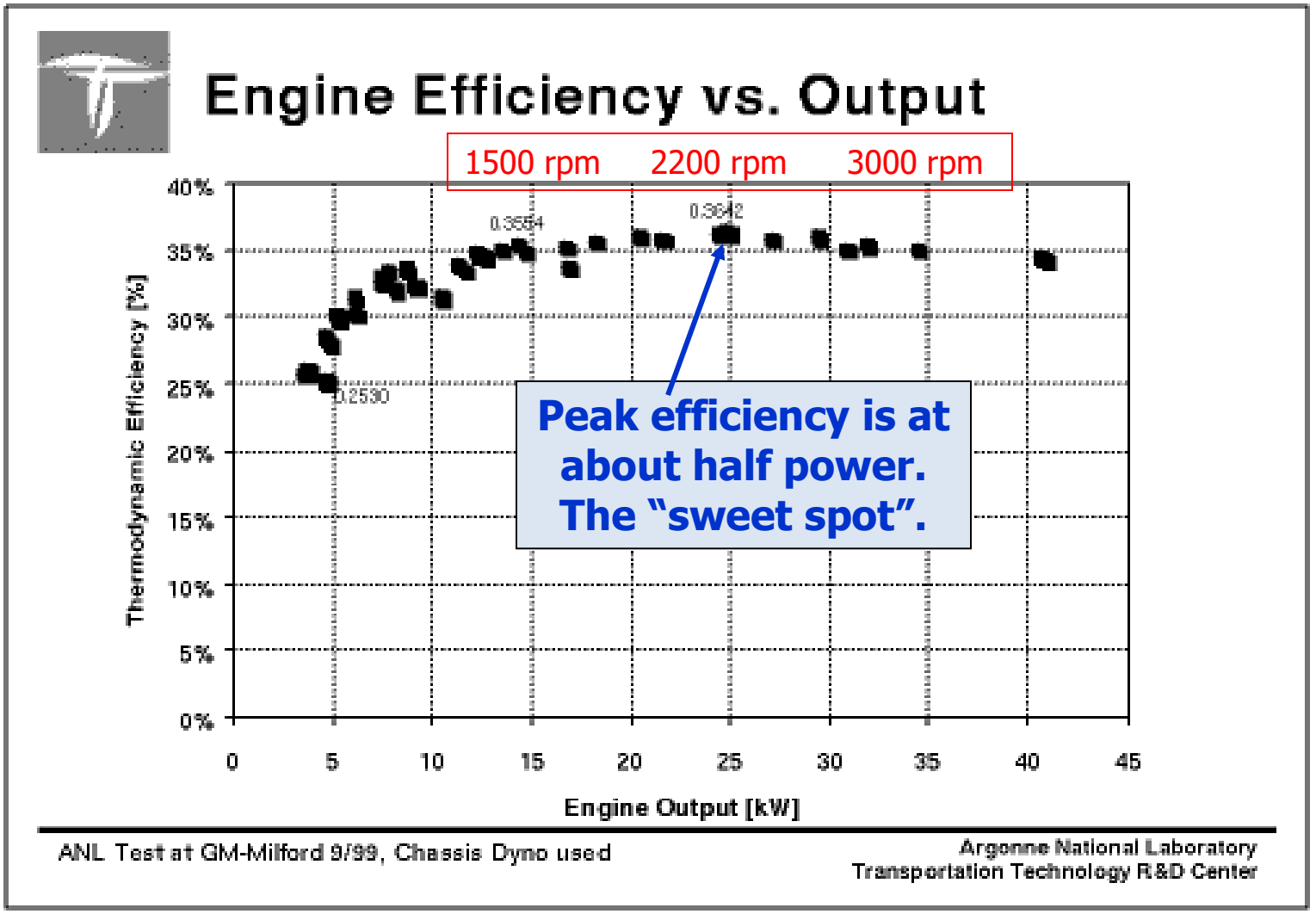
Be sure to move the motion selector back to "D" after using "B", or you will decrease the mpg for normal driving.

- When the battery is fully charged: **all battery bars are green** and you want to slow down; e.g., going down a hill.
- When a sign says "Trucks use low gear".
- When going down a steep hill and the cruise control cannot hold the car to less than 5 mph above the speed setting.

Differences in Driving a Prius

- Power button starts the hybrid system, rather than a key. The "key" fob must be somewhere in the car for "smart start" option; in the fob slot otherwise.
- Engine does not start immediately after system power is turned on; it starts about 7 seconds later to warm up the engine except in EV mode, then shuts off a few seconds later if not needed.
- Engine turns off at stops and when going down hills; also it does not provide power for backing up.
- Creep is built in at stops, provided by the electric motor. It is increased on an upward slope to hold car in place. It can be turned off by pressing the brake pedal or putting the movement selector in the **N**eutral position.
- Slight sounds occur after stopping the car as hot coolant is pumped into the thermos container.
- Electric whine during slows starts and braking.
- Special **B**rake position of movement selector to cause engine braking.

