Summary and Conclusions

Technology and Fuels Assessments

September 9, 2014
Diamond Bar, California

California Environmental Protection Agency
Air Resources Board

Key Findings

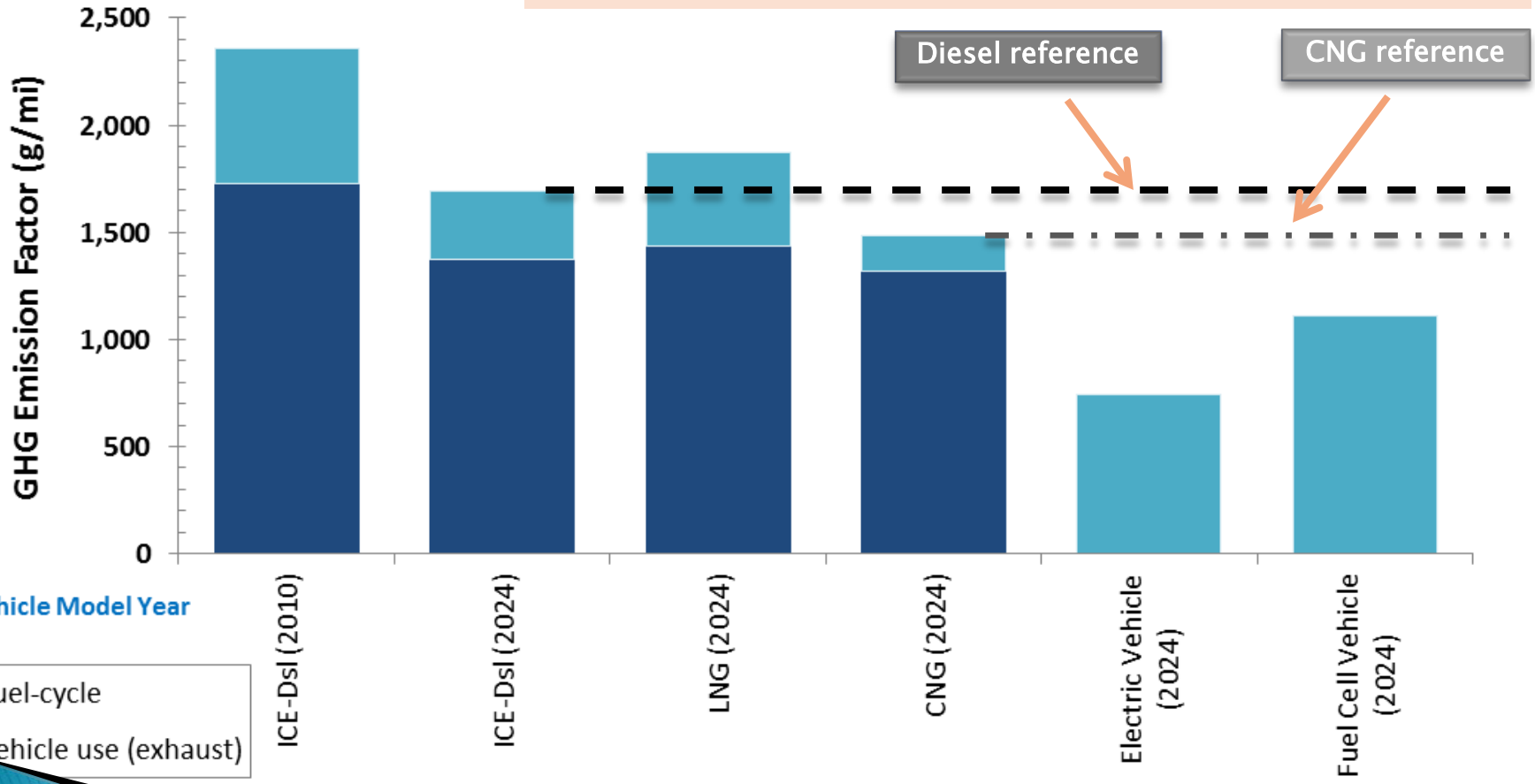
1. Well to wheel emission factors and natural gas uncertainties
2. Biofuels
3. Combustion engines, vehicles, & equipment
4. Hybrid technologies
5. Zero emission technologies
6. Automation and efficiencies

