



An Overview of Hybrid Vehicle Technologies

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Hybrid Vehicle Technologies Hold Great Potential but Face Barriers

Great Potential

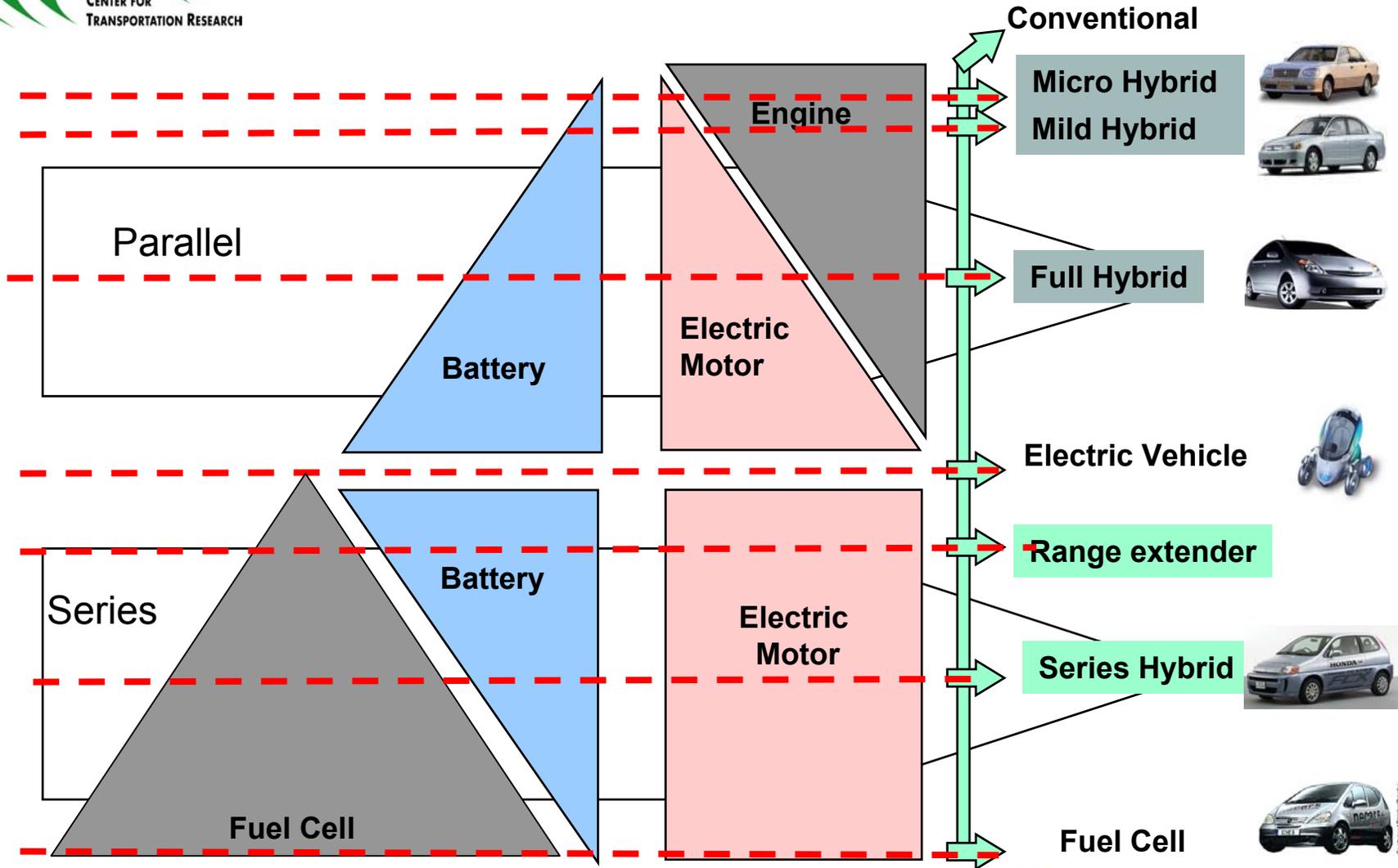
- HEVs have demonstrated significant potential to reduce fuel consumption and exhaust emissions
- Advances in battery, power electronics technologies have made commercialization possible
- Performance is generally as good as or better than CVs

