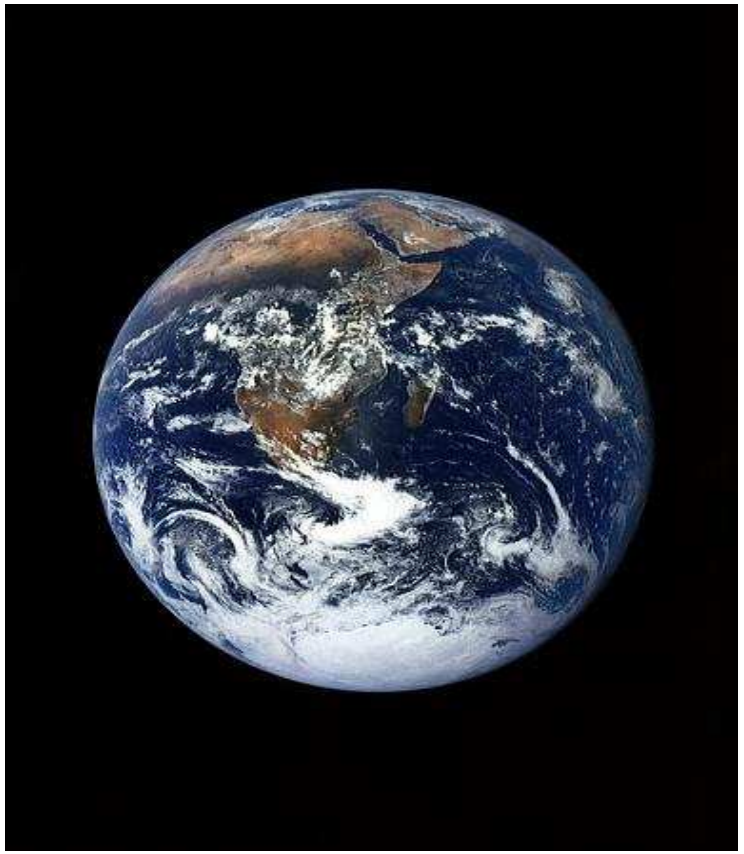
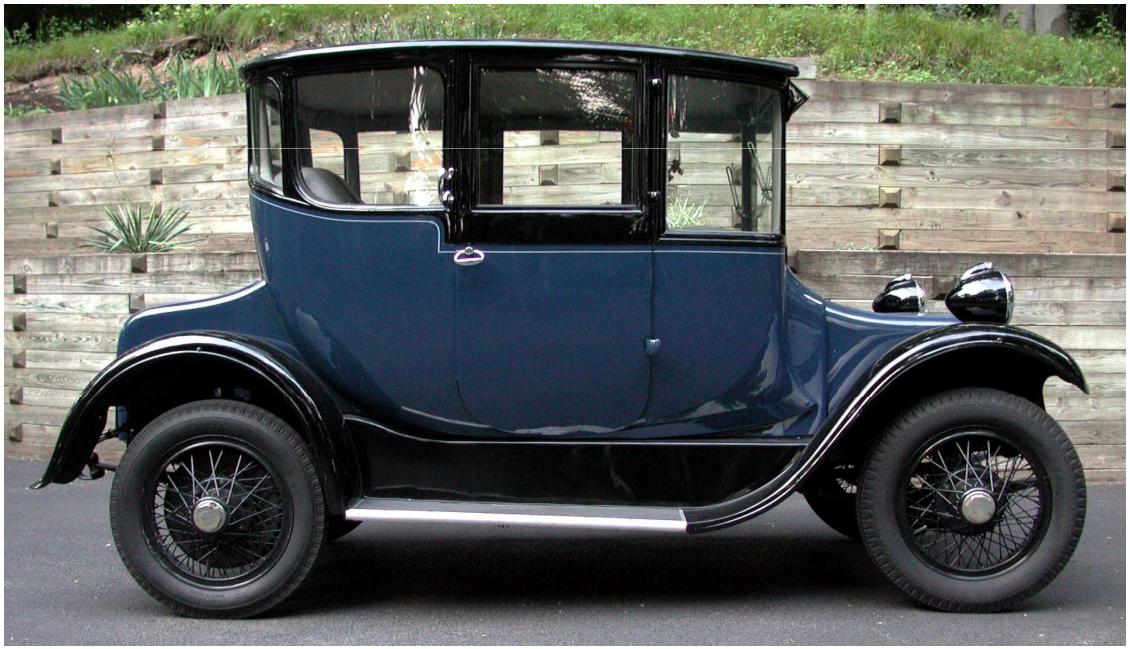
Lecture Content

- Electric Vehicles Lecture:
  - History of EV's
  - Motivation to EV
  - EV / HEV
  - Energy Storage
  - Example
  - Battery Disposal



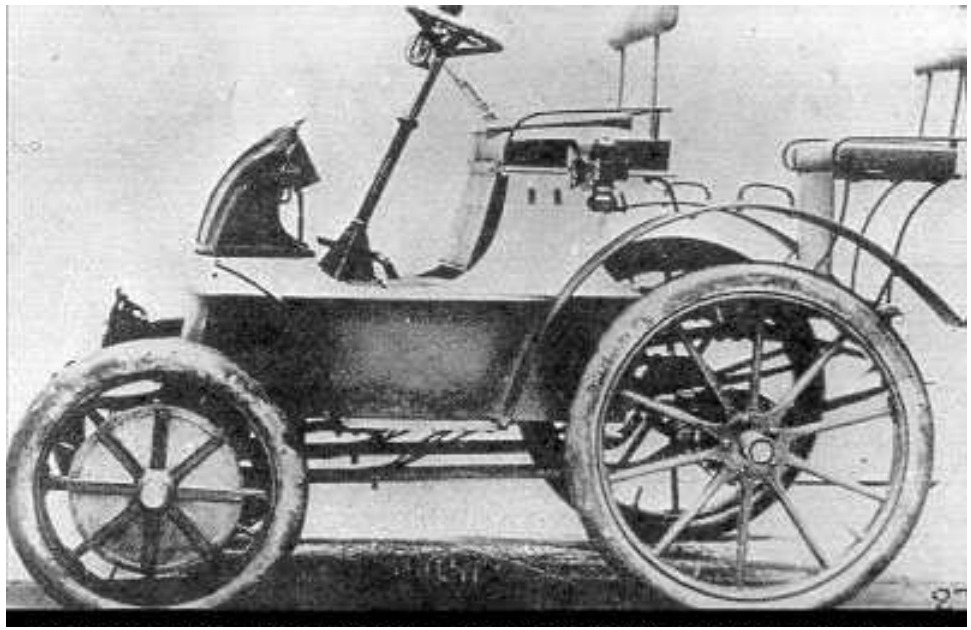
Early Electric Cars

- Electric vehicles are clean and easy to use.
- Low maintenance, available infrastructure.
- Electric motors were easy to control.
- Motors have high power-to-weight ratio.
- 1914 Detroit Electric car.
- Limited range.



Early Hybrid Cars

- The advantages of electric drives are substantial, but range is a challenge.
- Hybrids can deliver energy for long intervals.
- Retain the reliability and ease-of-use advantages of electric cars.
- The 1900 Porsche hybrid.