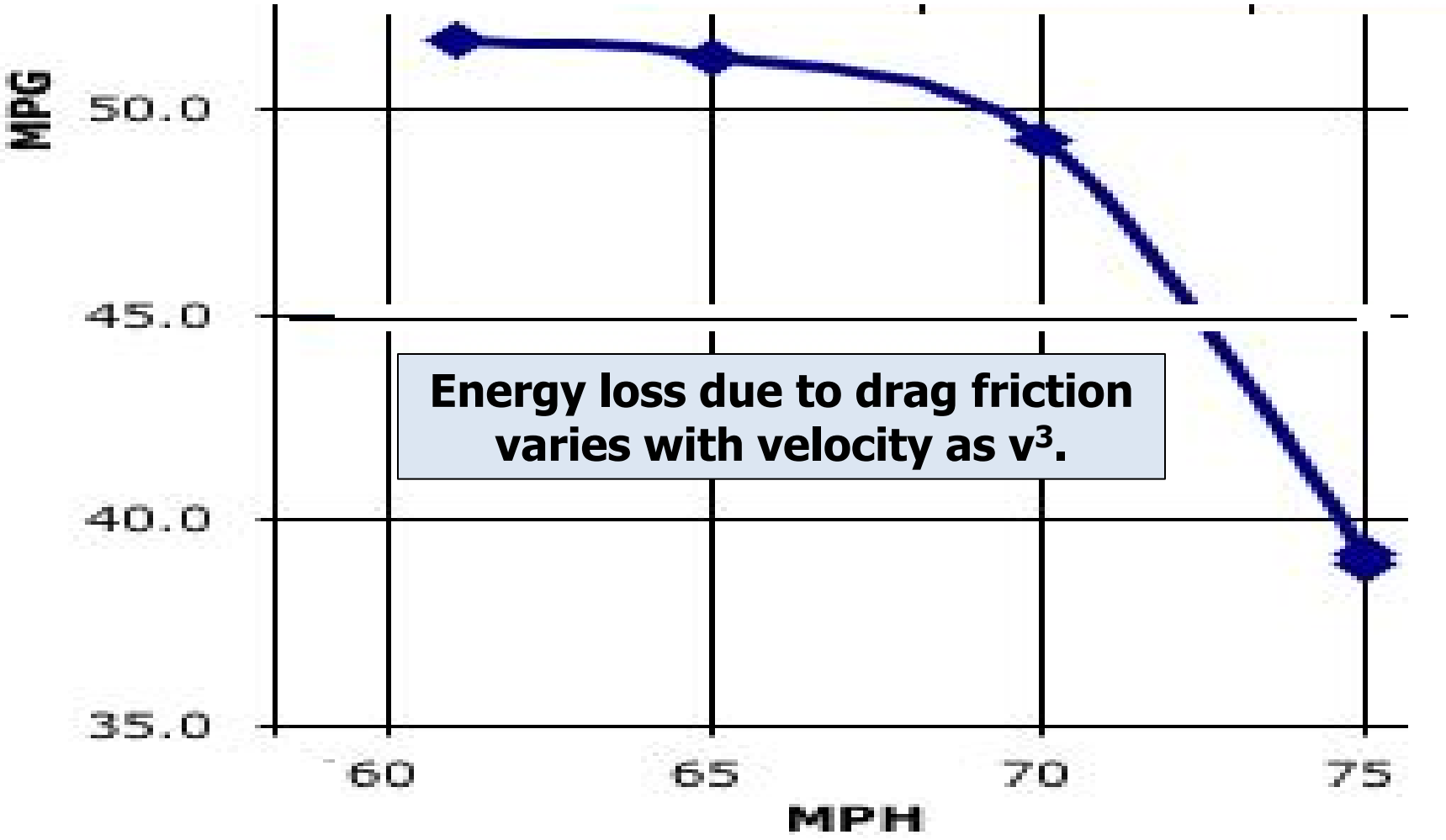
Prius I Engine Efficiency



Driving for Lowest Emissions and Highest MPG

- MPG is much lower for the first 5-10 minutes of driving, because the engine is run until it reaches the best temperature for the lowest emissions. So, **combine short-trips to save gasoline.**
- MPG, as for all new cars, increases as the miles are driven up to about 10,000 miles.
- Higher tire pressure=higher MPG.
  - **Example**: Maximum pressure for the tires=44 psi. (Standard=35 front/33 back) Should be 2 psi greater in front than in back. I used 38/36; many use 42/40.
- Use cruise control when possible to get best MPG.

MPG versus MPH for 2003-6 Prius



Note the big decrease in mpg above 70 mph!