Real Barriers

- Extra complexity adds significant cost
- Fuel efficiency improvements will vary
 - By hybrid vehicle type
 - By application
 - By driving cycle



Hybrid Powertrain Topology





Key Features of Hybrids, or How Do They Do It?

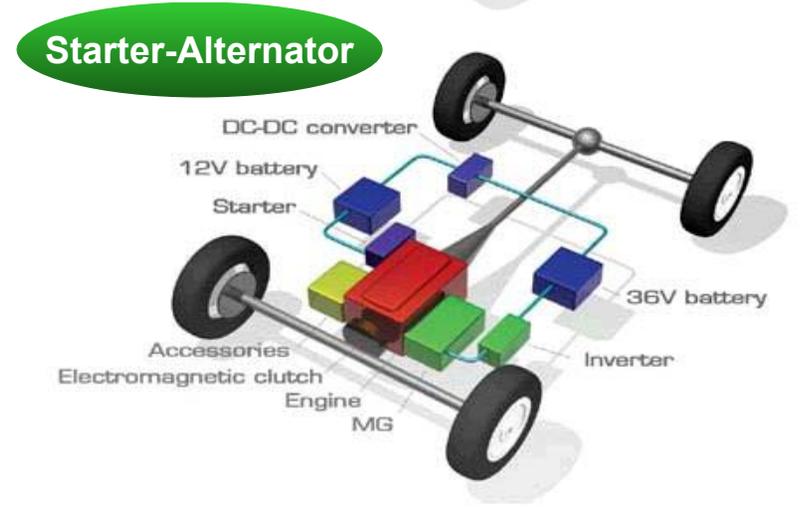
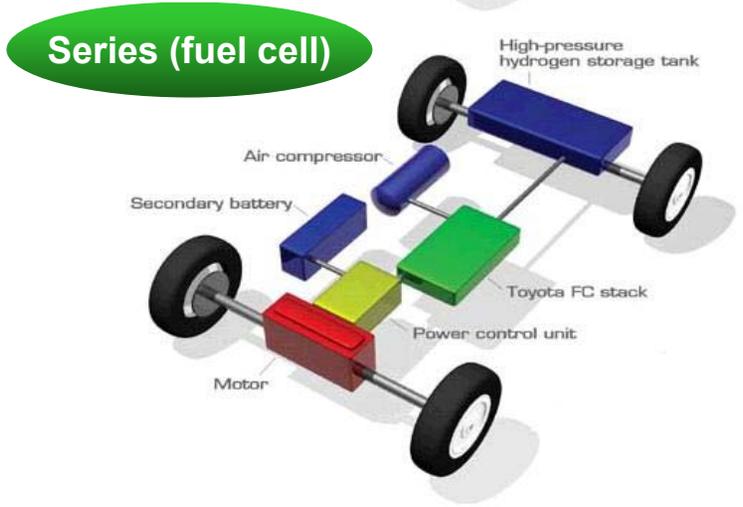
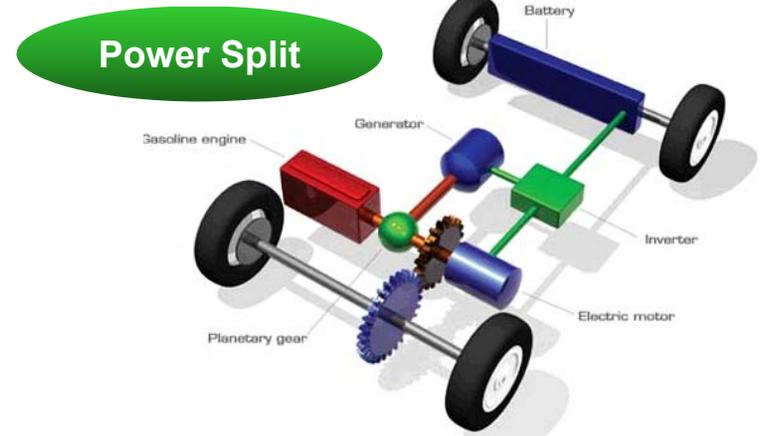
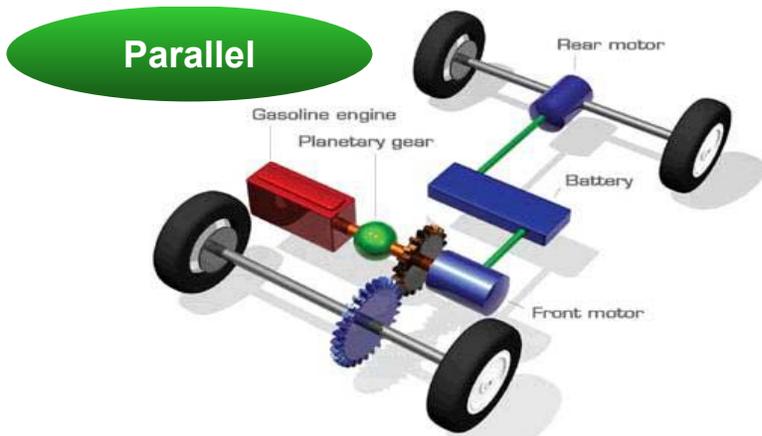
Hybrids achieve improved efficiencies using several approaches:

