



Environmental Life-cycle Assessment of Freight Transportation Services:

An overview of the contribution of infrastructure,
vehicles, and fuels to life-cycle emissions

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Transportation as a Service



VEHICLES

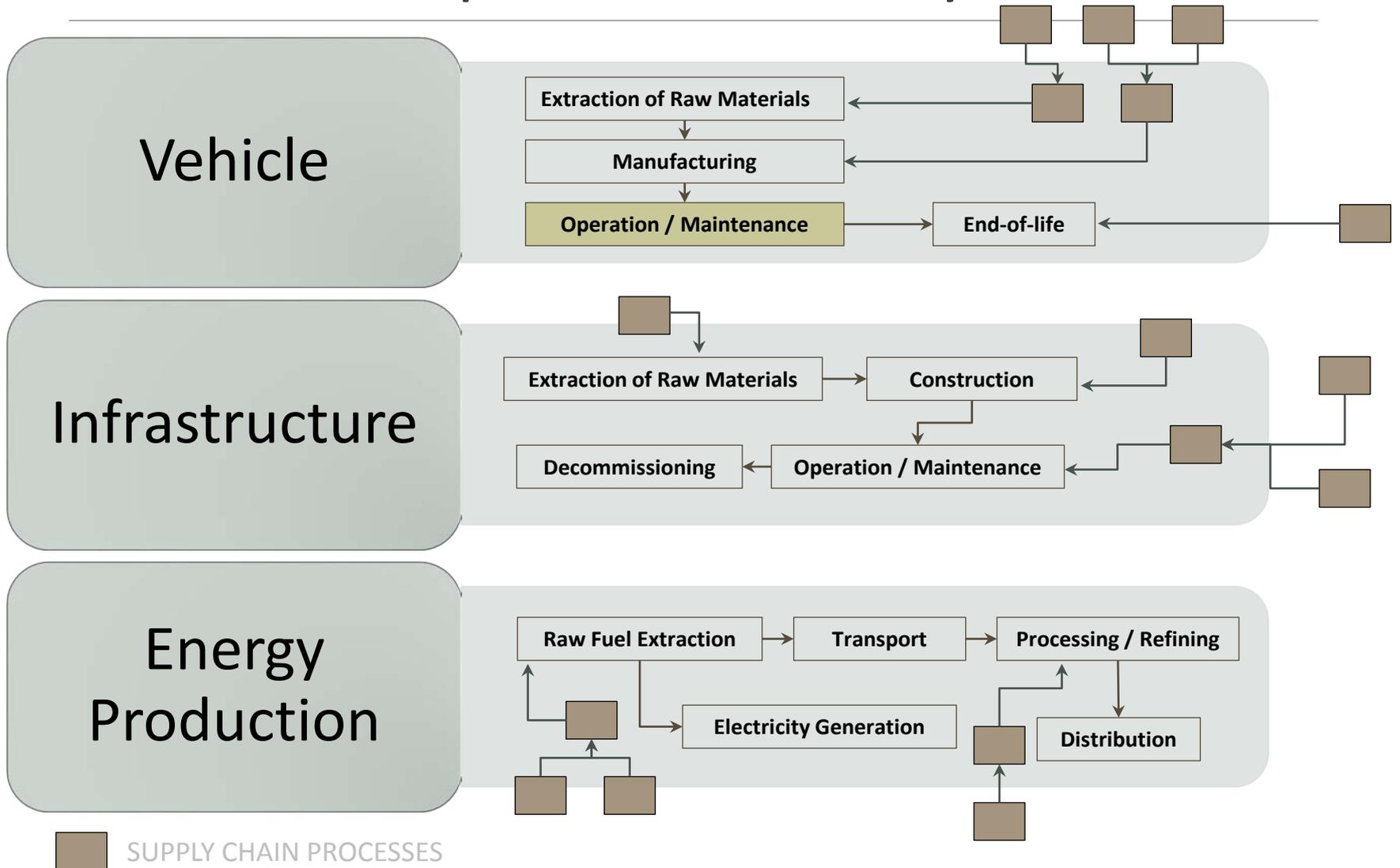


RIGHT-OF-WAY



TERMINAL CAPACITY

The Transportation "System"