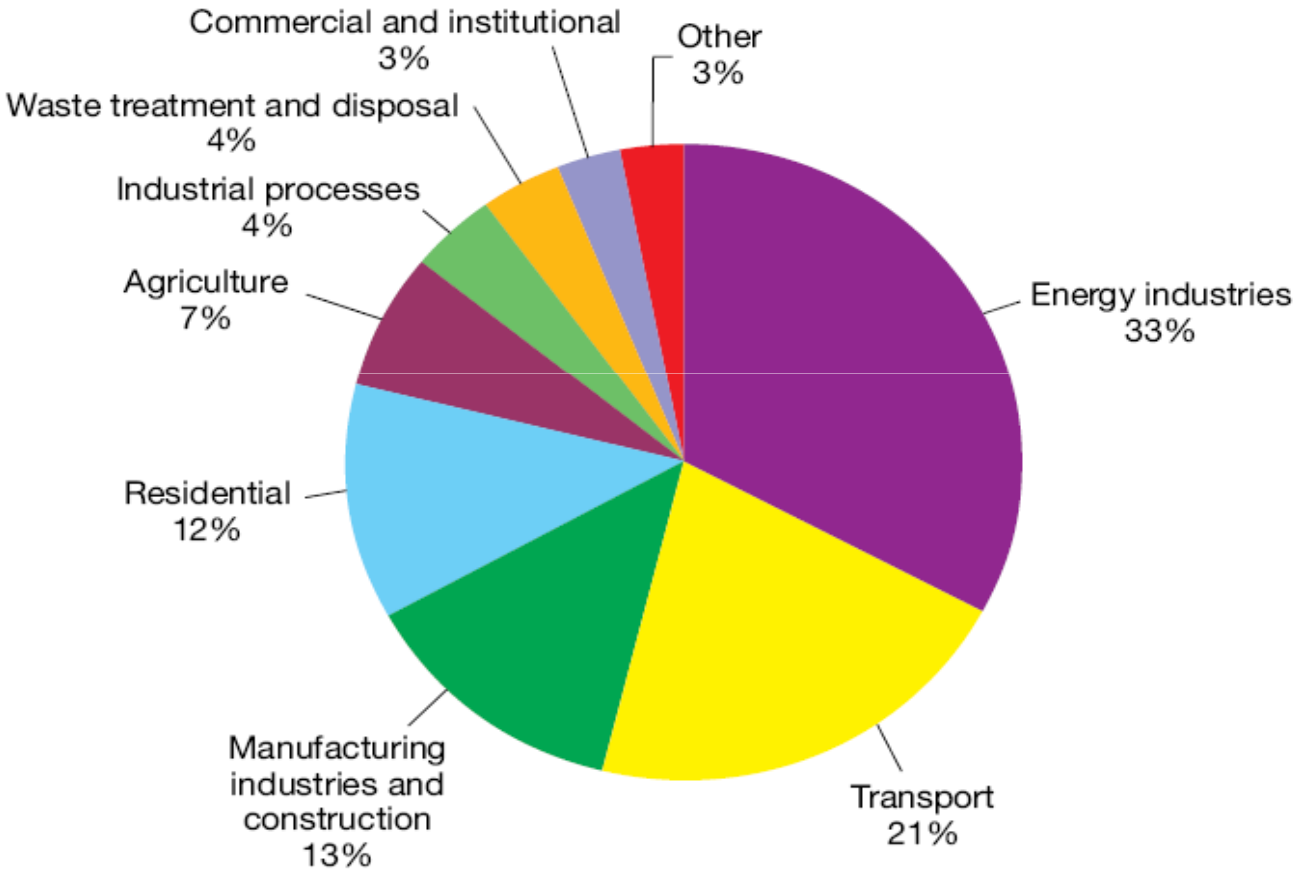


Petrol Car Culture

- The Ford Model T in 1909 made cars affordable. Original list price: US$290.
- Petrol was a waste product of oil refining.
- Low-cost mass production, low fuel costs, and performance limits helped fuel-driven cars overtake electric cars by 1920.
- Reliability has been improving continuously for fuel vehicles.
- There was little change in *electric* car technology until the 1960s.

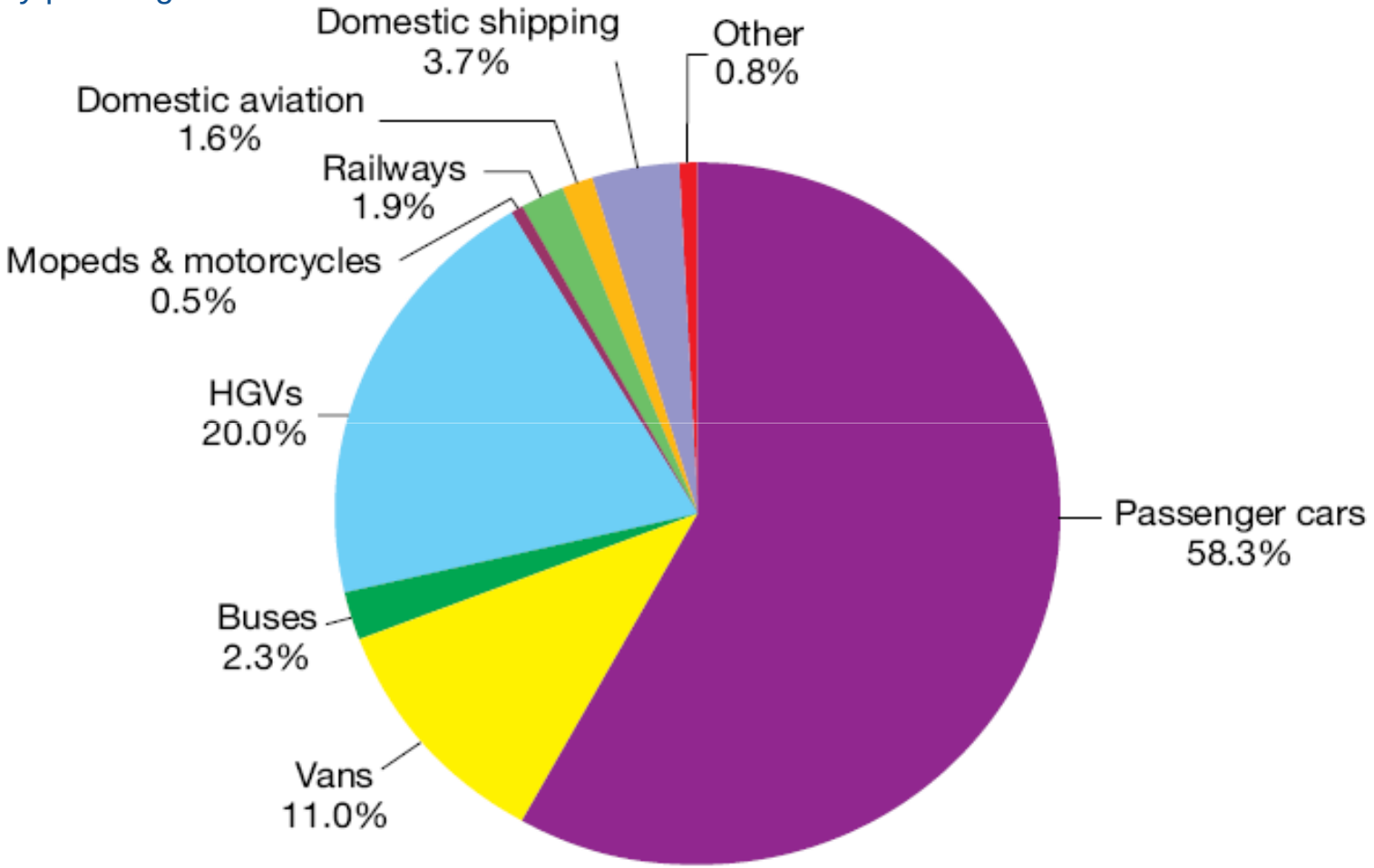
UK CO_2 Emissions

- A carbon reduction strategy for transport to meet the overall Climate Change Act target of 80% reduction in CO2 by 2050
  - Transport accounts for 21% of UK CO2 emissions



