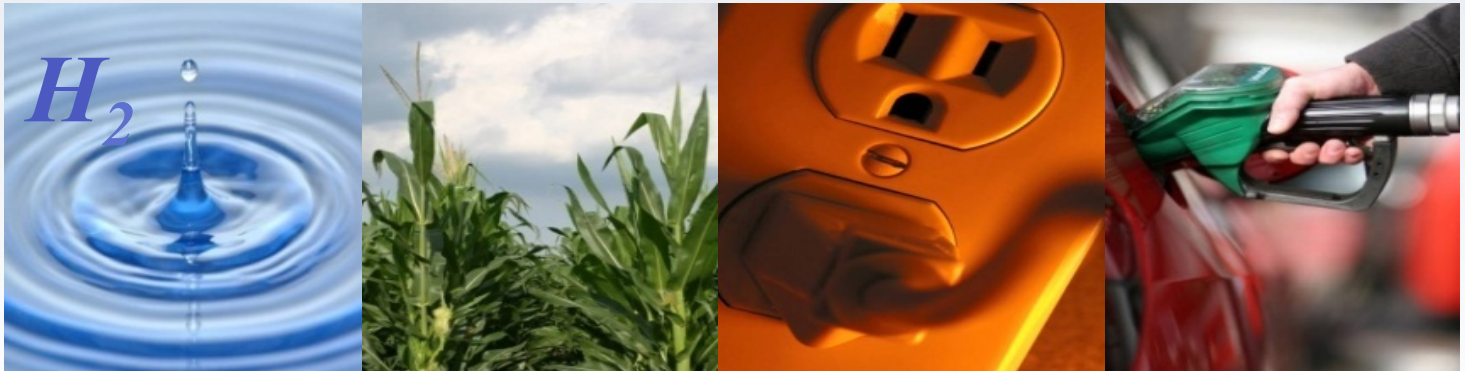


Transportation sector efficiency, electrification and hydrogen

Christopher Yang

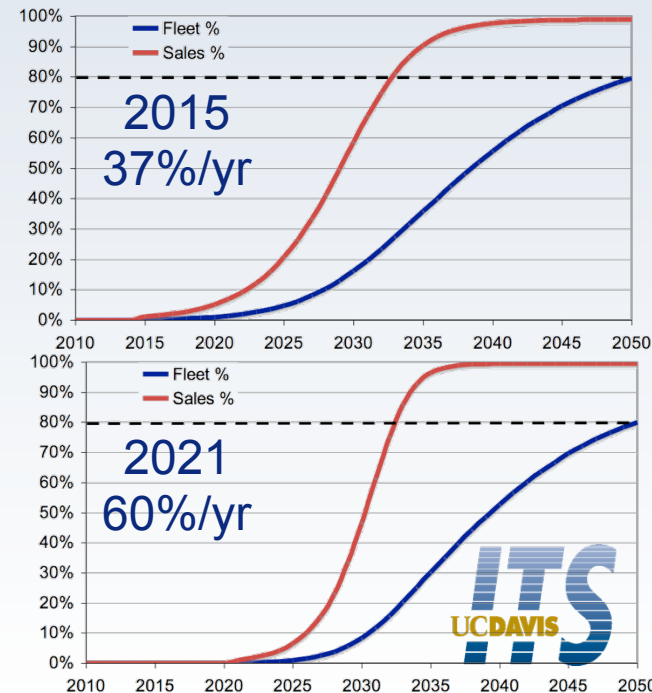
*Institute of Transportation Studies
University of California, Davis*