Environmental Indicators

Energy

Air Emissions

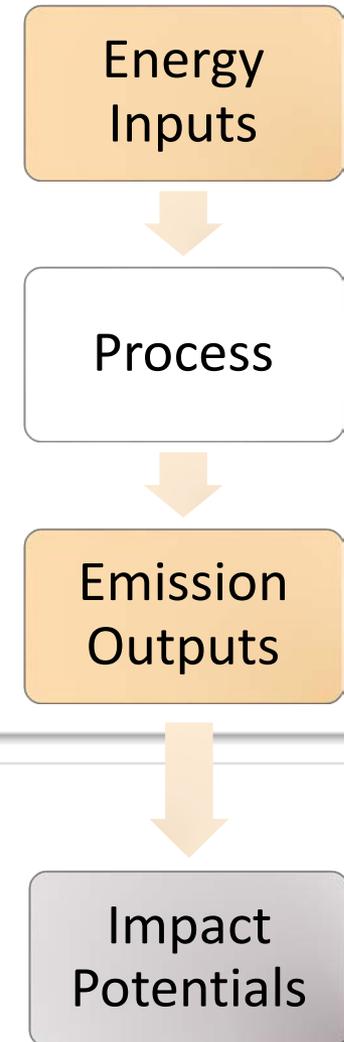
- SO_x Respiratory irritant, acid deposition
- CO Asphyxiant
- NO_x Respiratory irritant, smog
- VOC Photochemical smog, cancerous
- PM Respiratory and cardiovascular damage

Greenhouse Gases

- CO₂, CH₄, N₂O

Others

- Water, labor, costs, toxics, hazardous, etc.



Human Health and Environmental Impact Potentials

- Respiratory: SO_x, NO_x and PM_{2.5}
- Acidification: SO_x and NO_x
- Photochemical Smog Formation: CH₄, CO, VOC, and NO_x
- Eutrophication Potential

