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Considerations for Future Fuels
Meeting the Goals of AB 32: Fuels of the Future
Informational Hearing of the
Senate Transportation and Housing Committee
October 24, 2011

Slide 2: Current state

- US has nearly 250M cars, 97% dependent upon petroleum-based fuels, accounts for about 30% of the nation's GHG emissions.
- CA – 26M registered vehicles, 96% dependent upon petroleum, 40% of the state's GHG emissions.
- Historically inexpensive oil prices have led to this monolithic transportation mix.
- Over time, the auto industry has made tremendous technological innovation in cars.
    - A notable example is the present-day three way catalytic converter
- Efficiency improvements have been applied to performance – heavier, more powerful vehicles – while maintaining or improving fuel economy levels.

Slide 3: Targets

- California and the nation have made commitments to reduce petroleum consumption and GHG emissions.
    - These have taken the form of either technology targets or performance outcomes.
- Chart shows the RFS2 mandate for biofuels. It specifies ethanol targets as well as biodiesel and non-ethanol cellulosic fuel targets.
- RFS2 divides the renewable fuel requirement into four categories:
    - Ethanol from corn starch with life-cycle greenhouse gas (GHG) emissions at least 20-percent less than petroleum-based fuel.
    - Cellulosic biofuels derived from any renewable biomass that achieve reductions of at least 60 percent.

    - Advanced biofuels (other than ethanol – typo in chart says non-cellulosic, but really should read non-ethanol) with life-cycle GHG emission at least 50 percent less than petroleum fuels. Advanced biofuels can include cellulosic biofuels and biomass-based diesel.
    - Biomass-based diesel with life-cycle GHG reductions of at least 50 percent.
- Targets must be considered in context of existing technology, infrastructure, and policies
- Example – E10 makes up over 90% of the US gasoline market. There are nearly 160,000 gasoline stations in the US which can all utilize E10.
    - There are only about 2400 stations that dispense E85 (1.5% as many).
    - Flex fuel vehicle park currently ~3% or 8.35M of ~250M
    - Unless substantial change in infrastructure or the development of cellulosic biofuels generates infrastructure compatible fuels, will need to increase the ethanol blend in the gasoline market to absorb the cellulosic ethanol accompanying RFS2.
    - EPA has issued waivers that will allow E15 to be used in cars that are MY2001 and newer. Issued only after extensive testing.
    - EPA has also recently issued labels that will indicate to consumers the appropriate use of E15. Can't consider fuels without vehicles and infrastructure, and also must consider consumer acceptance and behaviors.

Slide 4: Scenarios

- Example of the RFS2 shows some of the complexity for an incremental change – it illustrates the need to consider evolving fuels and vehicles in the context of each other as interdependent technologies.
- If RFS2 is achieved, domestically produced biofuels can displace about 1.6M barrels of petroleum-based fuels a day, or about 12% of our petroleum use, so biofuels alone unlikely to meet our petroleum reduction targets.
- Need to add the next level of complexity, and consider seemingly parallel technologies that are currently evolving, like EVs and hydrogen fuel cell vehicles.

- Scenario analysis is one methodology that enables us to consider transition pathways from current to future state.
    - NRC report on Transitions to Alternative Transportation Technologies and other studies illustrate possible combinations of technologies – efficiency, hybrids, PHEVs, and biofuels.
    - Chart on the slide shows a scenario from CCST California's Energy Future Study.
- Scenarios like these illustrate that a mix of advanced technologies will need to be deployed aggressively over the next 40 years. Shift to a true diversified portfolio of transportation technologies.
- Substantial portion of the fleet will continue to rely on the internal combustion engine – hybrids and PHEVs still make use of an ICE; even in aggressive scenarios all electric vehicles may still only make up a fraction of the vehicle mix.
- Dominant engine on the road today is the port fuel injected spark ignition engine, which has a peak brake thermal efficiency of about 30%.
    - Auto industry has reported concepts that have reached nearly 45%.
    - Prius is at 38%, but this is an engine that is designed to be coupled with a battery at an additional cost and run over a limited load range.
    - Emission compliant diesel engines at 42-43%, but additional 2-3K
    - Current industry trends toward downsizing and turbocharging, which forces an engine to operate in the more efficient, heavier load range over a greater fraction of the typical drive cycle without sacrificing performance.
- Ongoing research demonstrated new low temperature combustion concepts in the lab that have the potential to achieve near 50% brake thermal efficiencies.
- Substantive fuel savings can be enabled with improved ICE technologies as part of the mix – need to consider how to incentivize these near to mid-term technologies in addition to incentivizing advanced biofuels and EV concepts

Slide 5: Speed, scale, standards, segmentation

- **Speed and scale**: Target timeframes will heavily influence technology options
    - Cars typically in park 15-20 years.
    - Hybrid first sold in 1997

    - 17 sold in the US in 1999
    - ~274,000 of the 5.6M new vehicles sold in 2010
- **Standards:**
    - Transition from E10 to E15 illustrated complexity of an incremental change
    - Path toward drop-in biofuels, electric vehicles, and hydrogen fuel cells, will be much more complicated – will need to continue to consider their specifications, standards, and interdependencies.
- **Segmentation:**
    - Clear that there will not be a single solution –biofuels, EVs, efficiency, other technologies will all be part of the mix.
    - Need to examine the interdependencies, regional demands, logistics, and resource constraints that will inform decisions.