- Employ regenerative braking to recover energy that is thrown away
- Downsize or “right-size” the engine or primary power source
- Control the engine or primary power source to operate more efficiently and/or work more often in a more efficient range

Other vehicle modifications applied to hybrids like aerodynamic improvements, low rolling resistance tires can be applied to CVs too



Hybrids Can Have Multiple Configurations

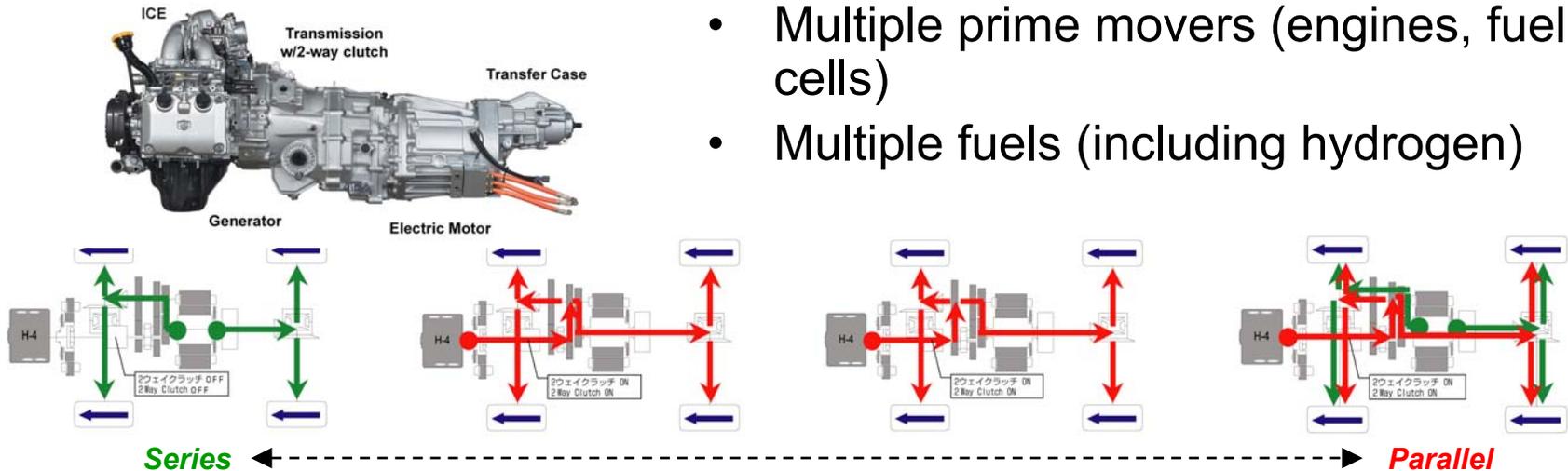


Graphics: Toyota Motor Corporation

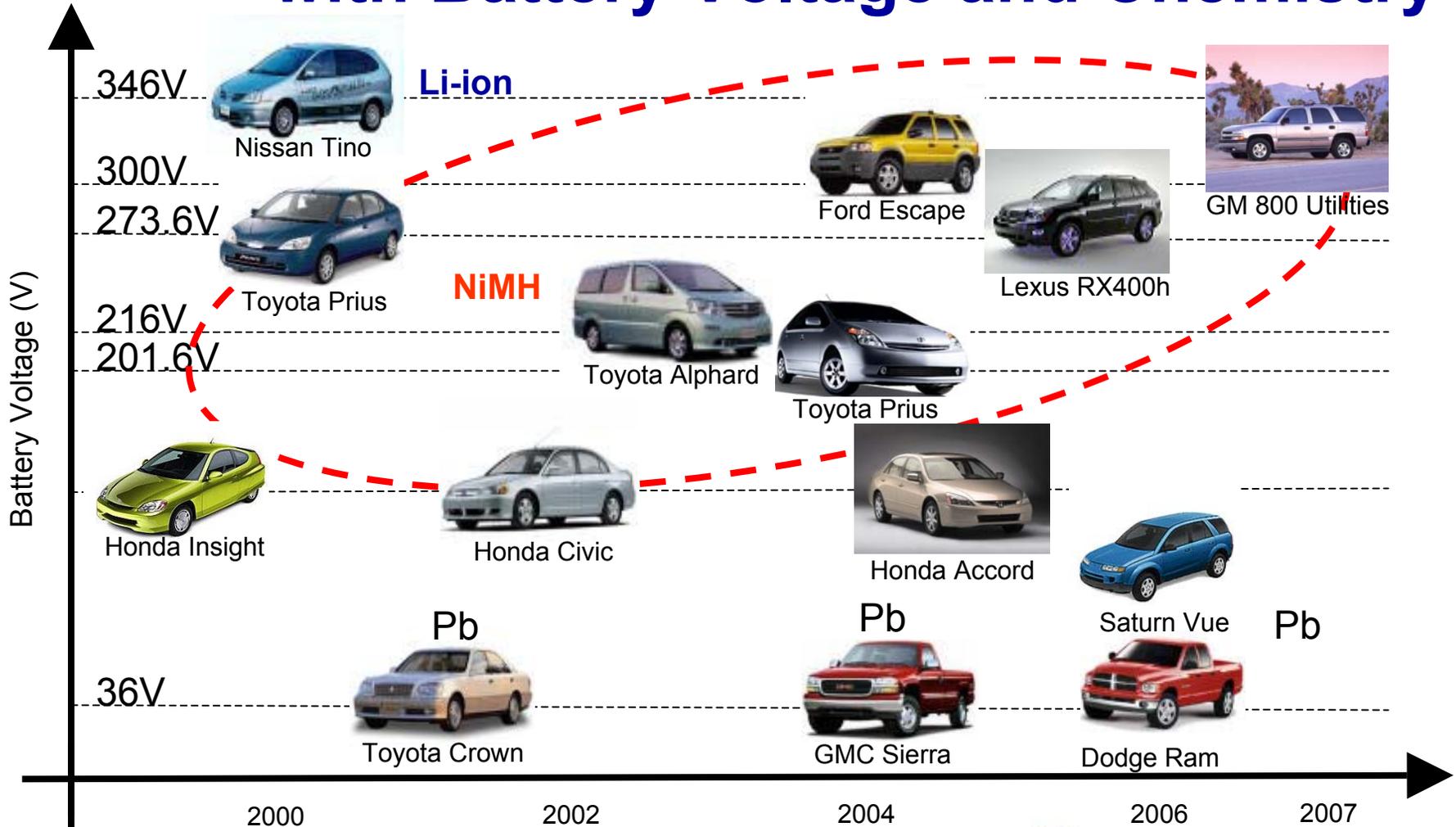
What Are Key Characteristics of HEV Configurations?