Environmental Assessment

- **VEHICLES** - model manufacturing and maintenance.
 - Process-based LCA modeling with SimaPro
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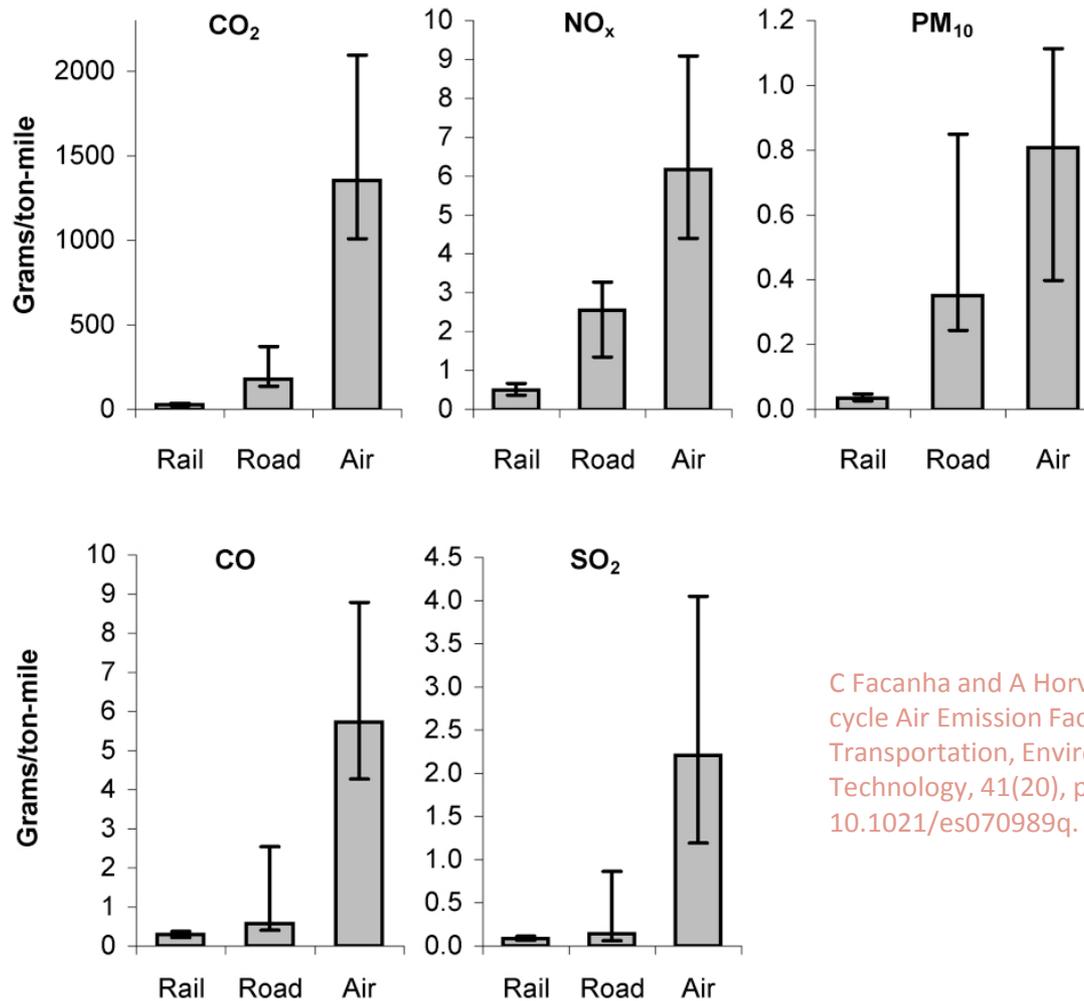
- **INFRASTRUCTURE** - develop infrastructure models.
 - Material production
 - Construction activities
 - Maintenance and rehabilitation cycles