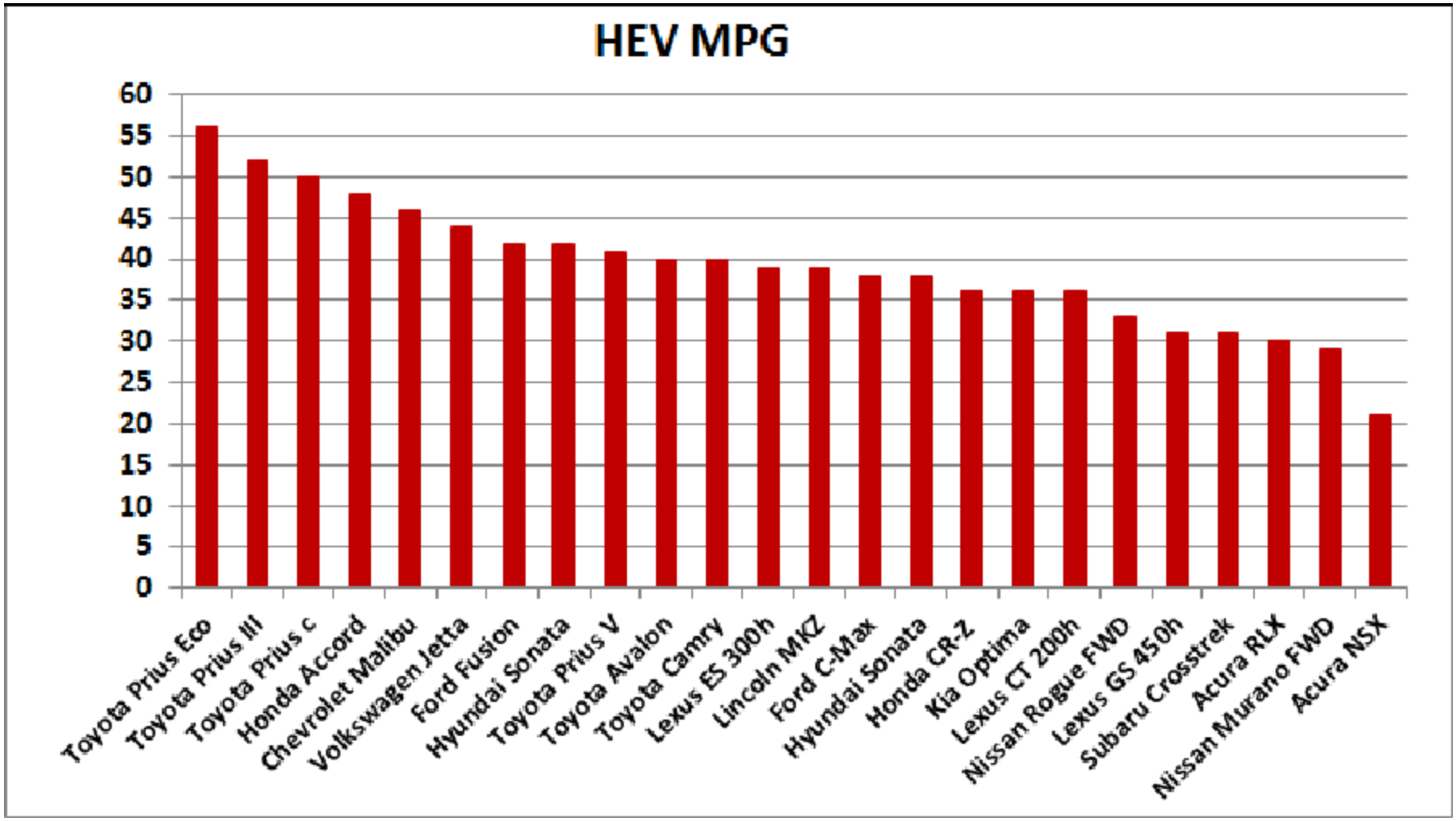
Other Hybrid Vehicles

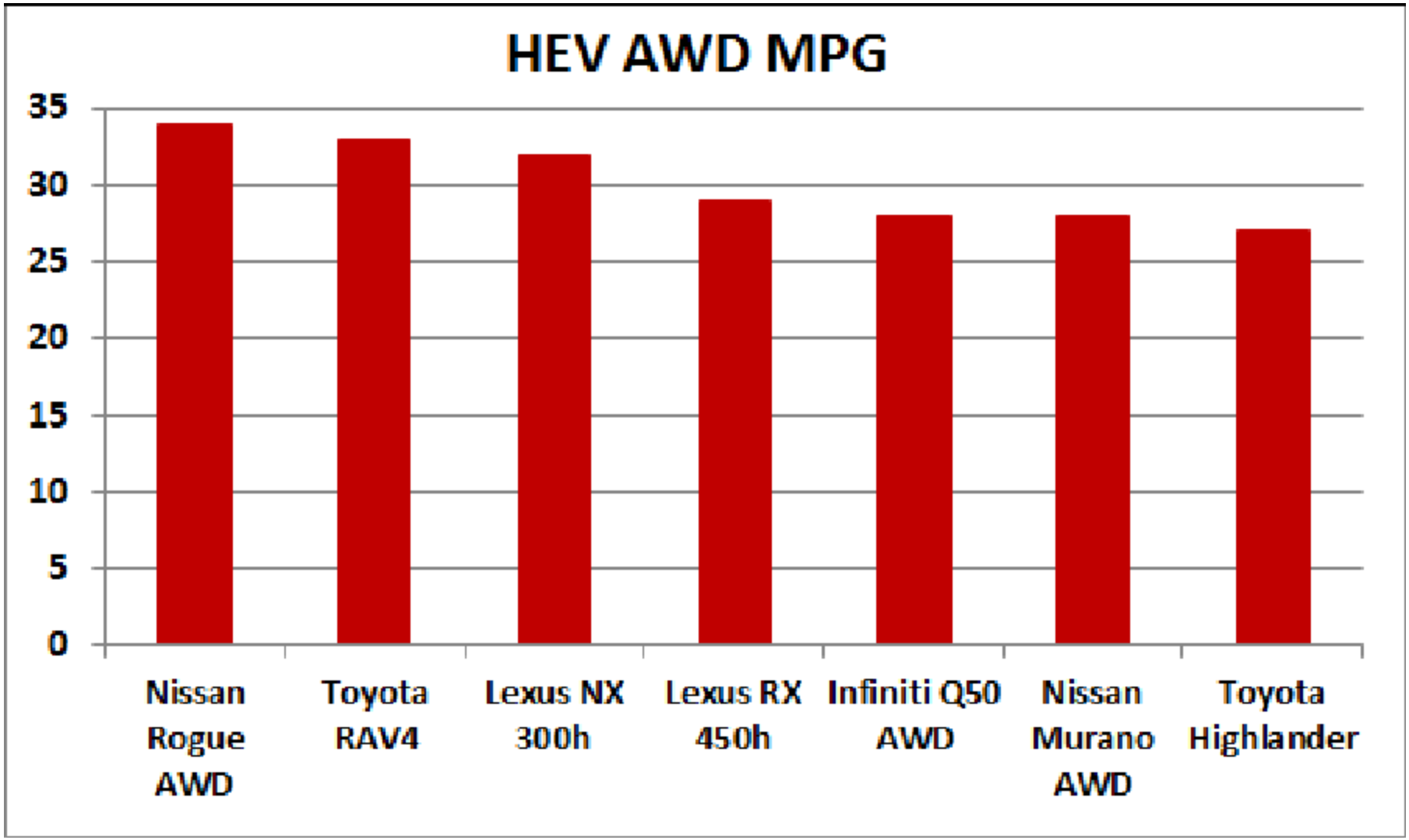
• Ford C-Max	188 hp	38 mpg	$24,170
• Ford Fusion	188 hp	42 mpg	$25,675
• Chevrolet Malibu	124 hp	46 mpg	$27,875
• Hyundai Sonata	193 hp	38 mpg	$26,000
• Hyundai Sonata	202 hp	41 mpg	$30,100
• Toyota Camry	200 hp	40 mpg	$26,790
• Toyota Avalon	200 hp	40 mpg	$38,100
• Honda Accord	212 hp	48 mpg	$29,605
• Honda CR-Z	130 hp	36 mpg	$20,295
• Kia Optima	199 hp	36 mpg	$25,995
• Subaru Crosstrek	160 hp	31 mpg	$26,395
• Lexus CT 200h	134 hp	36 mpg	$31,250
• Lexus NX 300h	194 hp	33 mpg	$39,720
• Lexus ES 300h	200 hp	39 mpg	$41,020
• Lexus GS 450h	338 hp	31 mpg	$63,080
• Lincoln MKZ	188 hp	39 mpg	$34,755

Other Hybrid Vehicles

• Volkswagen Jetta	170 hp	44 mpg	$25,560
• Toyota Highlander	280 hp	27 mpg	$47,870
• Toyota RAV4	194 hp	33 mpg	$28,370
• Nissan Rouge F/AWD	176 hp	32 mpg	$26,180
• Lexus RX 450h	308 hp	29 mpg	$52,235
• Infiniti Q50 AWD	354 hp	28 mpg	$44,400
• Toyota Prius Eco	121 hp	56 mpg	$24,685
• Nissan Murano F/AWD	250 hp	29/28 mpg	$30,680
• Acura RLX	377 hp	30 mpg	$55,390
• Acura NSX	573 hp	21 mpg	$157,000
• Kia Niro	139 hp	49 mpg	$23,800
• Hyundai Ioniq Hybrid	139 hp	55 mpg	$22,200
• Honda CR-V Hybrid SUV	?	?	?