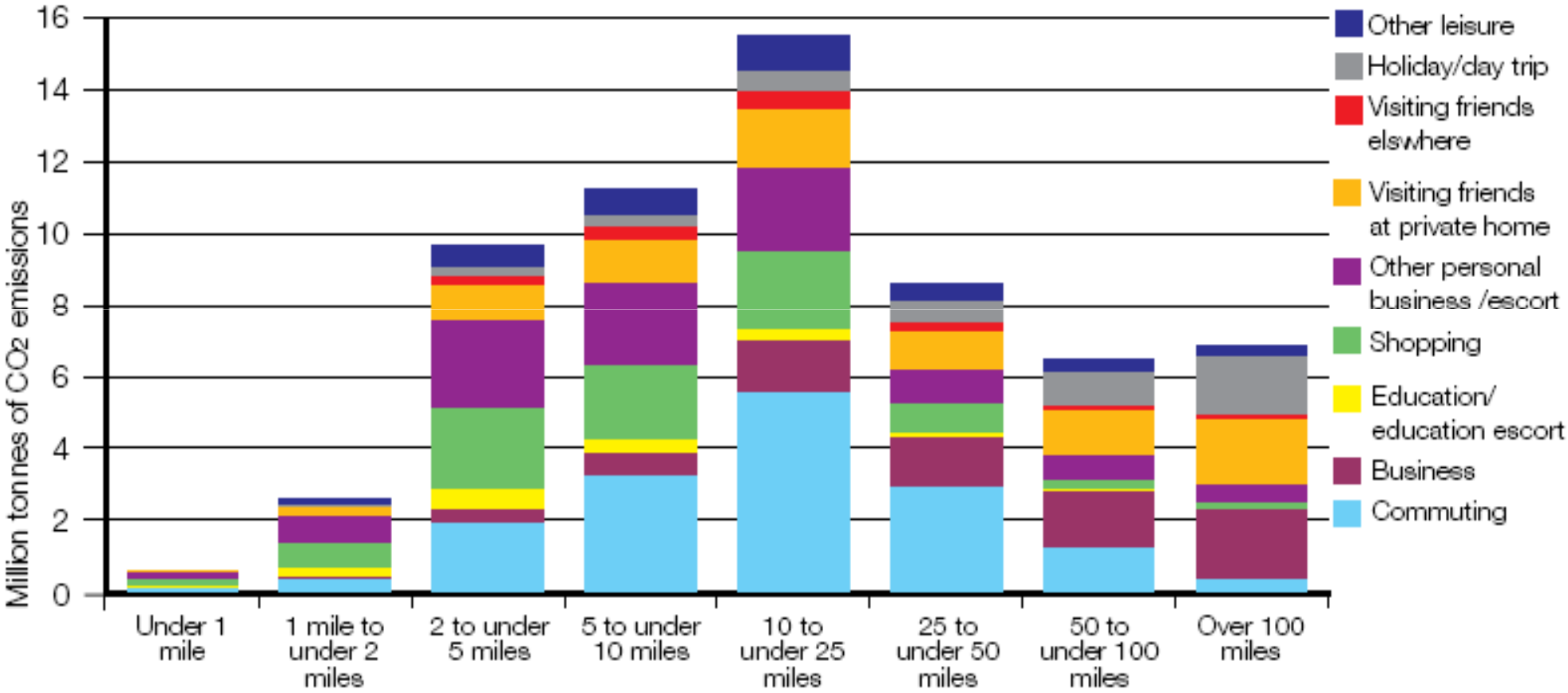
..of the 21% of Transport Emissions

- Road travel accounts for 92% of the transport sector's greenhouse gas emissions. 58% of emissions provided by passenger cars



Private Car Usage

- 77% of passenger car emissions are produced by journeys under 50 miles
- 88% of passenger car emissions are produced by journeys under 100 miles



Motives for Electric Vehicles

- Energy flexibility.
- Energy efficiency.
- Reduced emissions.
- Cleaner, quieter cars without performance changes.
- For electric cars, the ultimate fuel source is hydro, wind, nuclear, or any electricity source.
- Emissions are eliminated, or moved to a central plant where large-scale control is possible.

Emission Improvements

An HEV has at least five characteristics that reduce emissions:

1. The engine is smaller since the electric motor does some of the work, especially during peaks.
2. The engine can shut off when the car stops.
3. We can choose to operate the engine only at its highest efficiency.
4. The electrical system can be used to prepare emission controls for cold starts.
5. Braking energy can be recovered and stored in the batteries.

Efficiency and Emission Improvements

- Efficient engines not good for direct use can be installed.
  - Atkinson cycle
  - Brayton cycle (turbines)
- The Prius achieves about 90% reduction in exhaust emissions, with no sacrifice in performance.
- Large improvements in hydrocarbons and carbon monoxide.
- Possibility of zero-emission electric operation.

Electric Vehicle Emissions Aspects

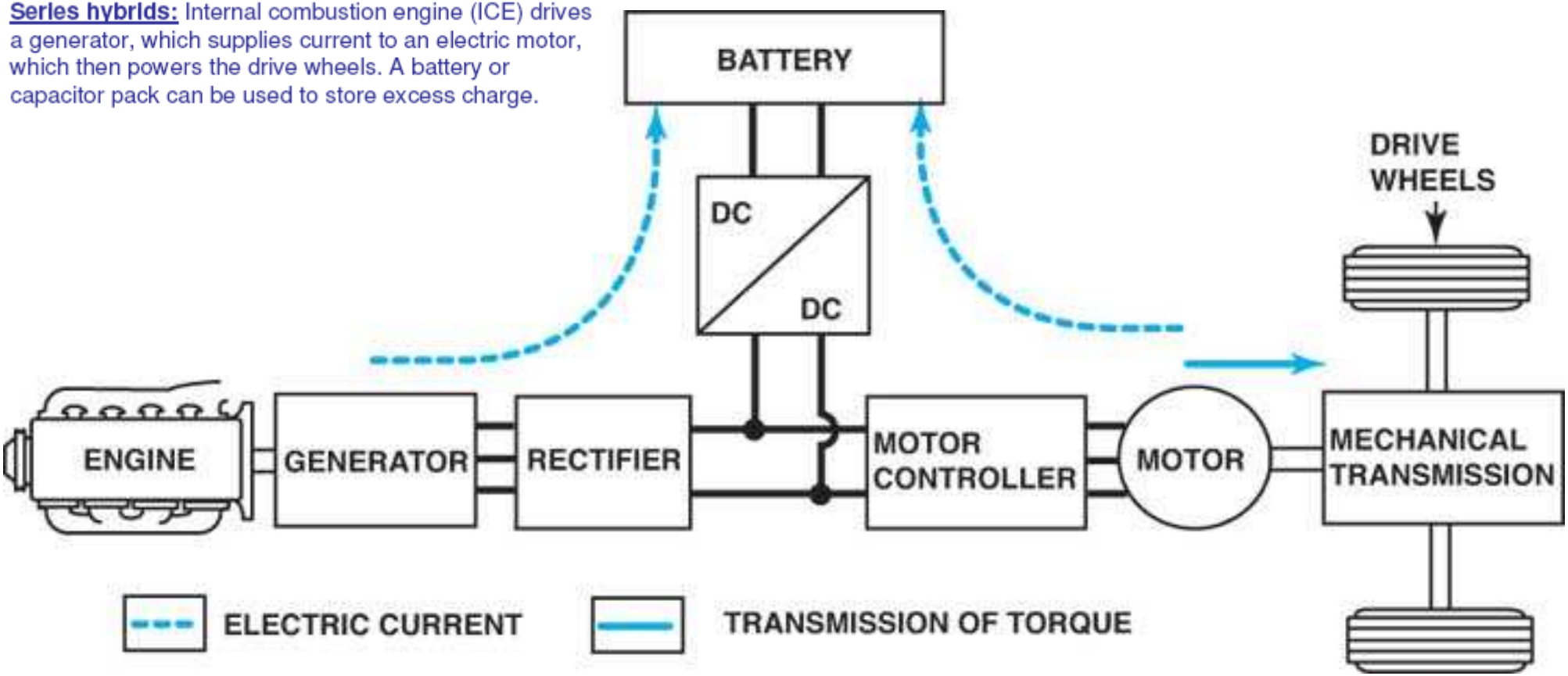
- "Just" moves emissions to a power plant.
- But:
  - Opportunity for large emission control infrastructure
  - Resource flexibility
- Higher overall system efficiency.

Classification of HEVs

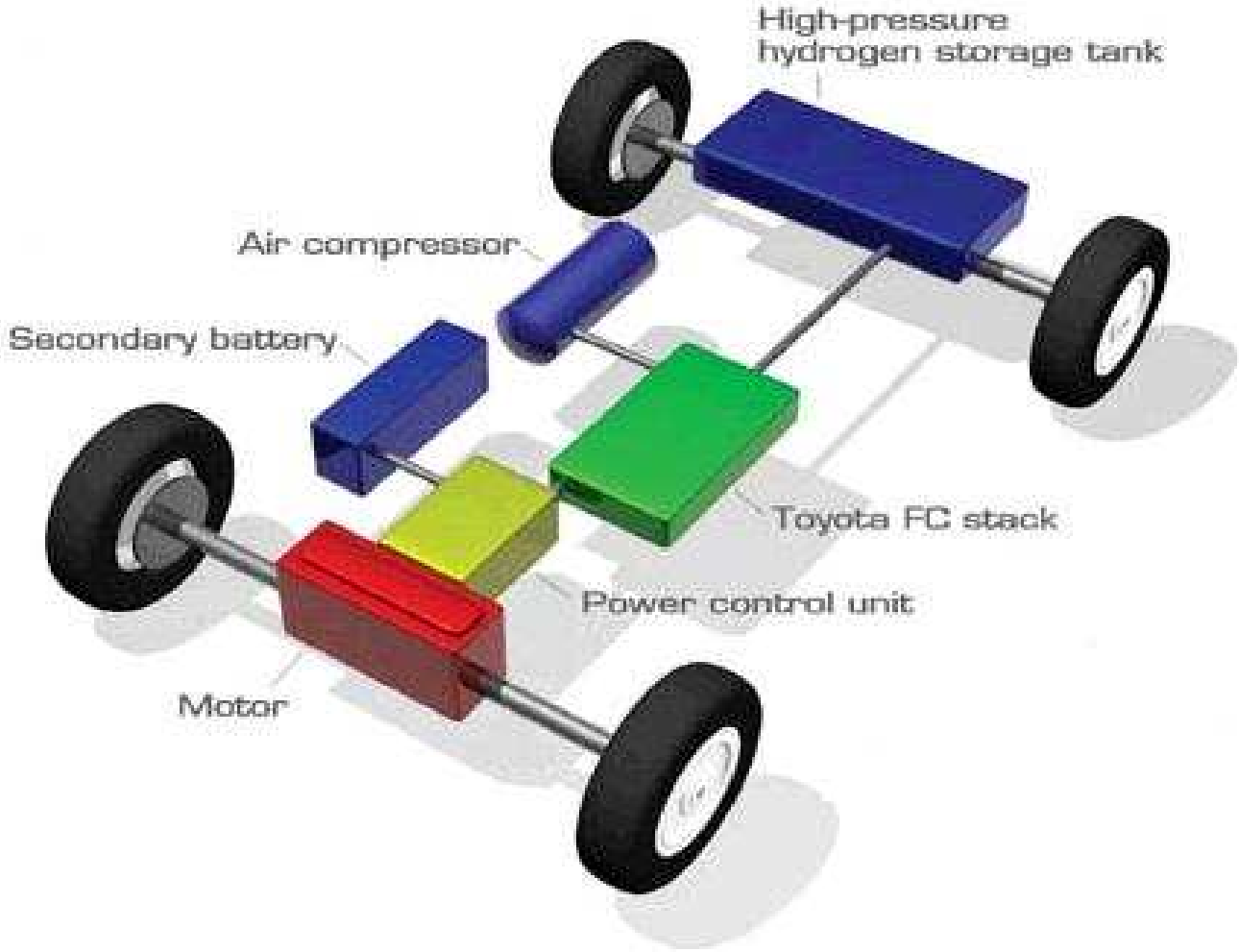
- The types of hybrid-electric vehicles can generally be split into:
  - Series Hybrid
  - Parallel Hybrid
- Also have:
  - Full Hybrid: Can move solely on electric power
  - Mild Hybrid: Requires at least some gasoline to power the transmission
  - Stop-Start Hybrids: Use electric power only while idling or during vehicle deceleration