- 2- and 4-Wheel Drive
- Mechanical complexity
- Range of system voltages, battery chemistries, electric complexity
- Sophisticated control strategies
- Multiple driving modes
- Multiple prime movers (engines, fuel cells)
- Multiple fuels (including hydrogen)

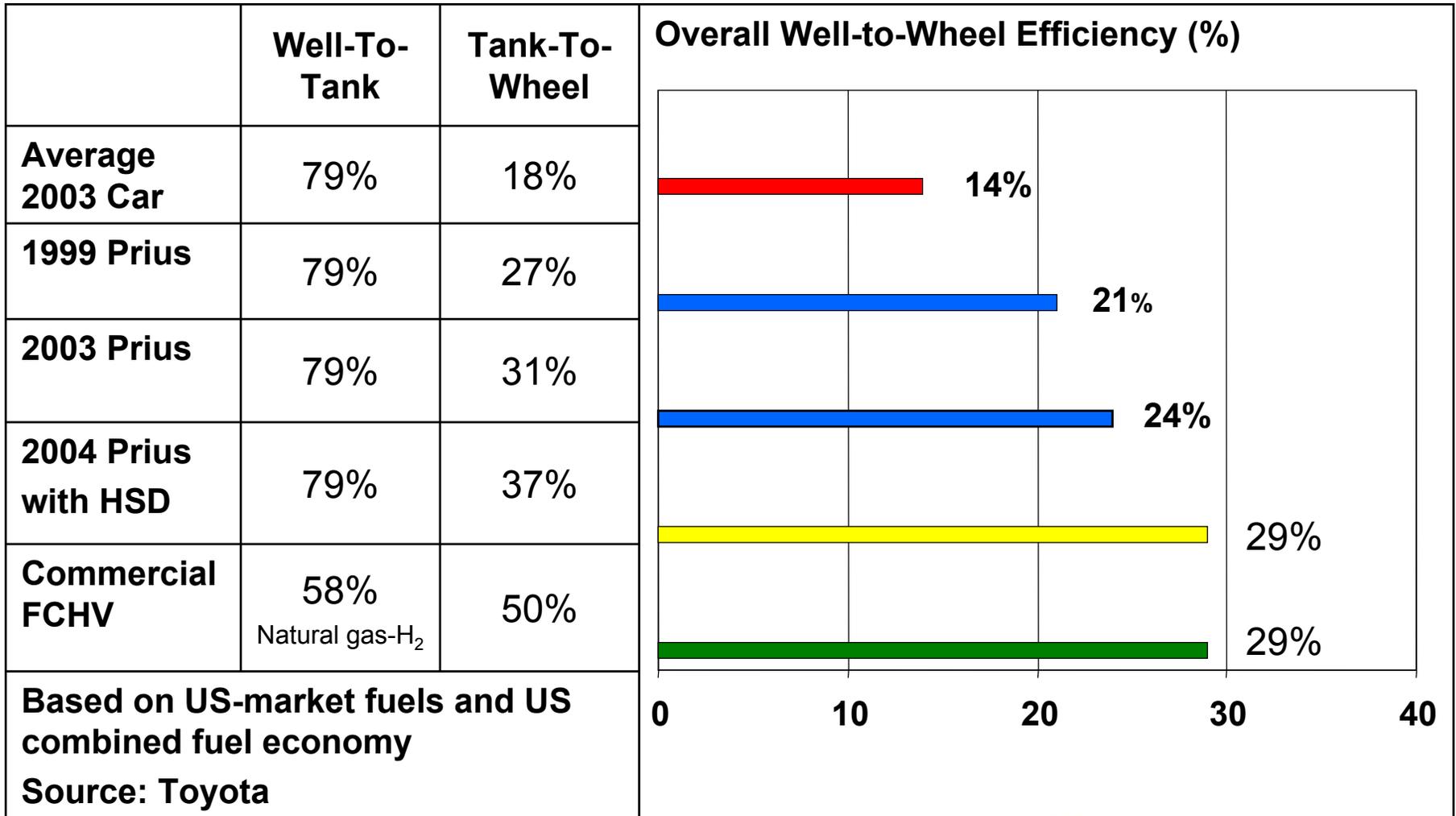


Current and Future Light Duty HEVs with Battery Voltage and Chemistry





WTW Efficiencies of Hybrids Impressive





Selecting the Right Application is Critical for HD Hybrid Success

Understanding a vehicle's duty cycle is essential to know if a hybrid makes sense

- Rules of Thumb:
 - Low-speed, stop-and-go duty cycle highly favorable
 - Mixed urban driving is modestly favorable
 - Highway driving is unfavorable
- Improvements in efficiency and emissions are directly related to driving cycle and configuration



Transit Bus Applications Are A Good Fit for Hybrids

- Bus duty-cycle ideal for maximum regenerative braking effectiveness
- Emissions reduction benefits highly valued
- Can have limited EV operation
- Reduced operating costs can pay back cost premium over time

BUT:

- Cost premiums now 80% - 100%
- Efficiencies 10% - 25% (up to 60% claimed); some emissions benefits
- Without UMTA grants, adoption unlikely



Heavy-Duty Truck Hybrid Applications Can Be Very Attractive

- Suitability is application-specific!
- Garbage haulers a natural
- City or urban delivery vehicles are attractive