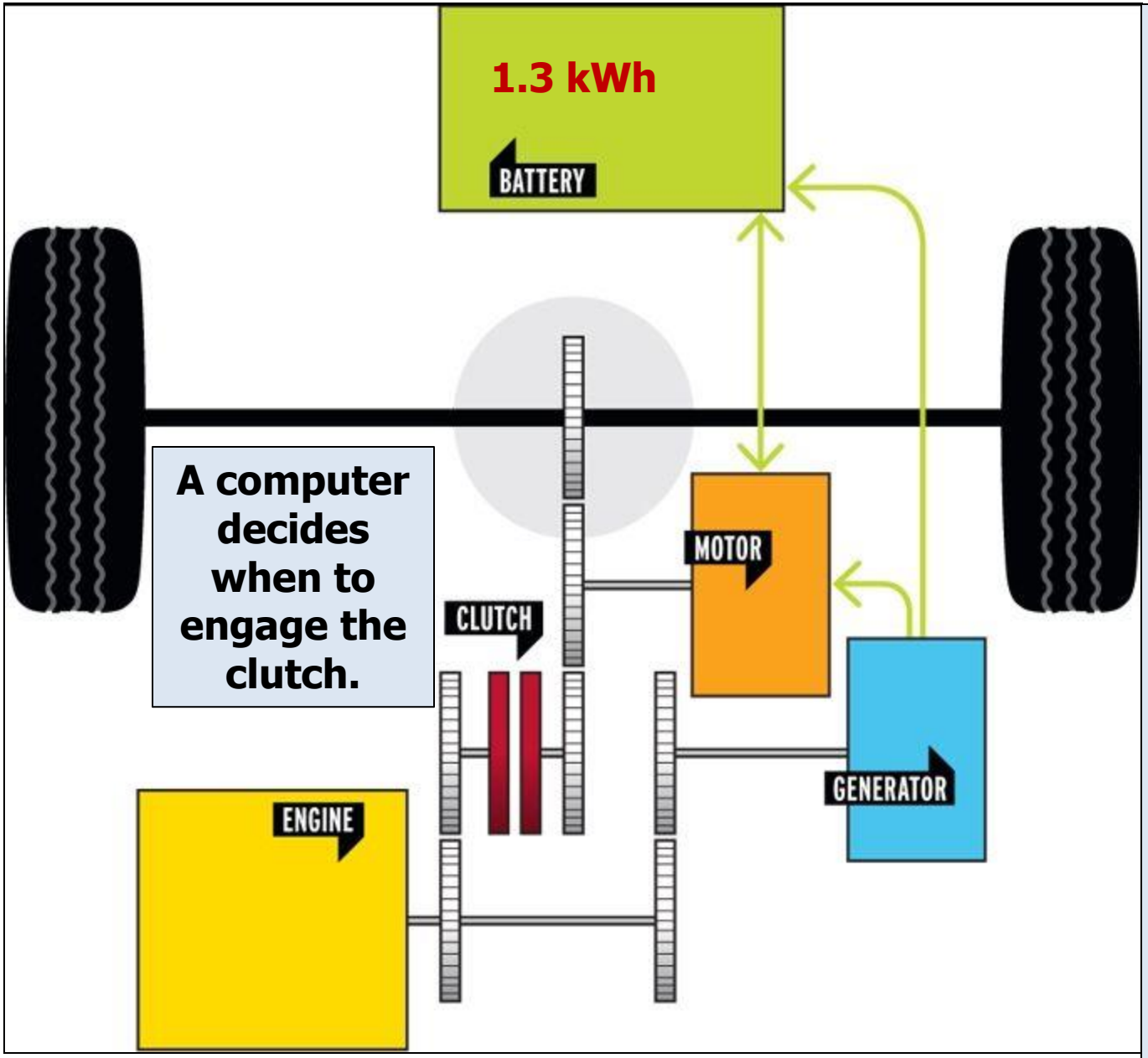
Latest ones have Lithium-Ion battery instead of NiMH battery.


HEV MPG
60
55
50
45
40
35
30
25
20
15
10
5
0
Toyota Prius Eco
Toyota Prius III
Toyota Prius c
Honda Accord
Chevrolet Malibu
Volkswagen Jetta
Ford Fusion
Hyundai Sonata
Toyota Prius V
Toyota Avalon
Toyota Camry
Lexus ES 300h
Lincoln MKZ
Ford C-Max
Hyundai Sonata
Honda CR-Z
Kia Optima
Lexus CT 200h
Nissan Rogue FWD
Lexus GS 450h
Subaru Crosstrek
Acura RLX
Nissan Murano FWD
Acura NSX



More HEVs with AWD coming soon.

Honda Accord Hybrid System



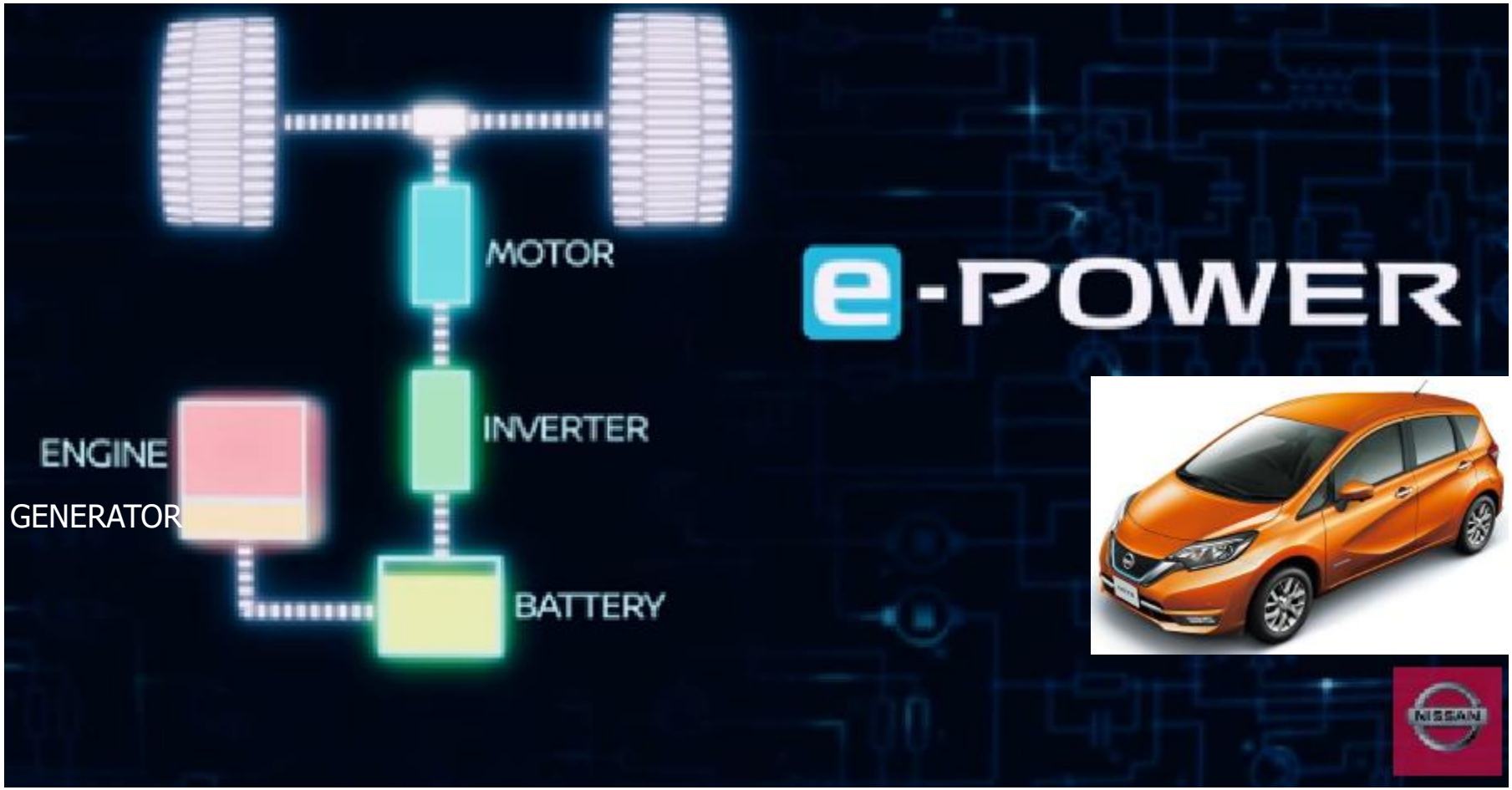
Has one electric motor (orange) and a smaller generator (blue) & a "computer clutch" (red).