Series HEVs

Series hybrids: Internal combustion engine (ICE) drives a generator, which supplies current to an electric motor, which then powers the drive wheels. A battery or capacitor pack can be used to store excess charge.

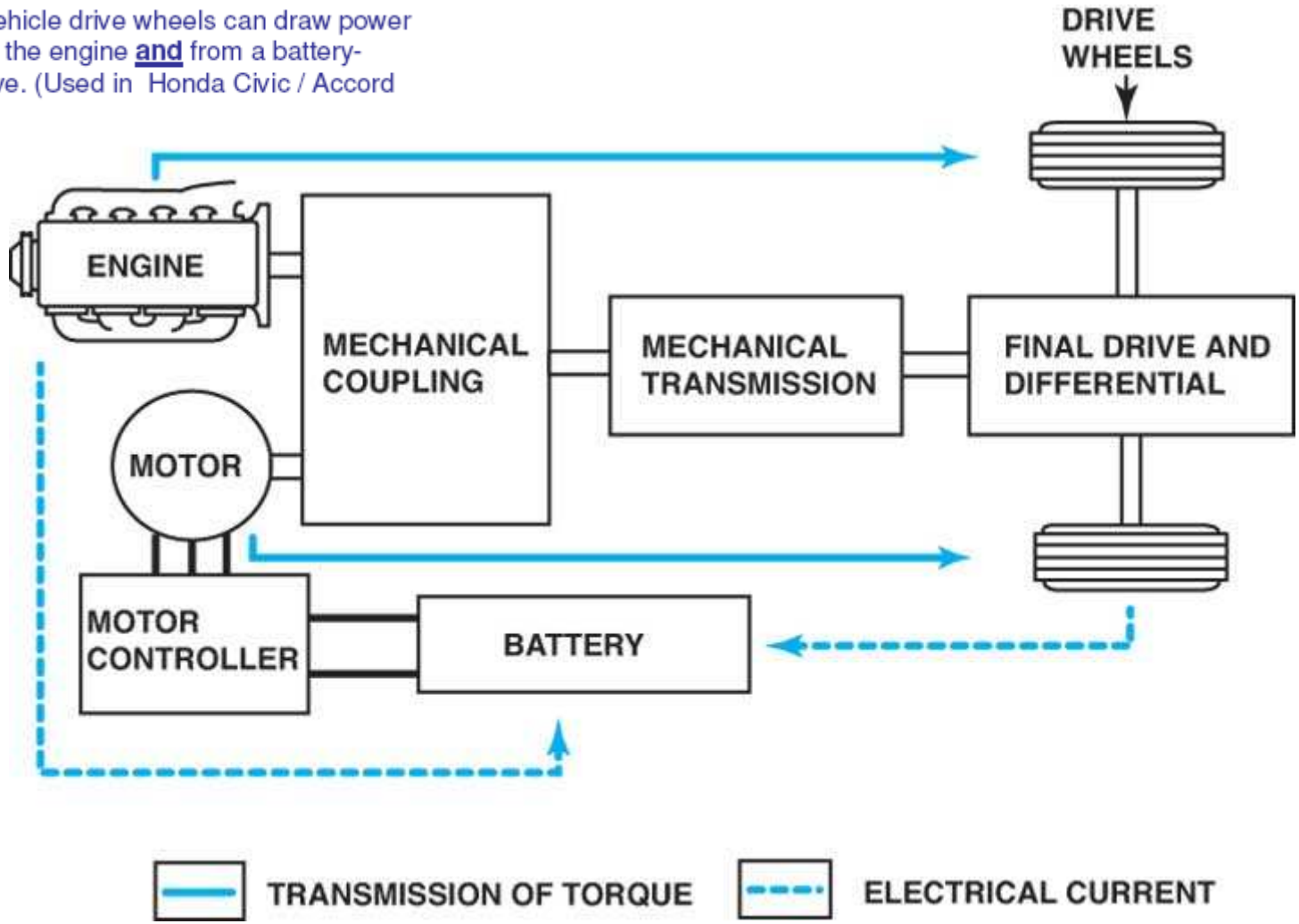


Series Fuel Cell HEV



Parallel HEVs

Parallel hybrids: Vehicle drive wheels can draw power simultaneously from the engine **and** from a battery-powered electric drive. (Used in Honda Civic / Accord hybrids)