- In general, the heavier the load and the longer the drive, the less hybrids make sense



**SERIES-PARALLEL HYBRID DRIVE SYSTEM
THE TRUCK OF THE FUTURE... TODAY!**



FedEx/Eaton HEV Demonstrator a Good Example of What Can Be Done

- “Next Generation” delivery truck
- Downsized diesel engine from 5.9 L to 4.3 L
- Added 44 kW motor, Li-Ion batteries, autoshift transmission
- Achieved:
 - 45% increase in fuel economy
 - 54% reduction in NO_x
 - 93% reduction in PM
 - 16% improvement in 0-60 accel
- However: incremental cost \$30,000
- Unfavorable economics cut initial test fleet size



Hybrid Vehicles Are Here To Stay

- Higher production volumes are bringing costs down
- Improved component performances – especially batteries – will make more applications attractive
- Adaptations of engines to HEV applications will increase the attractiveness of HEVs
 - Variable displacement
 - HCCI
 - H₂ ICE
- Changes in fuel economy regulations may drive hybrid adoption
- Hybridization will play a key role in future fuel cell vehicle design





There is Much More to Know about Hybrids: Some Resources

- SAE papers, books (www.sae.org)
- DOE technical reports (www.eere.energy.gov)
- National Laboratories (www.transportation.anl.gov; www.ctts.nrel.gov; www.cta.ornl.gov; www.ca.sandia.gov; aet.llnl.gov/trans.html)
- Vehicle manufactures web sites
- EPA, DOT, CARB, CEC, CFCP web sites
- Trade magazines
- Automotive and truck magazines



Thank You for Your Attention



Questions and Discussion?