*ARB, CEC, CPUC Discussions
July 15, 2011*

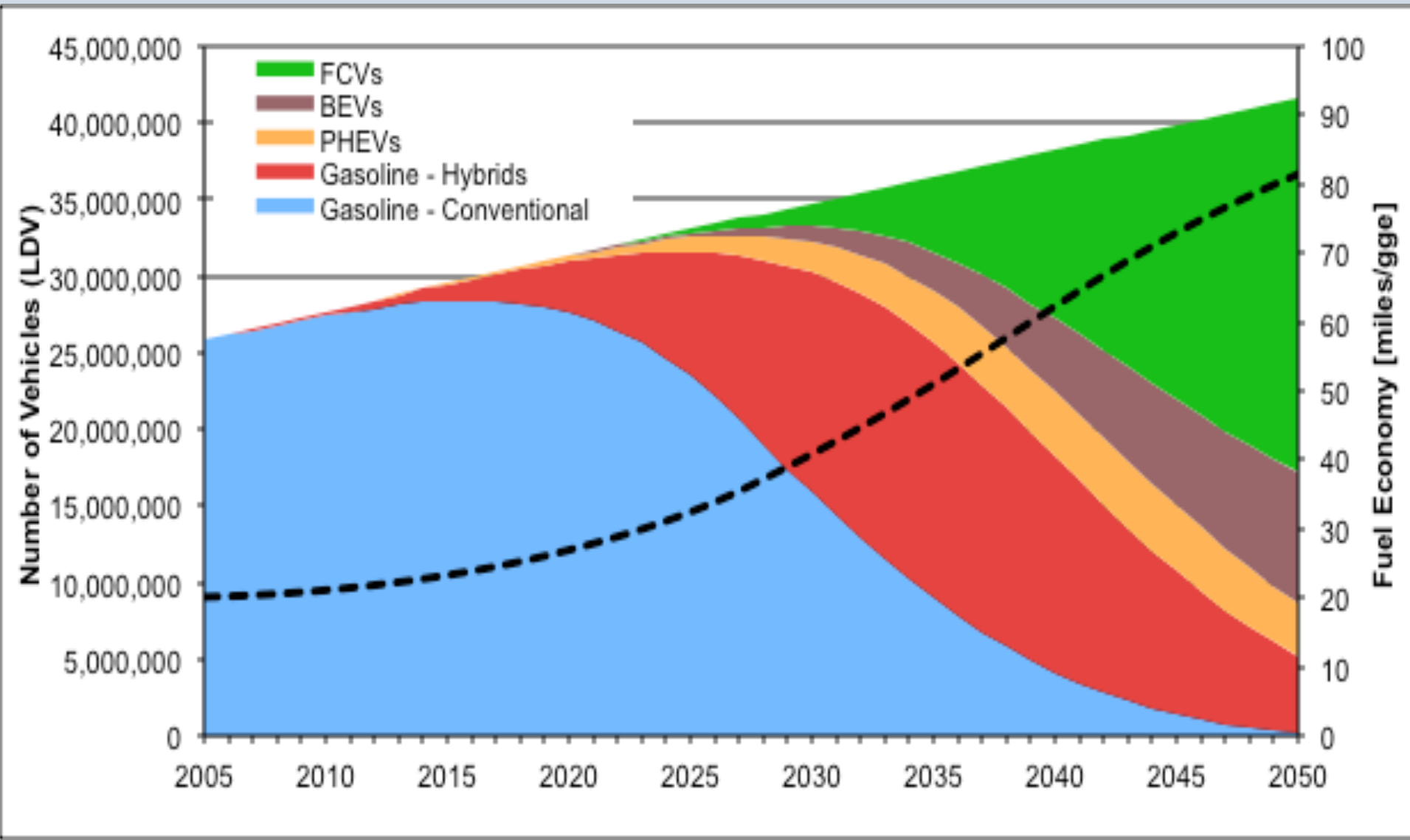


Light-duty scenarios

- Stock turnover - follow hybrid vehicle growth rates
- Slow initial growth - High vehicle costs, limited models, and consumer limitations/unfamiliarity
- Plug-in Electric Vehicles (PEVs)
 - 2050 fleet share is limited by lack of ubiquitous home charging (~60%)
 - Pricing policies are needed to overcome incremental cost
- H2 Fuel Cell Vehicles (FCVs)
 - Hydrogen infrastructure and vehicles requires subsidies
 - Infrastructure availability is an issue
 - FCVs can potentially displace more liquid fuel usage
- Remainder of vehicles are assumed to be conventional hybrids (HEVs)