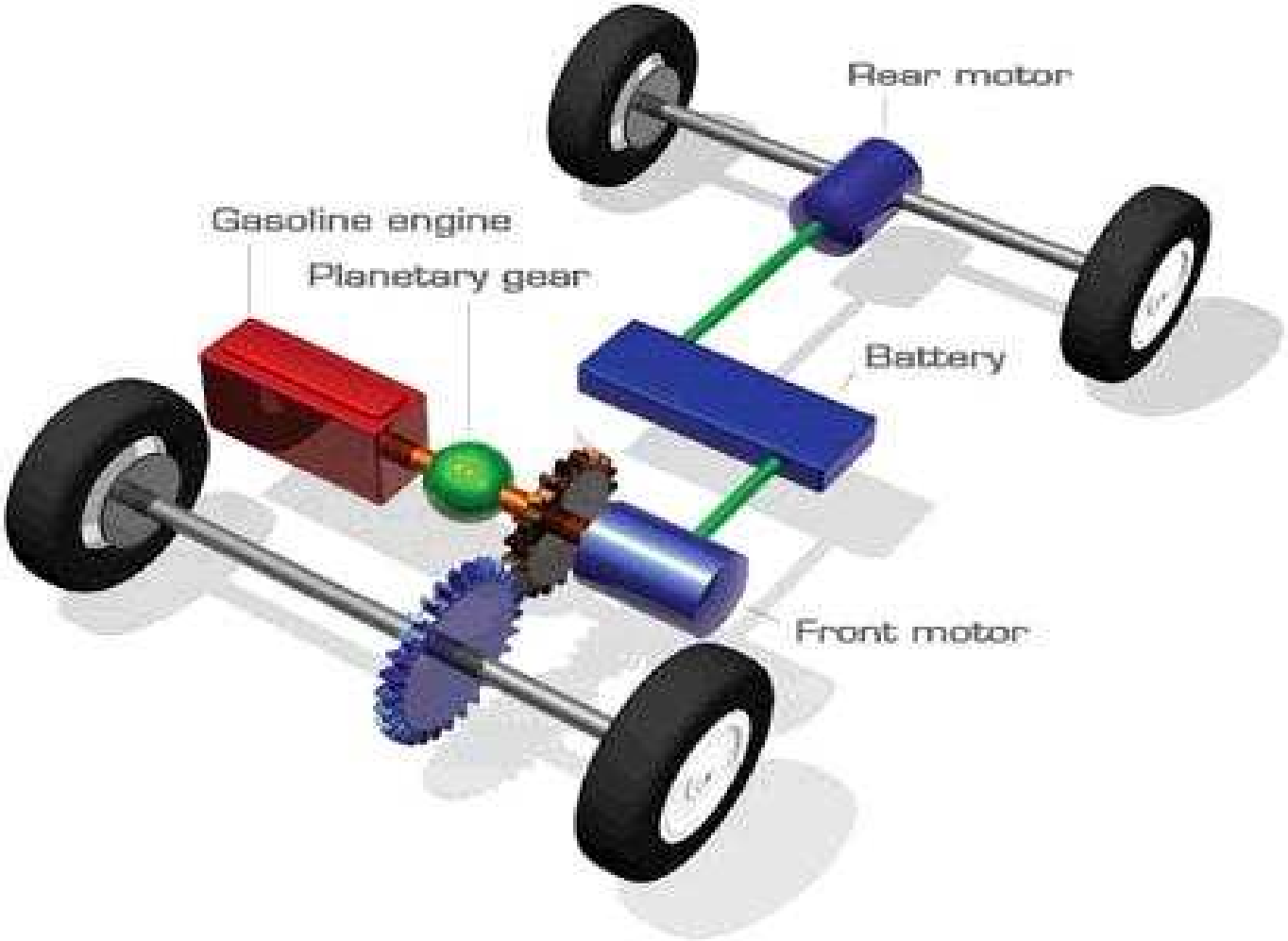


Parallel HEV – Honda Insight (2000)

6.5Ah NiMH Battery Pack

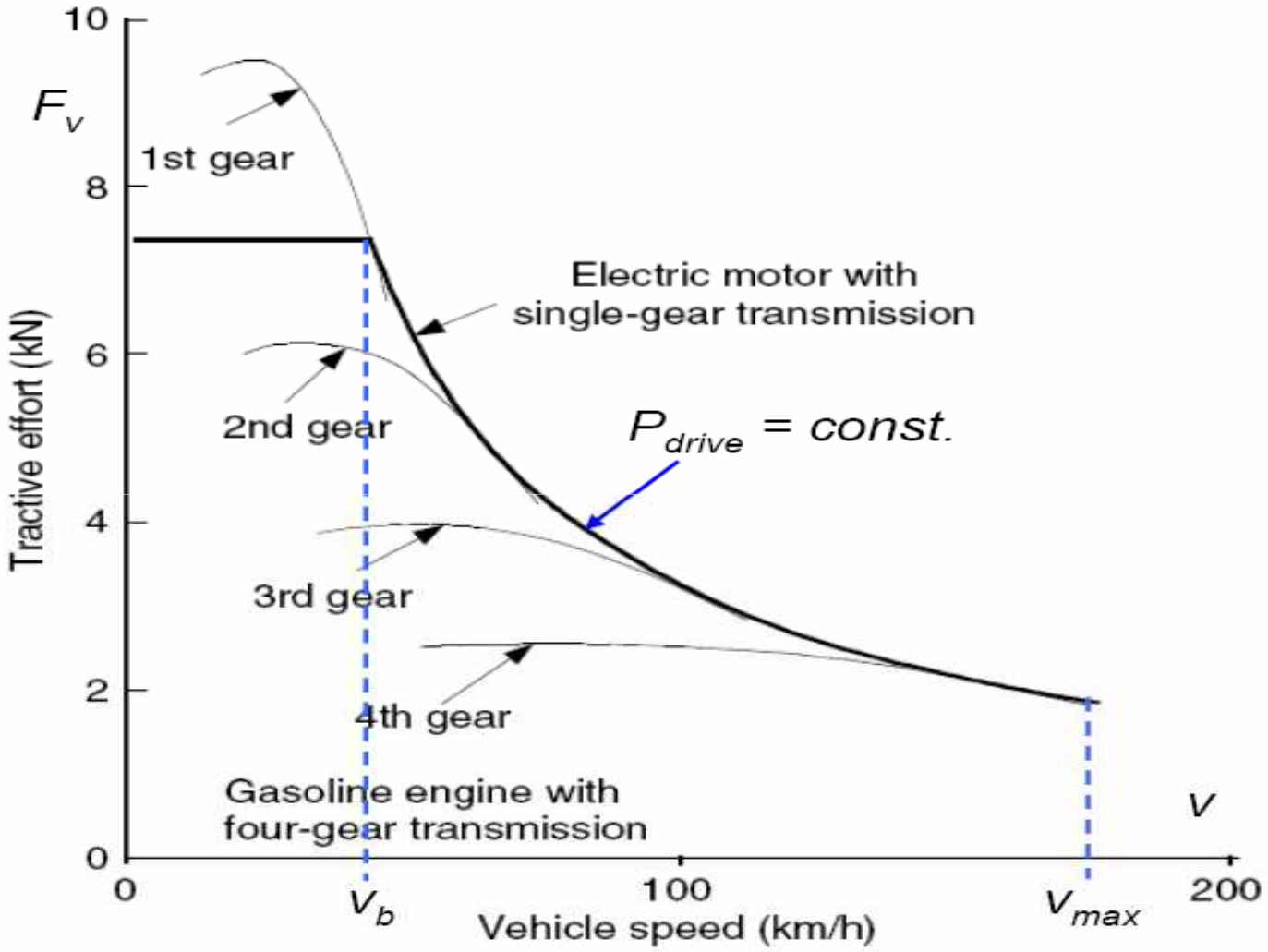
- Integrated Motor Assist
  - Starter
  - Motor
  - Generator
- 5-speed gearbox

Parallel Dual Motor HEVs



Matching ICE with Electric Motor

Comparison of a typical ICE with a 4 gear transmission against an electric motor with a single gear transmission



EV Perceptions



	Petrol (ICE)	Hybrid (HEV)	Plugin Hybrid (PHEV)	100% Battery (EV, BEV)
Range:	440 miles	440 miles	440 miles	100 miles
Refuel Time:	5min	5min	<1h Level 2 Charge	4– 8h Level 2 Charge
Usage:	1st car Familiy car	1st car Family car	1st car Family car	2nd car City car
Energy Efficiency:	Not Efficient	Efficient	More Efficient	Most Efficient
Customer Mind:	Benchmark	+ Electric motor	+ Charging	+ 100% Battery

Current HEVs

Honda Civic

Honda Insight

Toyota Prius

Ford Escape

Sports HEV?