Clutch engaged: engine & motor drive wheels & engine/generator charges battery & powers motor (Parallel Hybrid).

Clutch disengaged: Only motor drives wheels (EV: engine off; Series Hybrid: engine/generator charges battery & powers motor).

Nissan Note e-Power Hybrid System

Series Hybrid



Battery: 1.5 kWh, ~58 mpg

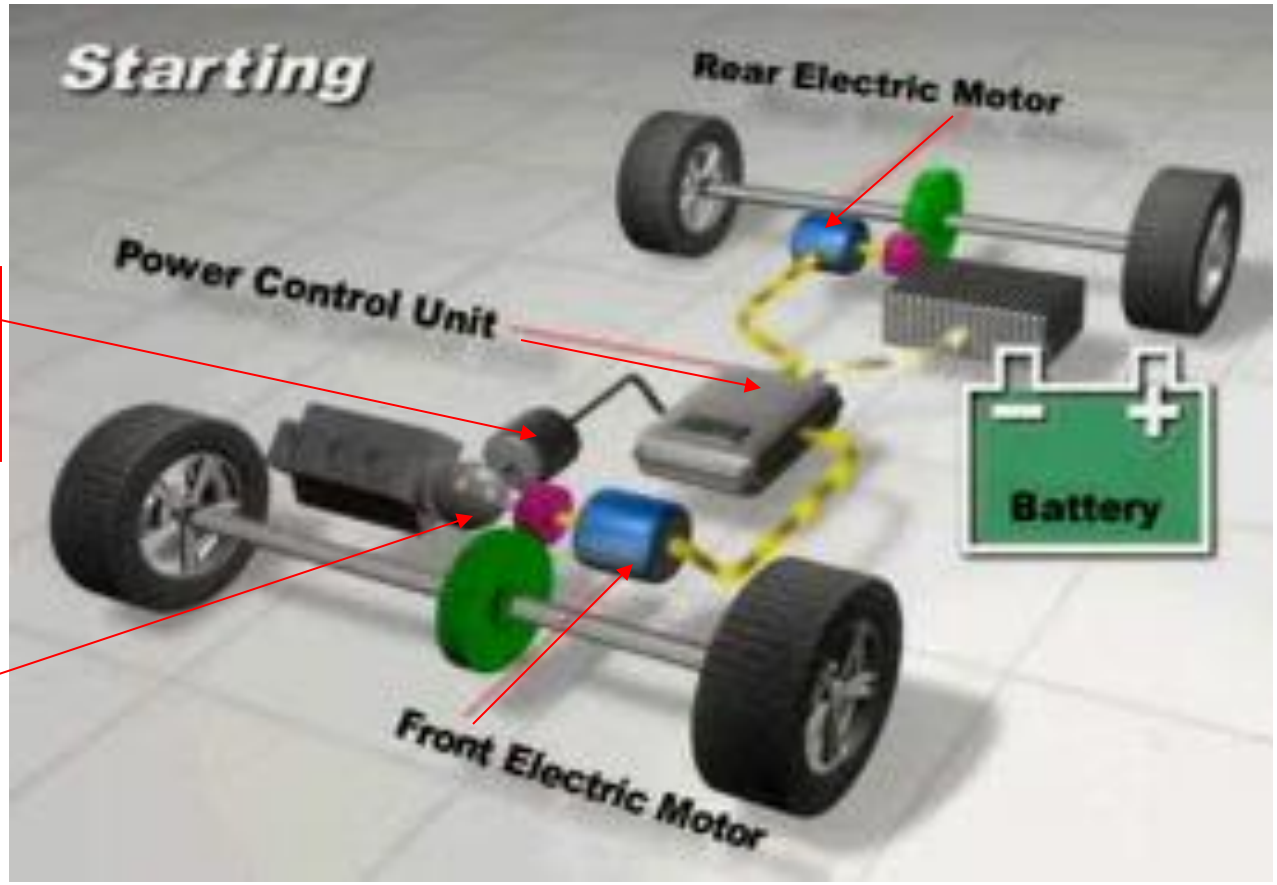
Outselling Prius in Japan!

Not in U.S. yet except as gasoline Versa Note.