Well to Wheel Emission Factors

- Considering upstream emissions is critical for assessing GHG impacts of vehicles
- Natural gas vehicle upstream emissions are uncertain due to methane leakage
- Advanced high efficiency engines and vehicles operated on biofuels could significantly reduce GHG
- Zero emission technologies produced with renewable fuels provide deep carbon reductions

Well to Wheel: HHD Truck
GHG Emission Factors

Note: Analysis uses draft LCFS CA-GREET 2.0 carbon intensities and assumptions as presented during the August 22, 2014 workshop. Updates to LCFS pathways are ongoing.



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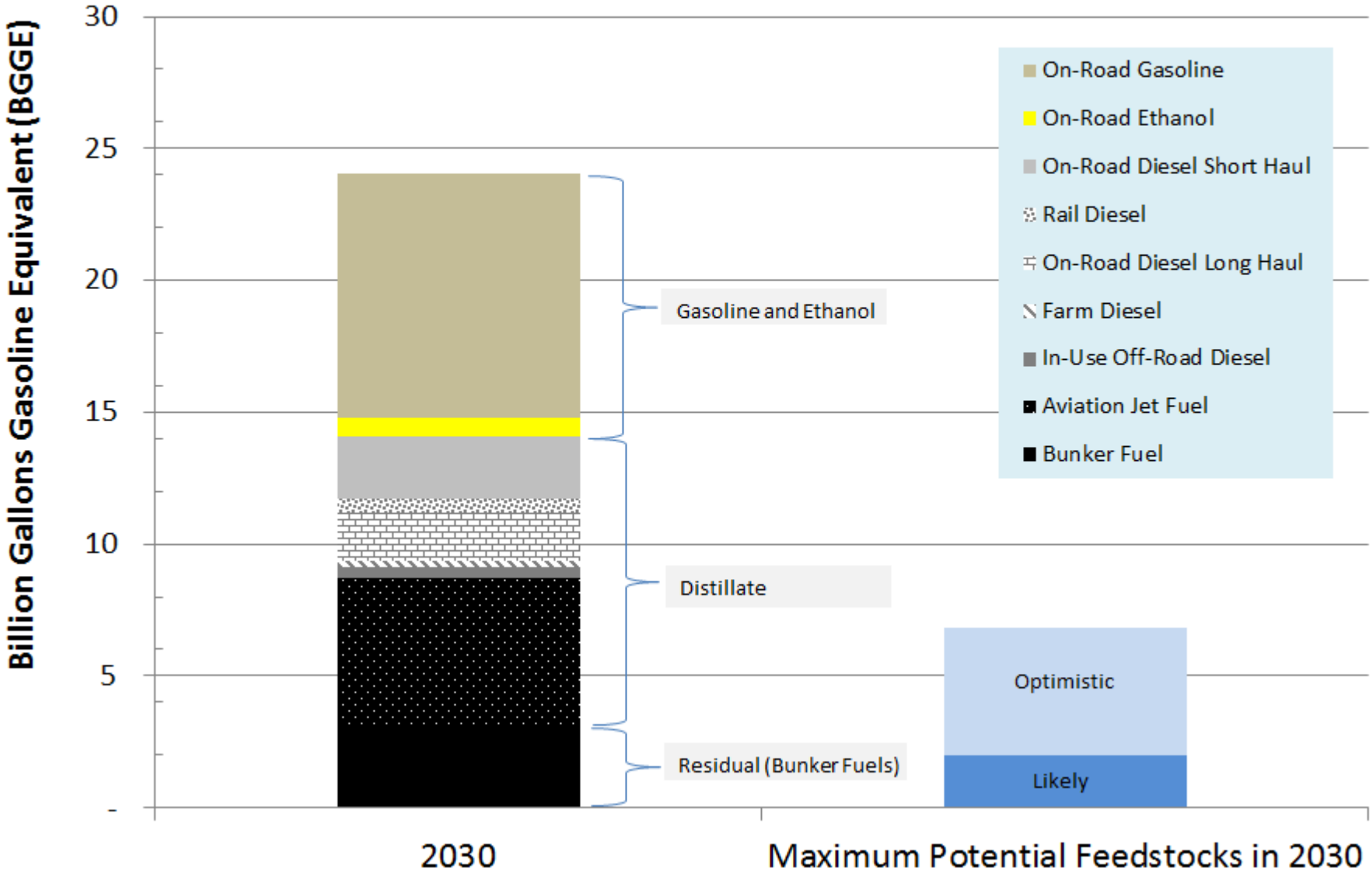
Role of Biofuels