Toyota Volta

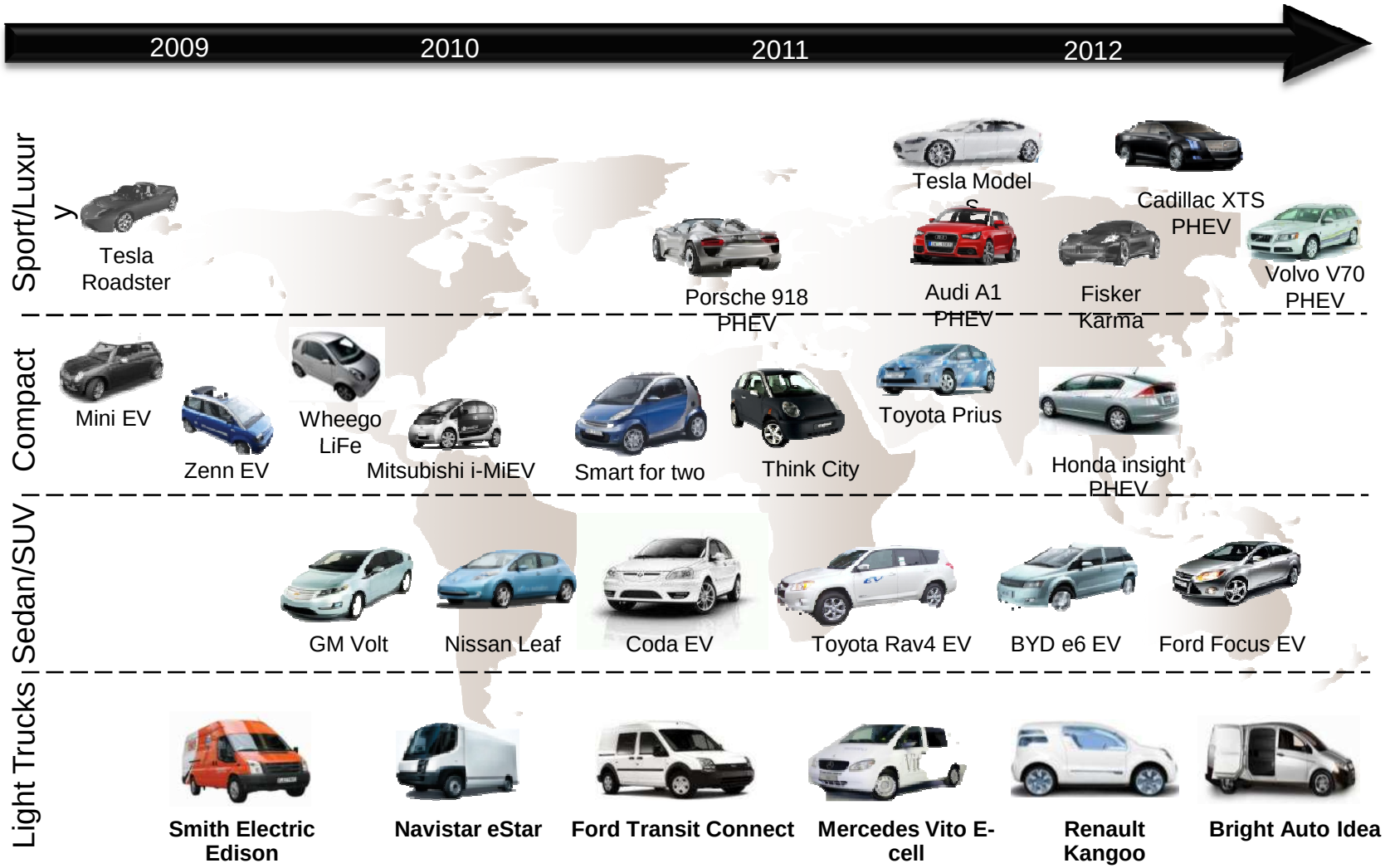
408 horsepower

3.3 liter V6 gas engine

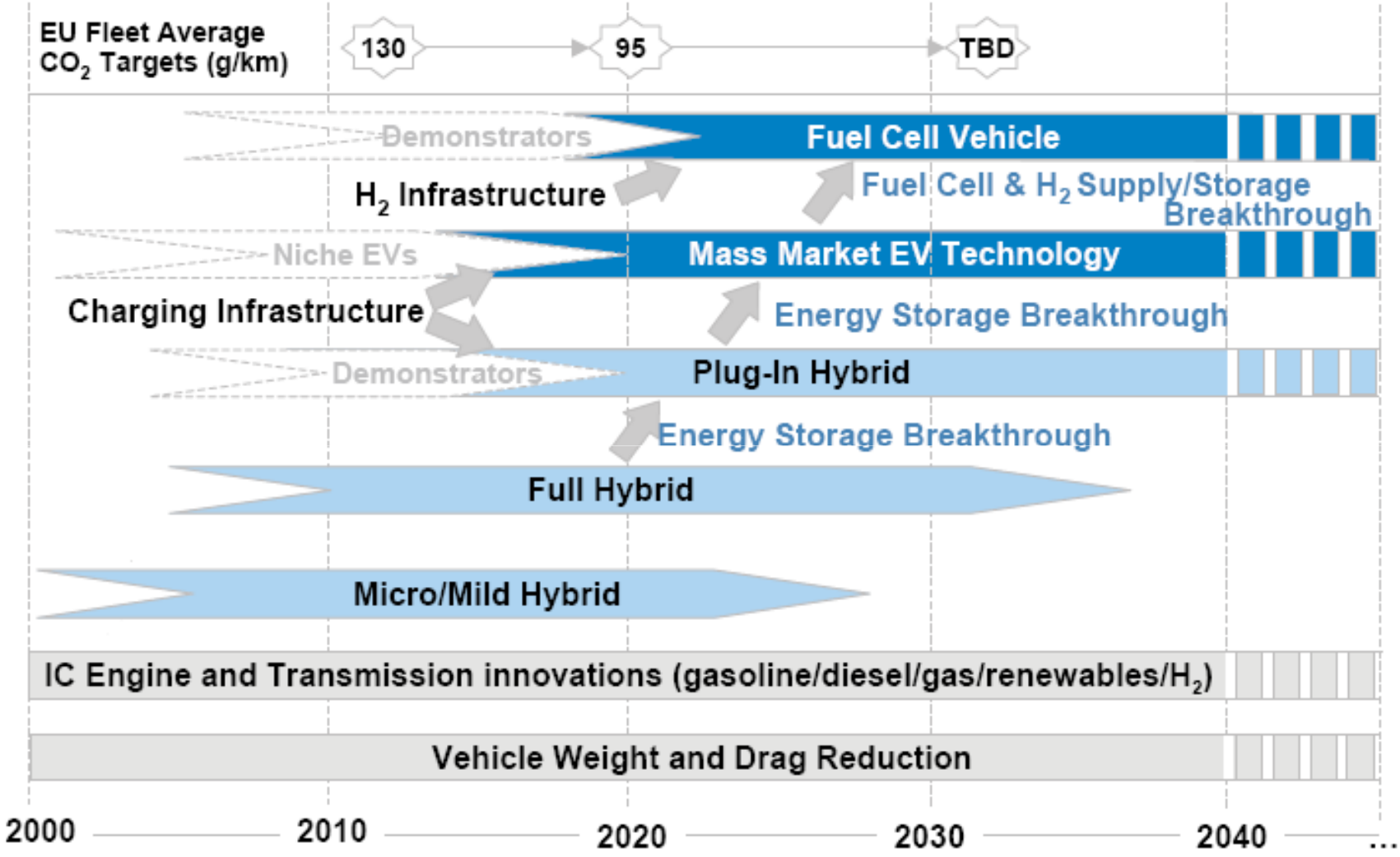
30 miles per gallon

Toyota Hybrid Sports Car

HEV Timelines



View of the Future of Cars



Energy and Power Needs

- Electric motors have high power density and good control.
- A car needs to store energy for range.
- Alternatives:
  - Capacitors or inductors
  - Flywheels or springs
  - Compressed air tanks
  - Batteries
  - Liquid fuel
- Figures of merit:
  - Useful storage per unit mass
  - Useful energy rate (power) per unit mass

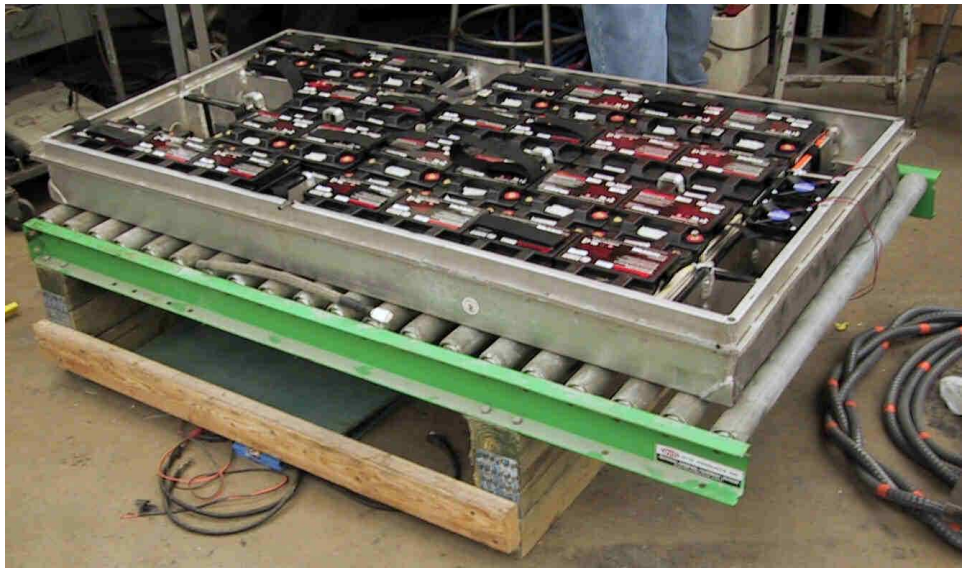
A 90 HP electric motor based on automotive duty.

Energy and Power Needs

Storage technology	Energy density
Lead-acid batteries	100 kJ/kg (30 W-h/kg)
Lithium-ion batteries	600 kJ/kg
Compressed air, 10 MPa	80 kJ/kg (not including tank)
Conventional capacitors	0.2 kJ/kg
Ultracapacitors	20 kJ/kg
Flywheels	100 kJ/kg
Petrol	43000 kJ/kg

Energy and Power Needs

- Lead-acid battery energy density is only about 1% of the usable energy in petrol.
- Sample test car: 275 kg battery pack → equivalent to 4 L of petrol!