PALATE
FHWA Infrastructure Carbon Estimator
CIRN-LCA

- **ENERGY PRODUCTION** - energy production models.
 - U.S. DOE Argonne's GREET1 model
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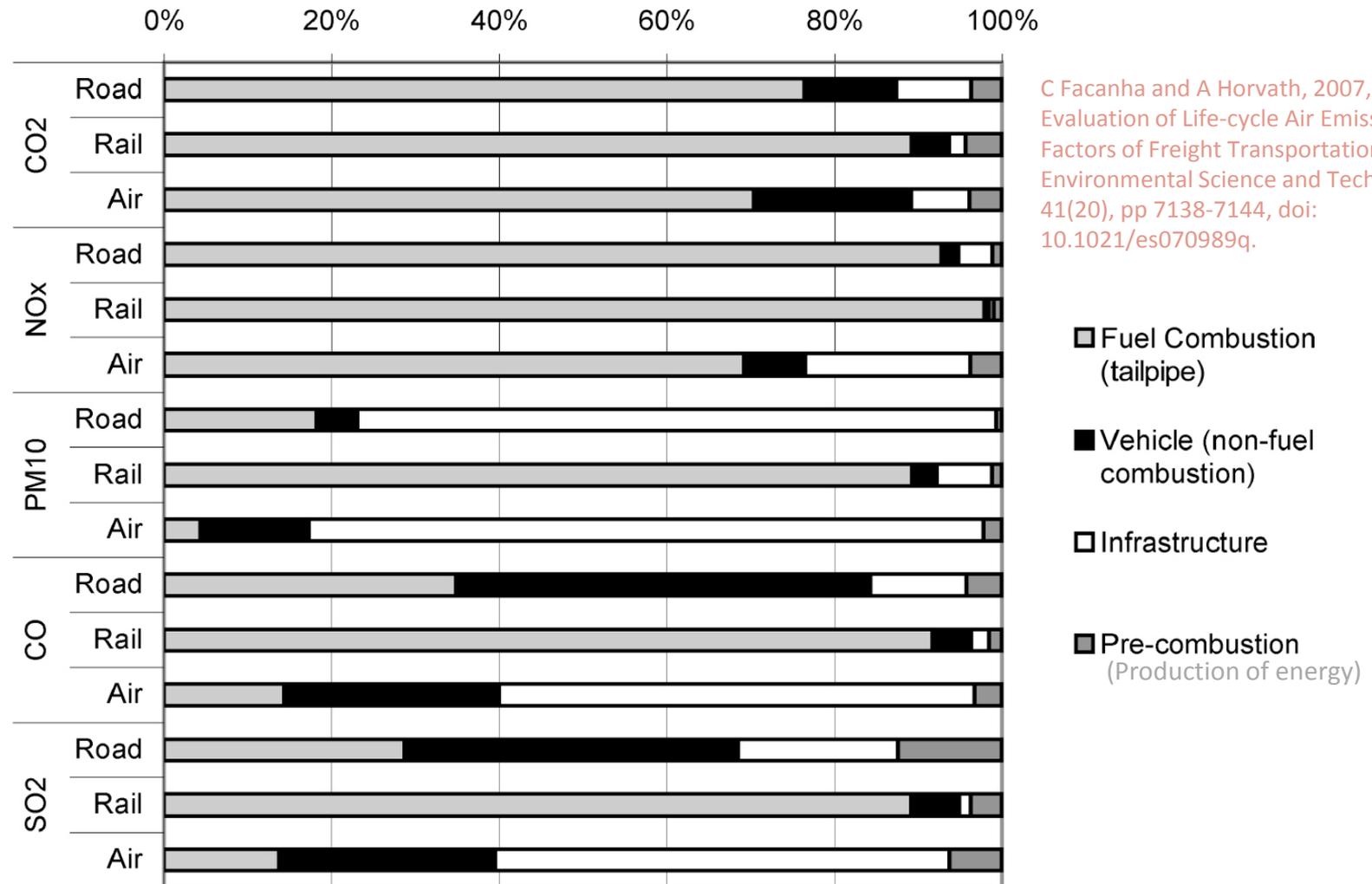
- **SUPPLY CHAINS**
 - Carnegie Mellon University's EIO-LCA
 - Moving more and more towards process-based models

Early Freight LCA Research



C Facanha and A Horvath, 2007, Evaluation of Life-cycle Air Emission Factors of Freight Transportation, Environmental Science and Technology, 41(20), pp 7138-7144, doi: 10.1021/es070989q.