- Could provide near-term GHG reductions when zero-emission technologies maturing
- Biofuels could provide substantial carbon reductions long-term
- Biofuels long-term supply may be constrained
  - Supply potentially limited by feedstocks
  - Need electrification in heavy-duty sector
- Low Carbon Fuels Standard (LCFS) program designed to spur market and technology innovation that is needed to expand long-term supply

2030 Fuel Demand vs Potential Long Term Liquid Biofuel Feedstock Supply



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Combustion Engines, Vehicles & Equipment – Main Findings

- Many sectors currently subject to ARB in-use requirements now and in future
- Incremental improvements to engines and vehicles can provide substantial GHG reductions
- Diesel in-use emissions can be improved
  - Improved certification; inspection & maintenance
- Lower NOx emissions being studied, most likely achievable
- Regulations can foster technology development

Combustion Engines & Vehicles – Trucks & Buses, Potential Requirements

- Trucks and Buses
  - Phase 1 achieved 6 to 23% GHG reductions, Phase 2 aerodynamics and powertrain improvements can achieve 13-25% more
  - Improved certification, durability, and warranty requirements needed and could reduce diesel in-use emissions
  - Lower NOx diesel and natural gas engines are feasible – goal is 90% reduction

Combustion Engines & Vehicles – Natural Gas Trucks and Buses

- Trucks and buses – today's natural gas
  - Fuel costs lower than diesel
  - In-use emissions likely a little lower than diesel
  - GHG lifecycle emissions uncertain due to methane leakage ~ LNG higher than diesel, CNG lower
  - Improvements for more competitive future:
    - Reduce upstream methane leakage in federal and state system
    - Certify to optional NOx standard
    - Use renewable methane to reduce GHG emissions

Combustion Engines, Vehicles & Equipment – Rail, OGV

- Locomotives (Rail)
  - Emission benefits possible with aftertreatment (SCR/DOC/DPF)* – 90% overall reduction in NOx and PM, 70% reduction beyond Tier 4
  - LNG may provide benefits, with reduced methane leakage
- Ocean going vessels (OGV)
  - Emission benefits with SCR/EGR*, advanced hull and propeller design – fleet turnover is key
  - LNG may provide benefits, with reduced methane leakage

*Selective Catalytic Reduction (SCR), Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), Exhaust Gas Recirculation (EGR)

Combustion Engines, Vehicles & Equipment – Aviation, Commercial Harbor Craft

- Aviation
  - Aerodynamics, lightweighting provides benefits on new aircraft
  - International and national efforts to reduce emission stds for NOx, GHG, promote biofuels
  - National effort to eliminate lead from av gas
- Commercial Harbor Craft
  - Emission benefits possible with new stds, hull design; retrofit aftertreatment on existing (SCR, DPF)

Combustion Engines, Vehicles, and Equipment

- Transport Refrigeration Units
  - Emission benefits beyond Tier 4 possible for new <25 hp
  - Diesel particulate filter (DPF) retrofits for existing <25 hp
  - Push for federal insulation requirements for refrigerated vans, railcars

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Hybrids – Main Findings

- Early commercialization for trucks and buses
- Demonstrated in cargo handling equipment, commercial harbor craft
- Provide significant GHG reductions
- Series hybrids could spur development of zero emissions technology components
- Systems integration and engineering necessary to achieve NOx reductions

Hybrids in Multiple Sectors

- Trucks and buses – early commercialization, short payback in some applications, need push for systems integration and market development
- Commercial harbor craft – hybrids possible for new or retrofit
- Cargo handling – hybrids an option for bulk terminals