AWD Lexus, Highlander & RAV4 Power Train

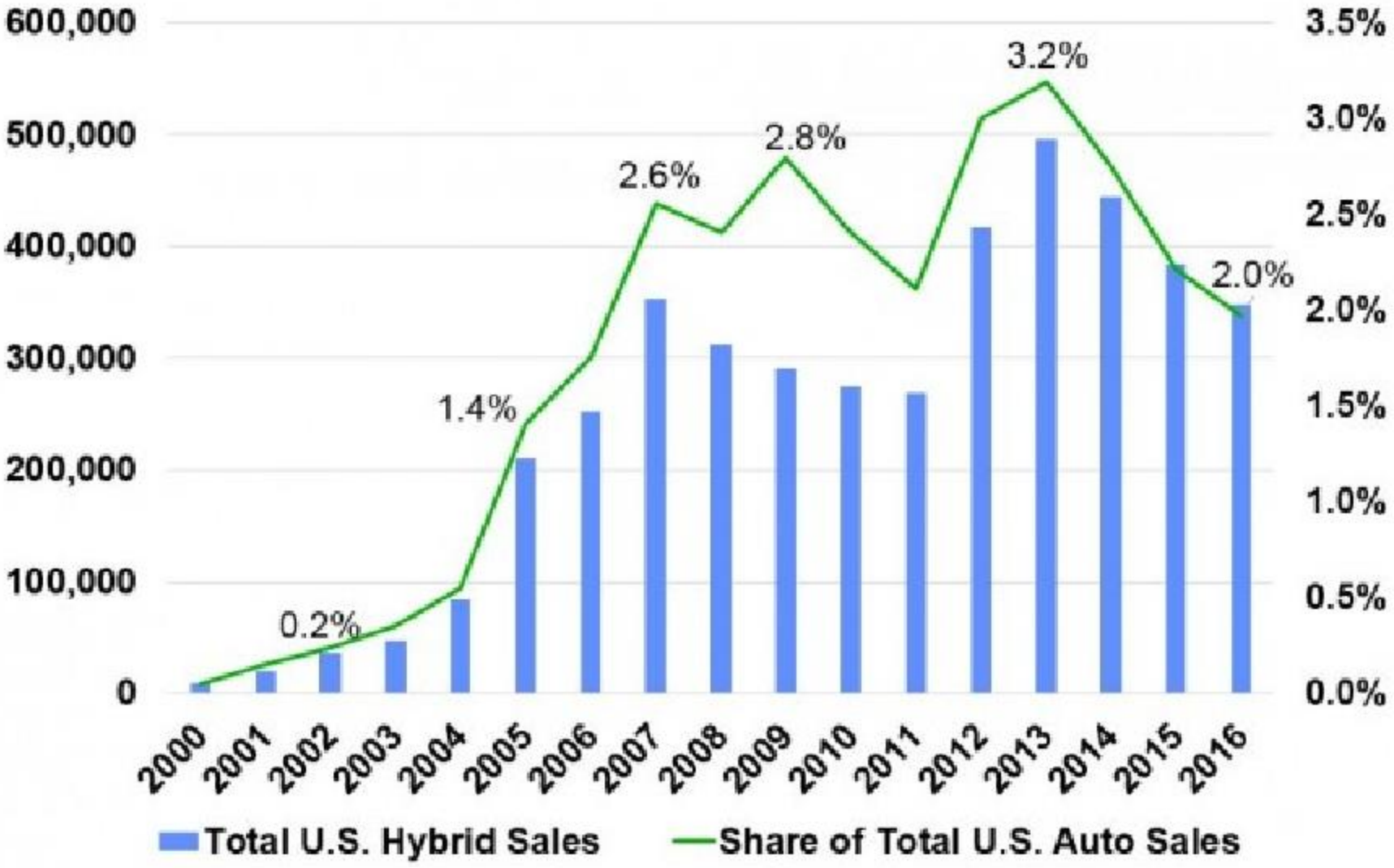
Small generator/ motor MG1

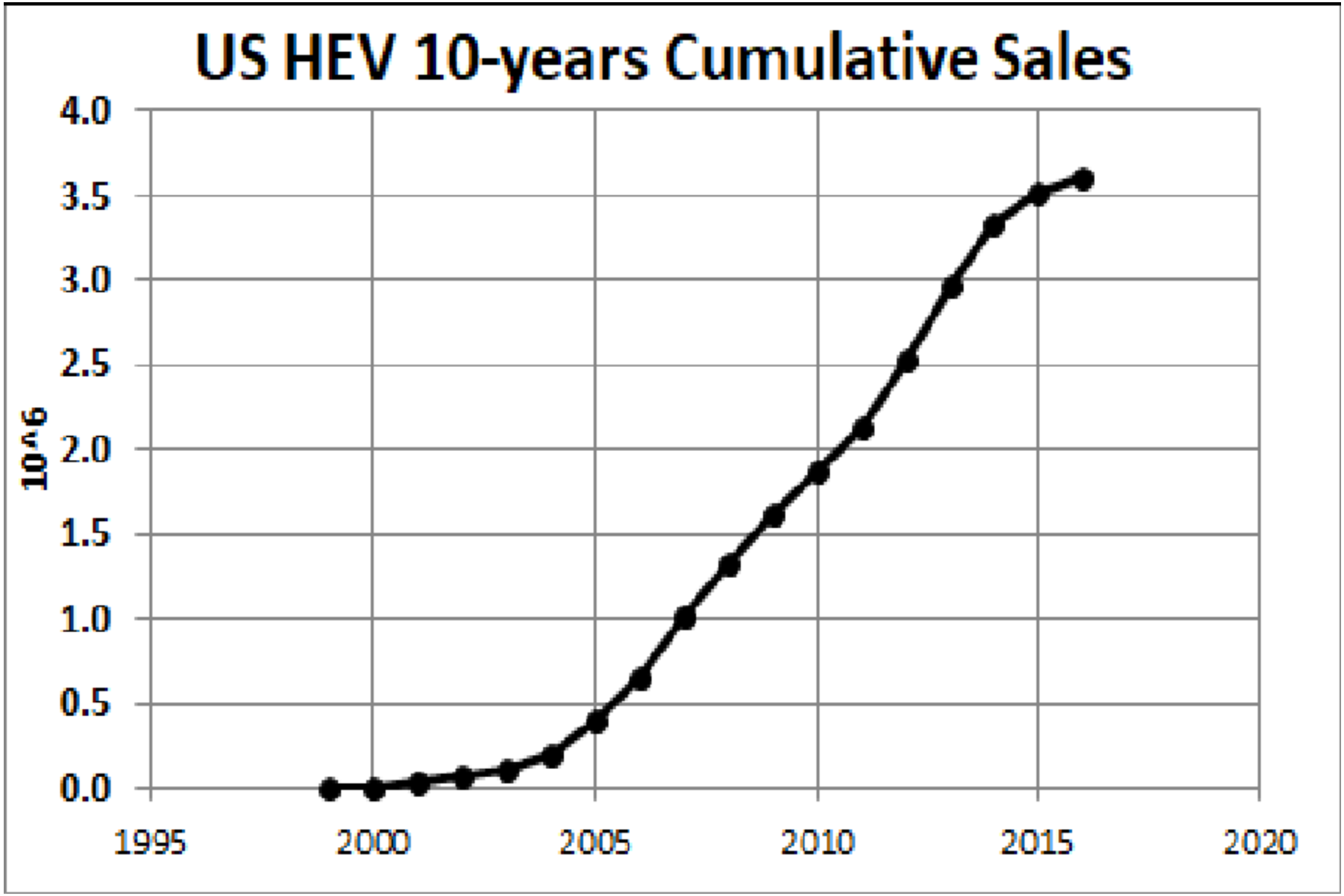
Power Split Devices



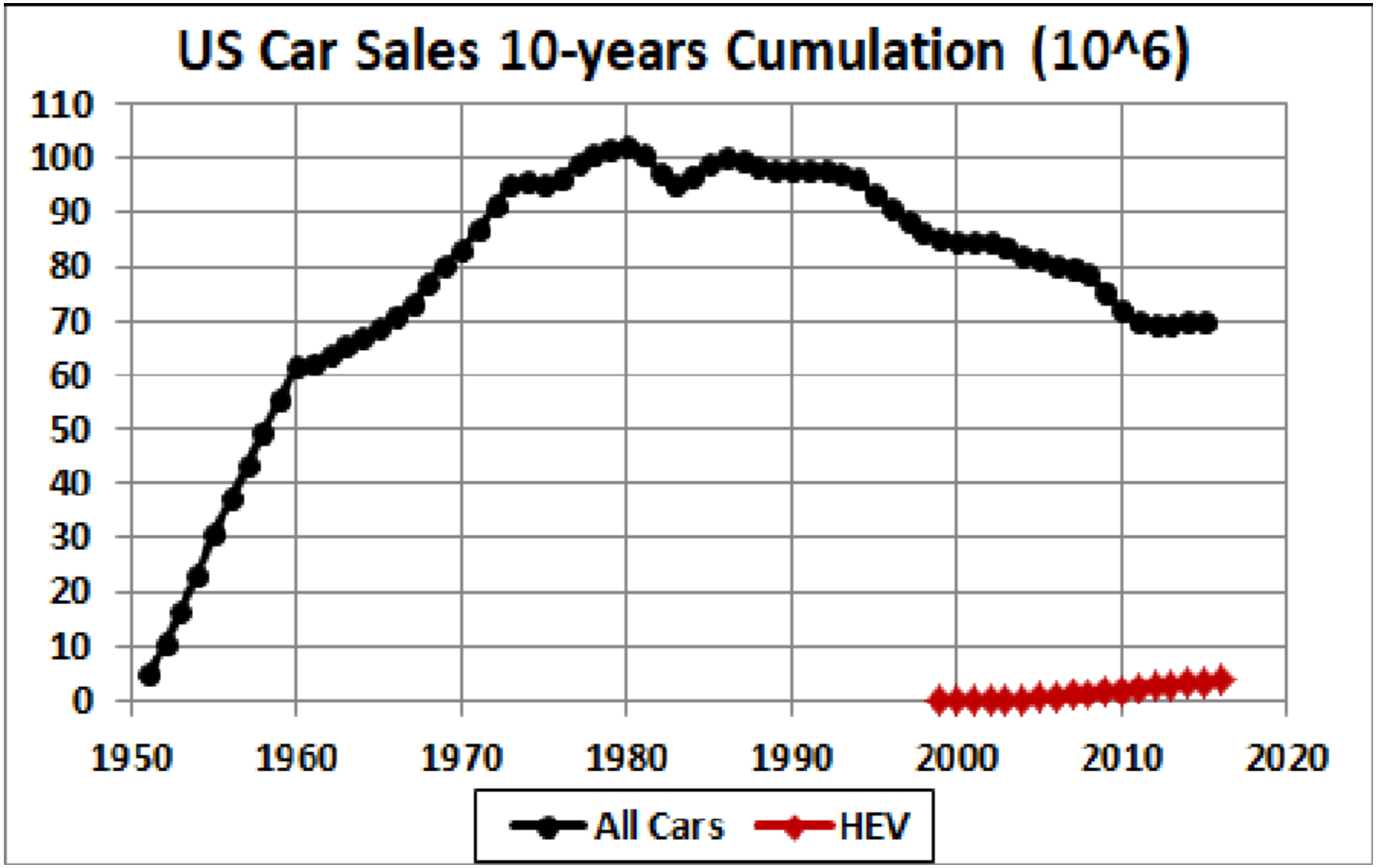
The rear electric motor has no mechanical connection to the front hybrid system (split drive train). It is totally controlled electronically. It operates during backup, high acceleration (linear or circular), when front wheels slip and during braking regeneration.

U.S. Hybrid Vehicle Market – Total Sales and Market Share, 2000-2016




US HEV 10-years Cumulative Sales
10^6
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1995
2000
2005
2010
2015
2020

All Cars & HEV Vehicles Sales for 10/year Periods



Other Energy Storage Methods for Hybrid Vehicles

- Hydraulic: pressure storage tank and a pump/motor. See http://en.wikipedia.org/wiki/Hydraulic_accumulator
- Flywheel: rotational energy storage. See http://en.wikipedia.org/wiki/Flywheel_power_storage Can capture more energy (~80%) by regenerative braking.
- Ultra-capacitors: electrical energy storage in carbon aerogel. See http://en.wikipedia.org/wiki/Aerogel

Why Did I Buy Hybrid Cars?

- To **emit fewer pollutants** and use less fuel when I drive.
- To be able to drive longer without refueling. Gasoline is going to be harder to find in the future.
- To put one more hybrid car on the road.
- To encourage car manufacturers to make more hybrid cars.
- To learn about hybrid cars so that I can encourage more buyers to buy them.