Early Freight LCA Research

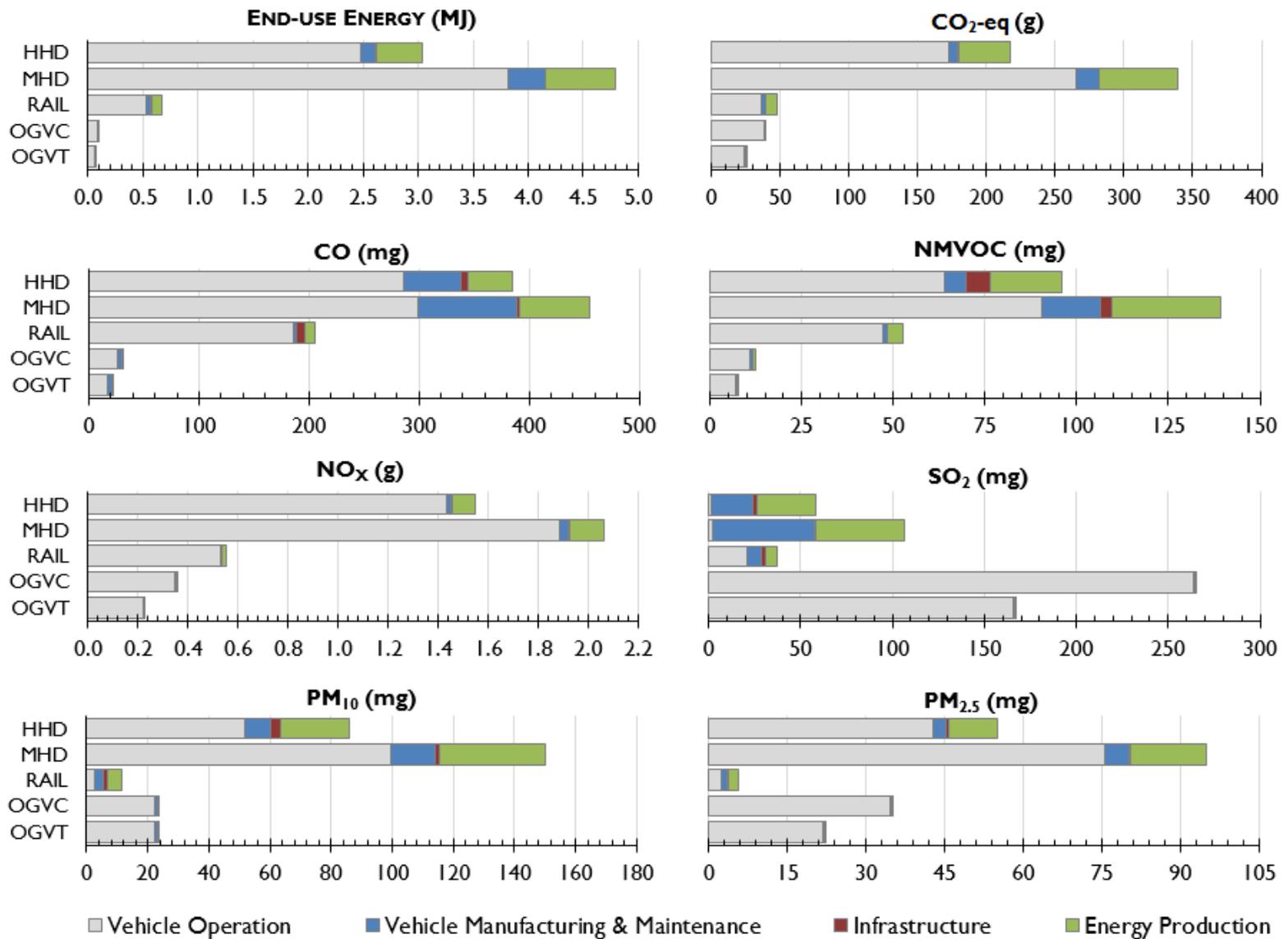


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- Fuel Combustion (tailpipe)
- Vehicle (non-fuel combustion)
- Infrastructure
- Pre-combustion (Production of energy)