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Zero Emissions Technology

- Benefits
  - Little noise
  - Zero tailpipe emissions
  - Opportunity for deep carbon reductions when used with renewable fuels
- Opportunities
  - Commercialized in aircraft ground support equipment, early commercialization in automobiles
  - Early pilots in buses, delivery trucks
  - Demonstrations for over the road trucks, cargo handling equipment
  - Locomotive tenders and fuel cells show promise but have not been demonstrated

Zero Emission Applications

- Applicable to short haul trucks, drayage trucks, buses, ground support equipment, cargo handling, and other off-road applications
  - Need to support market development and technology innovation
  - Infrastructure investments needed
- Locomotive tenders and fuel cells show promise but have not been demonstrated

Zero Emission Path to Future Applications

- Zero emission technologies deployed now in stop-and-go, lighter weight, shorter range applications
- Need to technology improvements for heavier loads, longer hauls
  - Wayside power can enable heavy load transport today
  - Fuel cells may be a longer-term solution in over-the-road applications
    - Infrastructure planning necessary

Zero emission technologies need renewable fuels for GHG benefits

- Zero emissions technologies benefit from renewable sources of electricity
  - Renewable portfolio standards are important
  - Grid needs to evolve to handle charging needs
  - Balance demand charges with renewable sources, distributed generation, and vehicle charging needs
- Use of renewable hydrogen could reduce upstream emissions from fuel cells
  - Beyond current future regulatory requirements
  - From lowest carbon upstream sources

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Automation and Efficiencies – Vehicle and Road Technologies

- Connected vehicles, Automated vehicles, and Intelligent transportation systems (ITS)
  - Separately or together these enable multiple strategies that can improve safety, reduce emissions, reduce congestion, and improve traffic flow
- Near-term Opportunity Examples
  - Port terminal, distribution center automation
  - Port truck queuing by appointment
  - Truck platooning (connected vehicles)

Automation and Efficiencies – Vehicle and Road Technologies

- Connected vehicles
  - Communication between vehicle and other vehicles, vehicle and infrastructure
- Automated vehicles
  - Multiple degrees of independent vehicle operation
  - Today – adaptive cruise control, anti-lock braking
  - Future – autonomous vehicle operation
- Intelligent transportation systems (ITS)
  - Communication between vehicles and infrastructure

ARB staff work on-going, seeking input

Automation and Efficiencies – Cargo Handling Equipment

- Port Terminal, Distribution Center Automation
  - Facilitate equipment electrification
  - Increase safety
  - Expedite loading and unloading
    - 30–40 percent operational cost savings ($/TEU)
- Terminal queuing by appointment
  - Organizes container pickup
  - Reduces truck queue lines and associated idling

Automation and Efficiencies – Truck Platooning (connected vehicles)

- Pilot studies show 10-20% reduced fuel consumption
- Benefits for lead and trailing vehicles
- Large scale testing possible on public roads by 2015
- Cost: $500-$2,600 for sensors and safety equipment (2009 dollars)

ARB Staff Seeking Input

- We have presented highlights of our current understanding of technology and fuels
- We are seeking input on gaps and areas where we can improve, including but not limited to:
  - Technology and fuels characterization
  - Current and future vehicle and equipment costs
  - Path and timeline to future technologies
  - Additional areas to consider

Next Steps – Tech Assessments

- Receive and address comments
- Release draft report for additional comment
  - End of October 2014
- Additional staff research
  - Intelligent transportation systems
  - Construction and industrial equipment
- Board Hearing
  - December 2014
  - Two items:
    - Technology Assessment Results and Findings
    - Sustainable Freight Strategy

Next Steps – Air Quality Planning

- SIP development 2015-2016
- Integrated planning for NOx and GHG
- Vision modeling
  - Scenarios to evaluate technology integration and timing

Multiple Opportunities to Comment

- Submit written comments on workshop slides by October 1st:
  - http://www.arb.ca.gov/msprog/tech/comments.htm
- Technology Assessment draft document released end of October
- Submit written comments on draft document by November 28th
- Meet with staff at any time to provide input

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