Energy and Power Needs

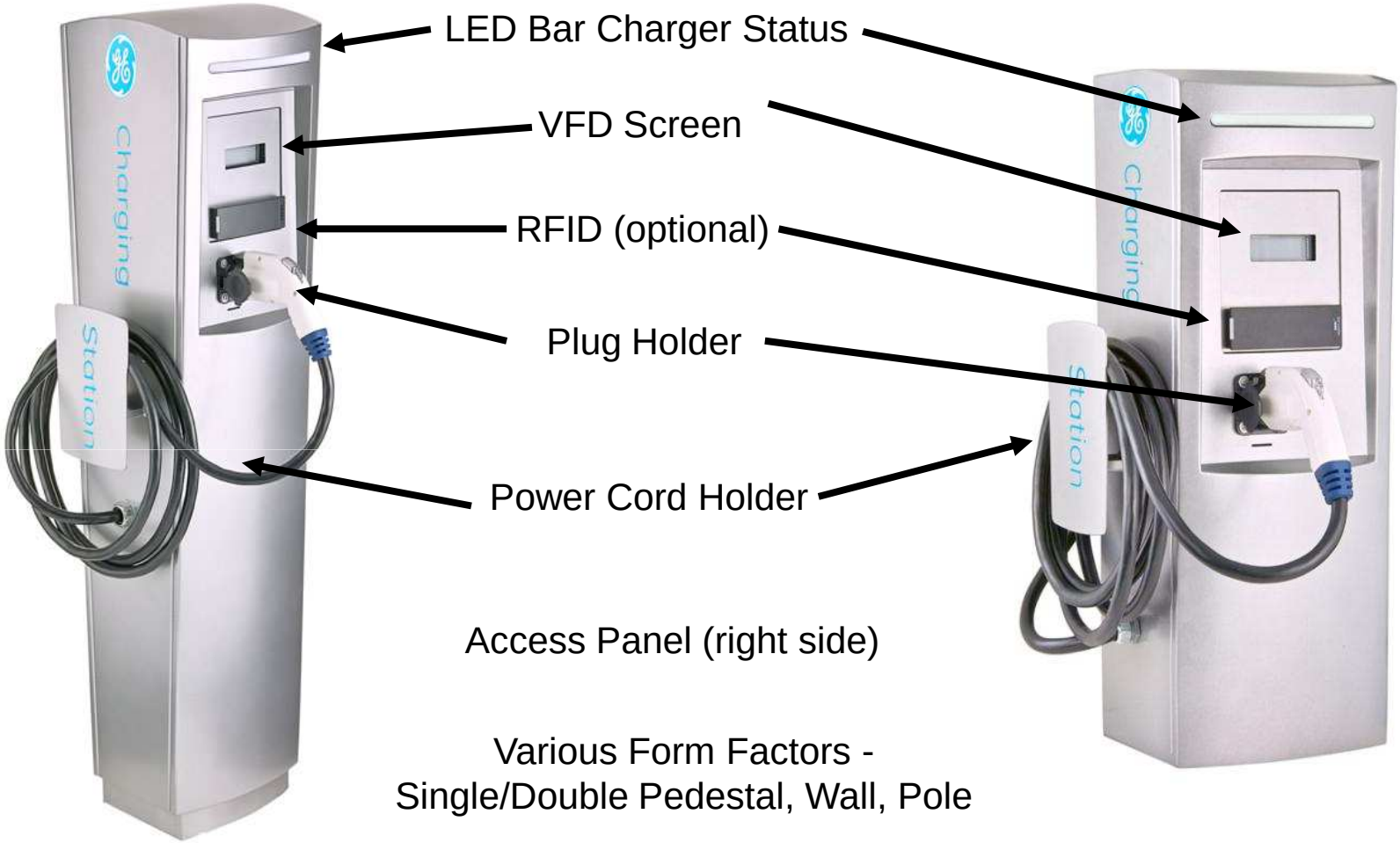
Toyota Prius-2 Battery Pack

- 53 kg Panasonic NiMH (nickel-metal hydride).
- Prius range: 2-3 miles all electric.
- Rated energy storage capacity is 1.8 kWh, usable capacity is 0.7 kWh.
- 80 amps discharge and 50 amps charge (~20 kW output and ~14 kW input).
- Electronics control charge between 40% and 80% of rated full charge (for best battery life).
- Battery thermal management system (cooling fans).
- Toyota claims 180,000 miles (290,000km) of normal driving with no battery performance degradation.

Energy and Power Needs

- Rate of delivery is a problem.
- Example: refill a petrol tank with 15 gal in 5 min.
- The power required to recharge an equivalent battery pack is roughly that used by several major university buildings!
- It is costly and problematic to fill batteries quickly.

Proposed GE EV Charging Station



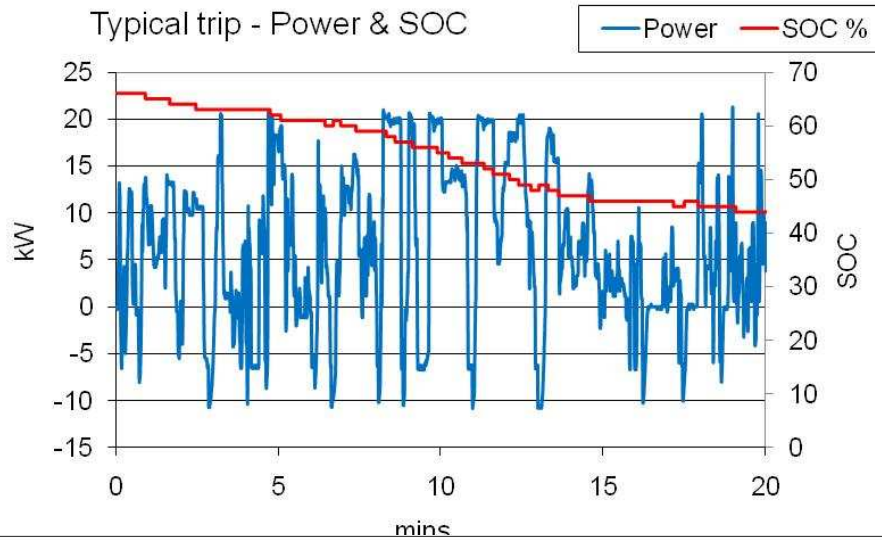
Cenex / Sheffield HEV Study

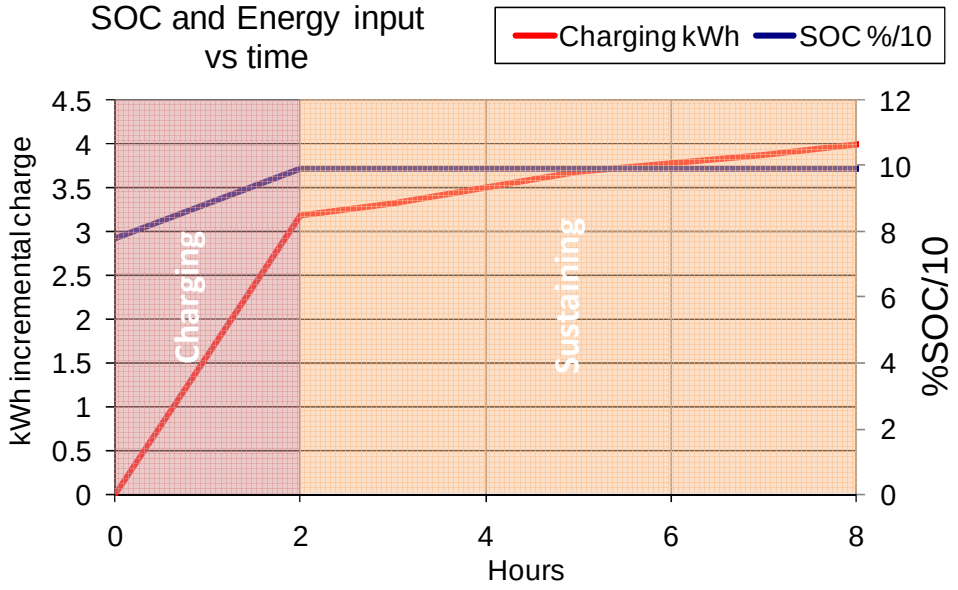
- **Smart ‘ed’**, support of pre-commercial trial 100 vehicles, 4 with Cenex
- Brushless PM machine (limited to 20kW)
- 12kWh high-temp ‘Zebra’ battery (Sodium Aluminium Chloride)
- ~ 245 deg C