Life Cycle Grouping	TRUCKING	AIR	MARINE (OGV)	RAIL
Vehicle				
Manufacturing	<ul style="list-style-type: none"> Truck Manufacturing Transport to Point of Sale 	<ul style="list-style-type: none"> Aircraft Manufacturing Engine Manufacturing 	<ul style="list-style-type: none"> Ship Manufacturing 	<ul style="list-style-type: none"> Train Manufacturing Transport to Point of Sale
Operation	<ul style="list-style-type: none"> Propulsion Idling 	<ul style="list-style-type: none"> APU / Startup / Taxi Out / Takeoff / Climb Out / Cruise / Approach / Landing / Taxi In 	<ul style="list-style-type: none"> Line Haul Near port Hoteling 	<ul style="list-style-type: none"> Propulsion Idling
Maintenance	<ul style="list-style-type: none"> Truck Maintenance Tire Replacement Battery Replacement 	<ul style="list-style-type: none"> Aircraft Maintenance Engine Maintenance 	<ul style="list-style-type: none"> Ship Maintenance Engine Maintenance 	<ul style="list-style-type: none"> Train Maintenance
Infrastructure				
Construction	<ul style="list-style-type: none"> Roadway 	<ul style="list-style-type: none"> Airport Runway, Taxiway, & Tarmac 	<ul style="list-style-type: none"> Ports (Buildings and Facilities) 	<ul style="list-style-type: none"> Tracks Terminals
Operation	<ul style="list-style-type: none"> Roadway Lighting Herbicide Use Deicing 	<ul style="list-style-type: none"> Airport Energy Runway Lighting Deicing Fluids Ground Support Equipment 	<ul style="list-style-type: none"> Ancillary equipment use Lighting Port energy use 	<ul style="list-style-type: none"> Track Lighting Herbicide Use Train Control Equipment
Maintenance	<ul style="list-style-type: none"> Roadway Maintenance 	<ul style="list-style-type: none"> Airport Runway, Taxiway, & Tarmac 	<ul style="list-style-type: none"> Port infrastructure Port equipment 	<ul style="list-style-type: none"> Track Maintenance
Energy Production				
Extraction, Processing, & Distribution	<ul style="list-style-type: none"> Gasoline/Diesel/Natural Gas Extraction, Processing, & Distribution 	<ul style="list-style-type: none"> Jet Fuel Extraction, Processing, & Distribution 	<ul style="list-style-type: none"> Heavy Fuel Oils Extraction, Processing, & Distribution 	<ul style="list-style-type: none"> Diesel Fuel Extraction and Processing, Electricity Generation, Transmission & Distribution

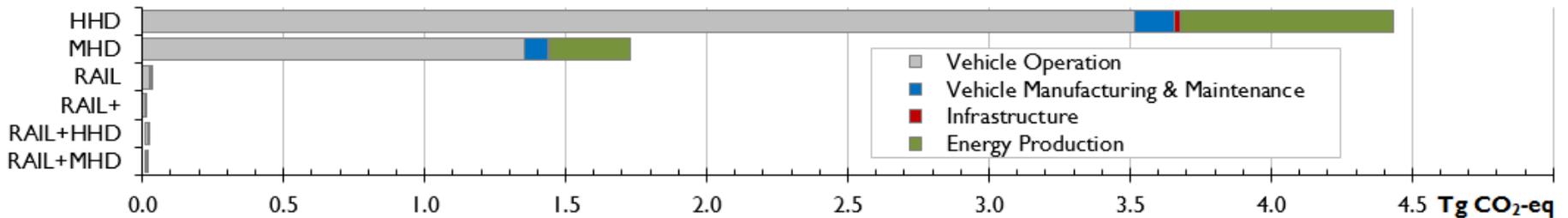
Life-cycle Energy Use and Emissions per Metric Tonne per Kilometer in California



HHD: Heavy duty truck. MHD: Medium duty truck. OGVC: Container ocean-going vessel. OGVT: Tanker ocean-going vessel.

M Nahlik, A Kaehr, M Chester, A Horvath, and M Taptich, Expected 2015, Goods Movement Life-cycle Assessment for Greenhouse Gas Reduction Goals, Journal of Industrial Ecology, Volume and Issue Forthcoming.

California Life-cycle Goods Movement Emissions Greenhouse Gas Emissions per Year



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Reducing Impacts in the Life-cycle

VEHICLE OPERATION

- Technology Improvements
- Fuel Switching
- Operations
- Smooth Pavements
- High Stiffness Pavements

