Trends in Onroad Transportation Energy and Emissions

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Trends in Onroad Transportation Energy and Emissions

Summary Article in June 2018 EM

50-page Paper in June 2018 Journal of A&WMA

Plus... Supplemental Materials
Scope of the Critical Review

• National and Global Energy Use and Emissions
• Factors Affecting Travel Demand and Vehicle Operation
• Vehicle Energy Consumption
• Vehicle Emissions
• Measurement Methods
• Impacts on Exposure and Health
Number of Registered Onroad Vehicles in the U.S.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Registered Vehicles (millions)</th>
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<tbody>
<tr>
<td>1900</td>
<td>0</td>
</tr>
<tr>
<td>1920</td>
<td>50</td>
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<tr>
<td>1940</td>
<td>100</td>
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<tr>
<td>1960</td>
<td>150</td>
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<tr>
<td>1980</td>
<td>200</td>
</tr>
<tr>
<td>2000</td>
<td>250</td>
</tr>
<tr>
<td>2020</td>
<td>300</td>
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</tbody>
</table>

FHWA

BTS/USDOT

Trends in Onroad Transportation Energy and Emissions
Public Road Mileage and Vehicle Miles Traveled in the U.S. Since 1920

Year


Public Roads (Millions of Miles)

0 1 2 3 4 5 6 7 8 9

Lane Miles
Public Road Mileage
VMT

Vehicle Miles of Travel (VMT)
(Trillion miles travelled)

FHWA, 2017
Global In-Use Onroad Vehicle Stock

44% Increase Over 10 Years

Source: OICA, 2018
Health Burden

• Air pollution from motorized road transport
• Premature death
• Global estimates range between 184,000 and 242,000 (Bhalla et al., 2014; Chambliss et al., 2014)
• Based on fine particulate matter (PM$_{2.5}$)
• By country:
  • India (39,000)
  • China (27,000)
  • U.S. (15,000)
On-road transportation accounts for 13% of global energy use
79.4 Quadrillion BTU
Global Onroad Vehicle Energy Consumption: Actual to 2014, Projected Thereafter

33% Projected Increase From 2014 to 2050

Source: EIA, 2017d

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OECD Light Duty Vehicles
OECD 2- and 3-Wheel Vehicles
Non-OECD Light Duty Vehicles
Non-OECD 2- and 3-Wheel Vehicles
OECD Buses
OECD Heavy Duty Trucks
Non-OECD Buses
Non-OECD Heavy Duty Trucks
U.S. Light Duty Vehicle Fuel Economy Trends

Source: EPA, 2018

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Trends in U.S. Light Duty Vehicle Technology: Fuel Delivery

Source: US EPA, 2018
Trends in U.S. Light Duty Vehicle Weight and Horsepower

Increasing share of downsized turbo-charged engines

Source: US EPA, 2018
U.S. Sales (1,000s) of Electrified Powertrain Vehicles from 2011 to 2017

https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/
Autonomous Vehicles

- Uncertainties regarding market share in 2030, 2050
- Legal issues, social acceptance, institutional adaptation
- Could reduce travel delay and improve travel time reliability
- Could be inherently safer
- Could have shared AVs that are "right-sized"
- Platooning, efficient routing, efficient driving
- Possibly lower "cost" of travel, more accessibility
- Long-term effect on land-use patterns
- Adaptive traffic management via dynamic road pricing or other schemes
- Could decrease or increase energy consumption and emissions
Impacts of Climate Change

• In 2009, the U.S. Environmental Protection Agency (EPA) issued an endangerment finding for six greenhouse gases (GHGs) because of their contribution to climate change (EPA 2009b).

• Anthropogenic emissions of GHGs are “extremely likely to have been the dominant cause of the observed warming since the mid-20th century” - Intergovernmental Panel on Climate Change (IPCC), 2014

• “Choices made today will determine the magnitude of climate change risks beyond the next few decades” - U.S. Global Change Research Program, 2017

• Significant possibility for unanticipated changes based on compound events and critical threshold/tipping point events (US GCRP, 2017)

• Impacts from climate change on extreme weather and climate-related events, air quality, and the transmission of disease through insects and pests, food, and water increasingly threaten the health and well-being of the American people, particularly populations that are already vulnerable (US GCRP, 2018)
Greenhouse Gas Emissions

• Global road transport emissions grew from \(3.3 \text{ GtCO}_2\) in 1990 to \(5.7 \text{ GtCO}_2\) in 2015 (18% of global emissions)

• For road transport in the U.S., \(\text{CO}_2\) contributes 96.4% of the total global warming potential, followed by HFCs (2.8%), \(\text{CH}_4\) (0.7%), and \(\text{N}_2\text{O}\) (0.1%).