5 Steps to Hybridization

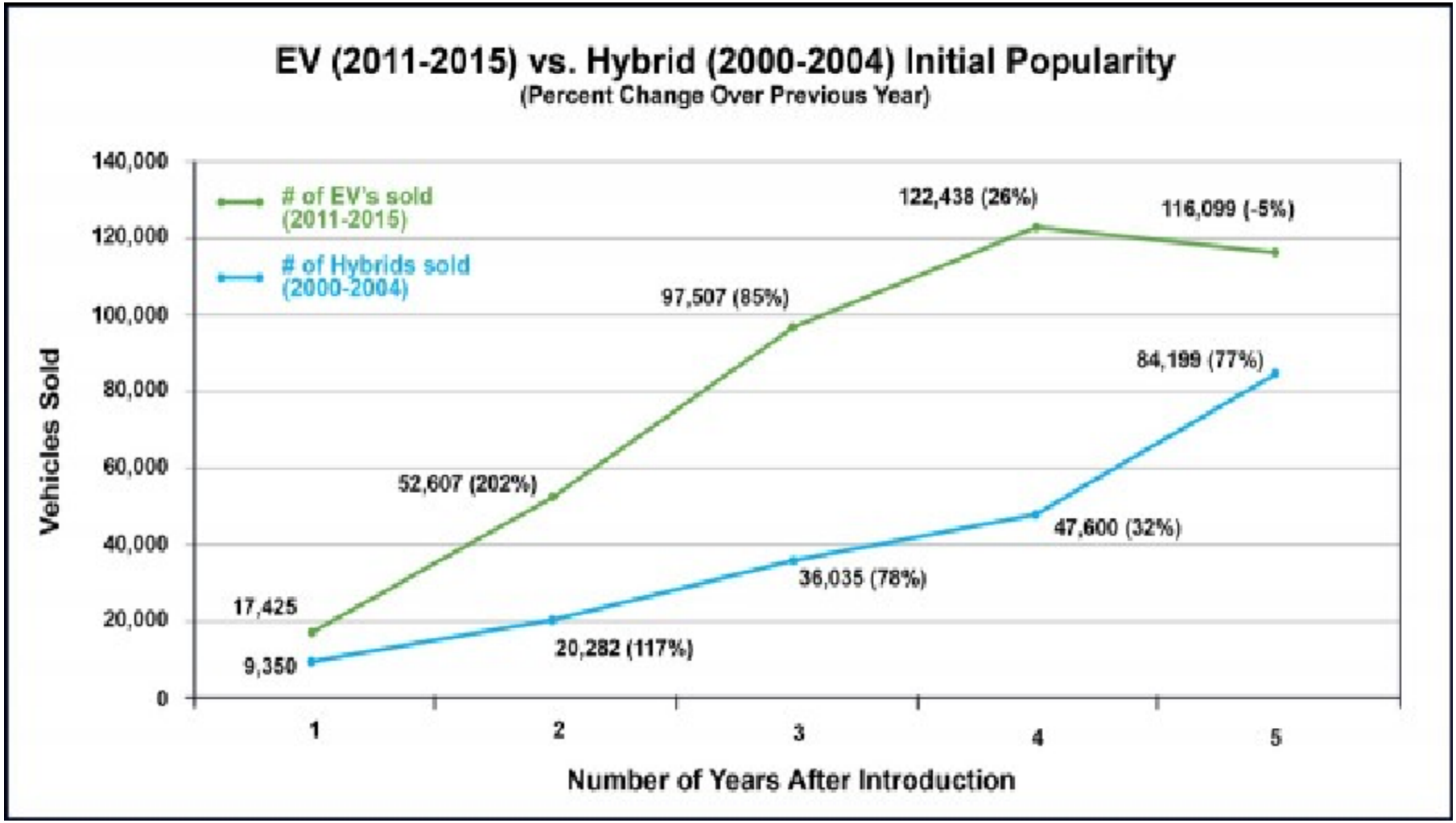
- Idle and slow-speed engine off
- Regenerative braking
- Motor power assist and clean/efficient engine downsizing (mild hybrid)
- Electric-only drive option (full hybrid)
- Extended battery-electric range (plug-in hybrid) (Hybrids run on electric power only about 10% of the time.)

http://www.hybridcenter.org

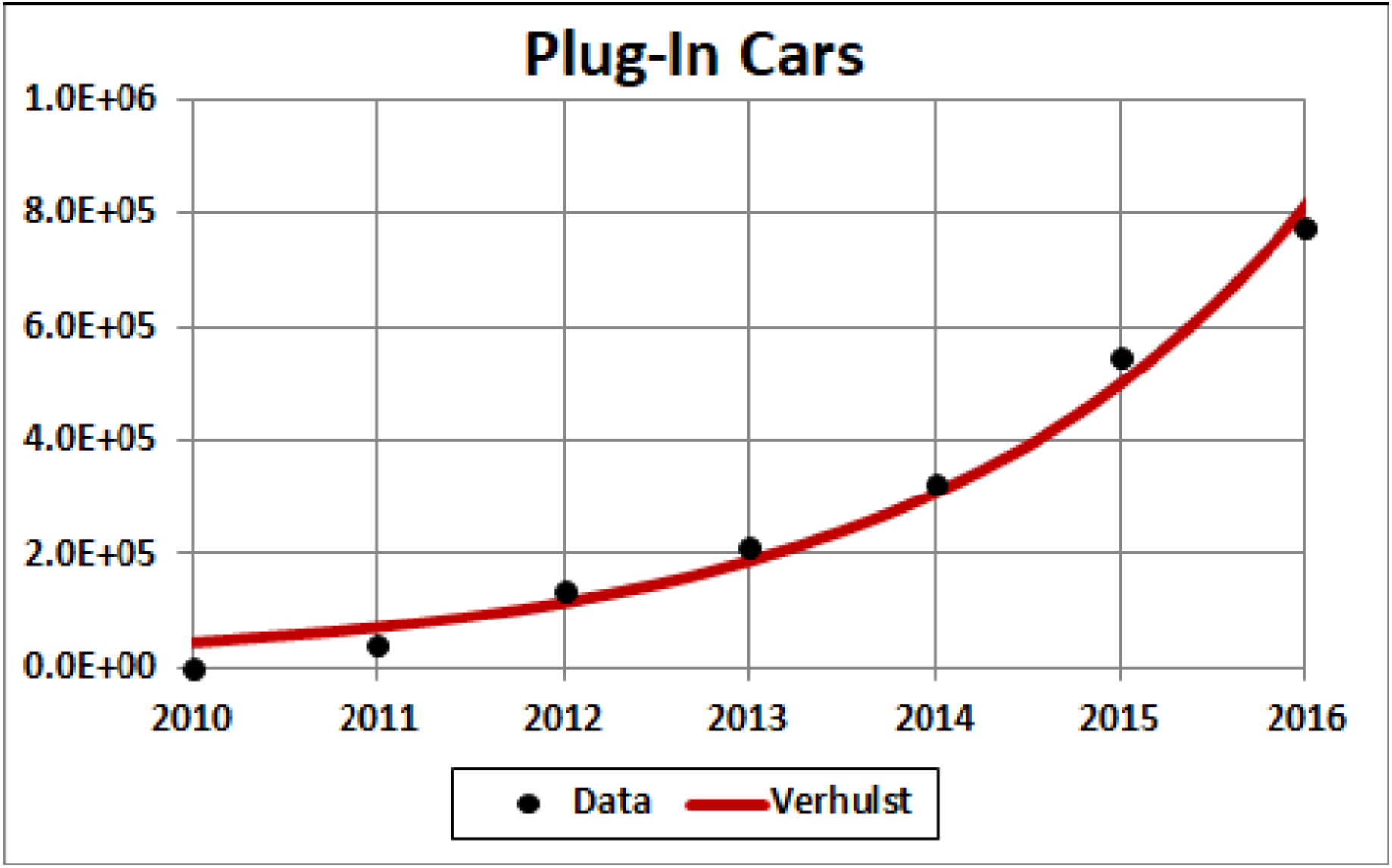
Hybrids, Greenhouse Gases & National Grid

- Hybrid vehicles reduce greenhouse gases by 22% compared to gasoline vehicles.
- Plug-In hybrid vehicles reduce greenhouse gases by 36%, assuming 50-60% coal power plants.
- Full electric vehicles reduce greenhouse gases by 67%, assuming 50-60% coal power plants.
- The last two could be greatly increased by cleaner coal power plants.
- The last could be no emissions with solar.

Plug-In Sales Grew Faster than Hybrid Sales Did in U.S. in First 5 Years after Introduction



Exponential Rise of World Plug-ins (BEVs & PHEVs)



Doubling time = ~1.4 years.