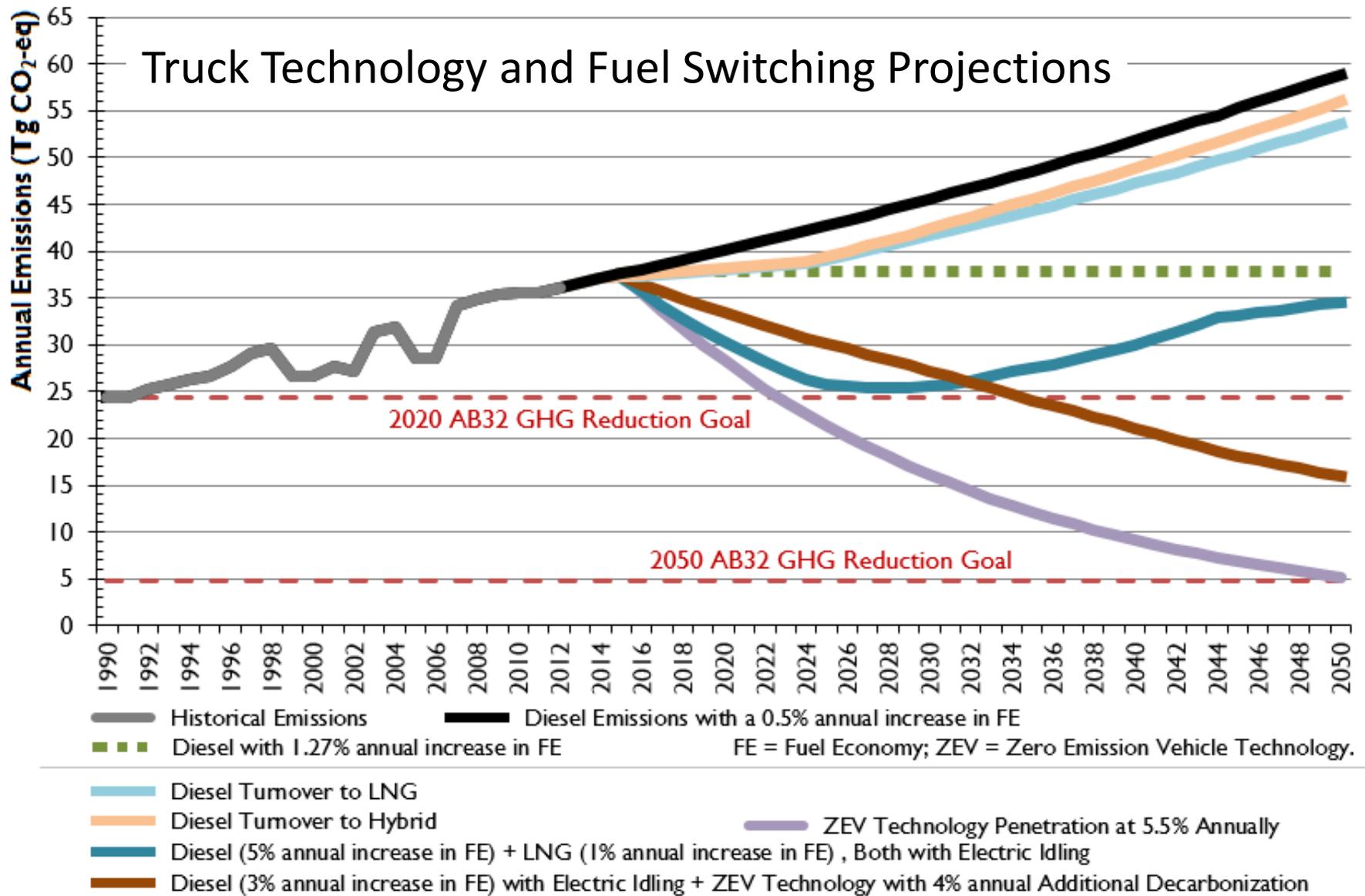
INFRASTRUCTURE CONSTRUCTION, OPERATION, and MAINTENANCE

- Reduced Material Use
- Use of Recycled Materials
- High Albedo Pavements
- Light Colored Pavements and/or Efficient Lighting
- Projects with Few Construction Activities over Infrastructure Life

ENERGY PRODUCTION

- Petroleum Source
- Fuel Switching
- Electrification

Truck Technology and Fuel Switching Projections



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