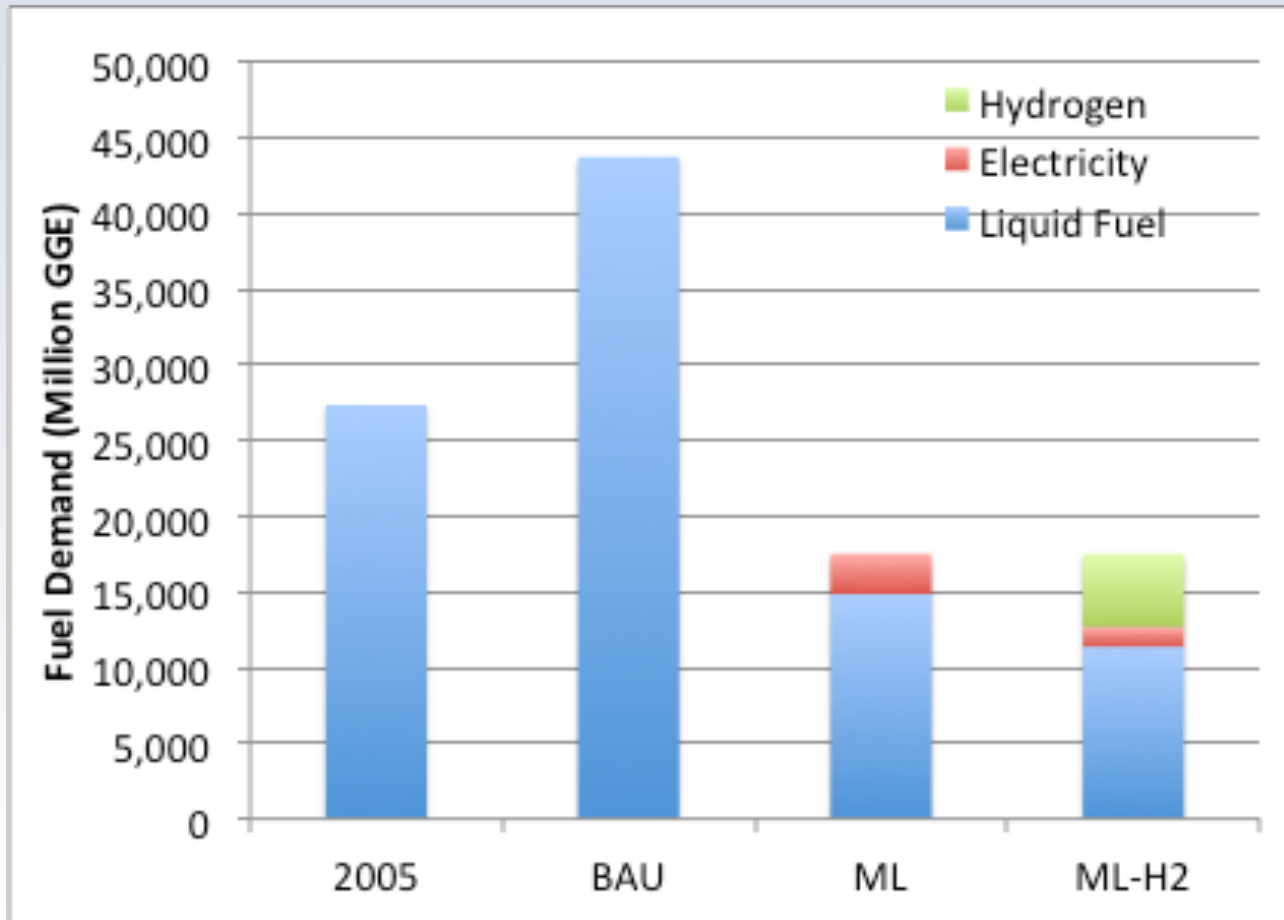


Combined PEV and FCV scenario (80%)



Fuel Demands

- Efficiency counteracts travel demand growth
- Electrification (including H2) reduces the demand for liquid fuels but there is still substantial remaining demand



Other Transportation Sectors

- Some sectors continue to rely on liquid fuels because of limited energy storage, power and weight issues
 - Heavy trucks reduce energy use through improved engines, transmissions and hybridization, cab and trailer aerodynamics, double trailers, speed reduction, routing and logistics (50% reduction in energy intensity)
 - Aviation can rely on improved jet engines, aerodynamic improvements, and operational improvements, including some more radical designs like blended wing (60% reduction in energy intensity)
 - Marine can take advantage of higher efficiency engines/propulsion systems and reductions in hydrodynamic drag and speed reduction (40% reduction in energy intensity)
 - Much of these improvements (1/3 to 1/2) are cost effective
- Electric drive can play a role for some sub-sectors
 - Buses and short-haul delivery trucks (either using H₂ or electricity)
 - Rail can also be electrified
 - Reduction in energy use per mile/seat-mile around 60%

H2 Scenario

- Hydrogen is another decarbonized fuel
- Provides greater energy density and total range than batteries
- Barriers include vehicle costs, subsidy requirements and early infrastructure deployment
- Fuel cells and infrastructure is still maturing (Bin 1 and 2 technology)
- Identify applications where it may be successful
 - LDVs, buses, some medium duty trucks
 - Replace NG in some industrial applications
- H2 mix:
 - 10% onsite natural gas
 - 33% renewable electrolysis
 - 57% fossil with CCS
 - Carbon intensity (12-20 gCO₂e/MJ, 80+% reduction in CI)
- Electricity → H₂ → biofuels → fossil