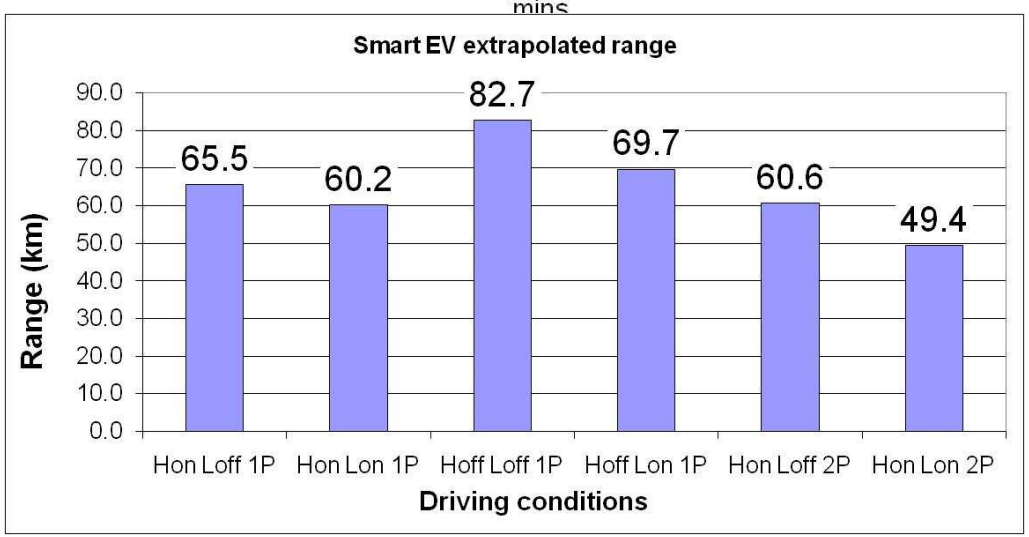
Sheffield HEV Results

Full study - 32 drivers (5 regular), 6 months, >3000km

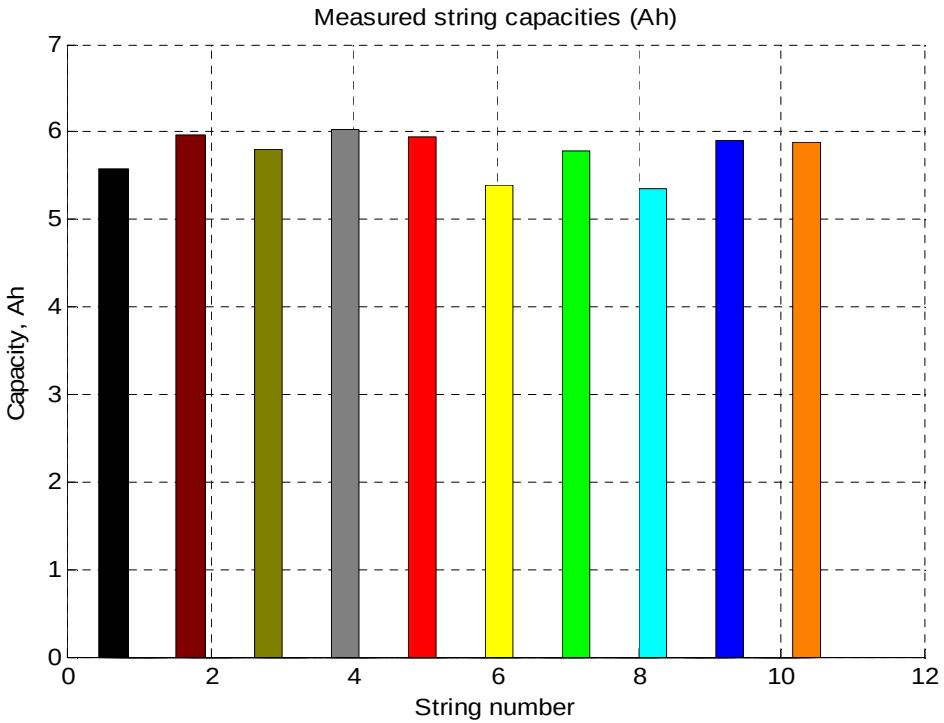
- Typical urban duty ~19km
- 6.6kW mean motoring power, 1kW regen.
- ~24% SoC consumed

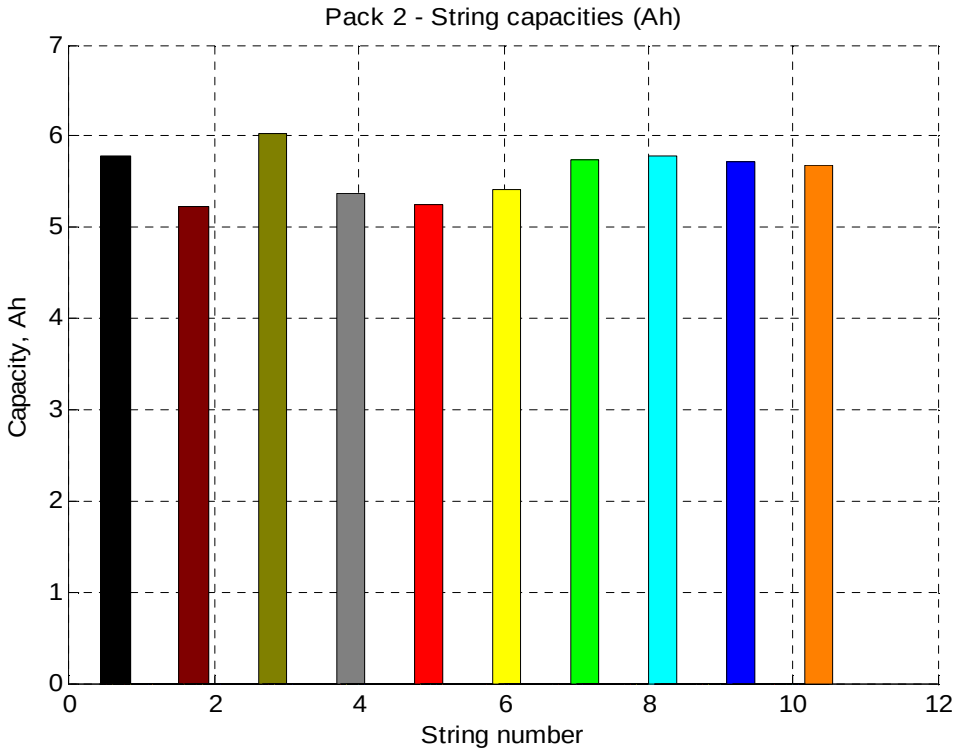






Battery Second Life?

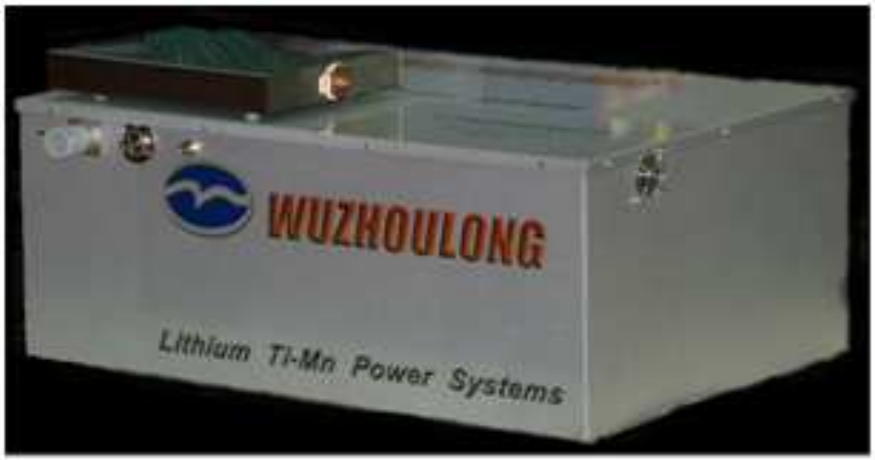




- Sent for recycling when less than 80% of original capacity.
- Still 80% left.
- Why waste all that storage?

Battery Second Life?

- Possible use for distributed storage
- Local storage of alternative energy generation
- Buffer for charging of EV's
- Issues with WEEE directive



HEV / EV Voltages

The following voltages are currently used in North American passenger vehicles

- ✓12 Volt – ALL vehicles
- ✓36 Volts – Saturn Vue
- ✓42 Volt – some conventional and hybrid models
- ✓72 Volt – NEVs
- ✓144 Volt – ALL Honda hybrids
- ✓300 Volt – Toyota first generation Prius hybrids
- ✓500 Volt – Toyota Prius (second generation)
- ✓650 Volt – Toyota Highlander SUV, Lexus RX 400h and GS 450h hybrid

Summary

- Electric vehicles are here to stay
- Need a step change in energy storage to give long range.
- Ideally placed for a family second car
- Significant infrastructure changes needed.
- Alternative energy sources for charging
- Second life issues with batteries