• In the U.S., GHG emissions are up 16% for passenger cars and 79% for medium- and heavy-duty trucks since 1990.
EPA Light Duty Vehicle GHG Emissions Standards

- Promulgated in 2010: 2012 to 2016 model years
- Promulgated in 2012: 2017 to 2025 model years – “54.5 mpg”
- Mid-Term Evaluation, January 2017: standards are appropriate
- Reconsideration, April 2, 2018: standards are “not appropriate”

- EPA Science Advisory Board:
  - “The April 2, 2018 final determination relied extensively on public comment without peer review or independent evaluation or validation of claims made by public commenters.”
  - “The SAB should consider this action for review with regard to the adequacy of the supporting science”

- Proposed “Safer Affordable Fuel-Efficient (SAFE)” rule published August 24, 2018, would roll back the 2012 standard
- The Proposed Action “is projected to result in an increase in energy consumption, an increase in most criteria pollutant emissions...(O)verall U.S. health impacts associated with air quality (mortality, asthma, bronchitis, emergency room visits, and work-loss days) are anticipated to increase across the Proposed Action.”
Electric Vehicles: A Panacea?

• The U.S. Clean Power Plan was an attempt at the Federal level to reduce GHG emissions from power generation
  • Regulatory action is in progress to replace the Clean Power Plan with proposed “Affordable Clean Energy Rule” based on incremental heat rate improvements
  • EPA projects an increase in mortality from greater exposure to PM$_{2.5}$ for the proposed ACE rule compared to the CPP
  • The social cost of carbon (SCC) has been revised downward ($6 to $11 versus $35 to $66 per ton CO$_2$, from 2015 to 2050, 3% discount rate).

• State renewable energy portfolio standards can be effective
Trends from 2010 with Projections to 2040 in the Global Fuel Mix for Electric Power Generation

Source: EIA, 2017

Source: EPA, 2018
Three Way Catalyst

- Fully implemented in 1996
- Estimated to have reduced emissions through 2007:
  - 4 billion tons of HC
  - 4 billion tons of NO\textsubscript{x}
  - 40 billion tons of CO
  
  Source: Mooney, 2007
- Widely applicable to stoichiometric burn engines
Vehicle Emission Controls: Diesel Particle Filter (PDF)

Widely used in U.S. on-road diesel trucks since 2007

Removes more than 95% of particle mass and 99% of particle number

Particles emitted from DPF-equipped vehicles tend to be very small (nucleation mode)
Vehicle Emission Controls: Selective Catalytic Reduction

- Widely used in U.S. on-road diesel trucks since 2010
- Requires urea: “diesel exhaust fluid”
- Requires sufficient operating temperature
- May not be effective at low exhaust temperature
Empirical Trends in Vehicle Emissions (Example)

- From 1990 to 2010, onroad CO emission rates decreased by 80% to 90% in Los Angeles, Houston, and New York.
- From 1990 to 2012, ambient concentrations of diesel particulate matter decreased by 68% in California.
- VOC emissions have decreased.

Warneke et al., 2012
Secondary Organic Aerosols

- SOA Precursors
  - Intermediate Volatile Organic Compounds (IVOCs): 13-19 carbon atoms
  - Semi-Volatile Organic Compounds (SVOCs): 20-26 carbon atoms
- Sub-micrometer particles
- SOA formation depends on atmospheric chemistry (e.g., peroxy radicals)
- SOA yield appears to have decreased from 1970 to 2010 by approximately 33% to 50%

May et al., 2014
Emissions Processes: Total Hydrocarbon Emissions

Gasoline Passenger Cars
- Running Exhaust
- Start Exhaust
- Crankcase Running
- Crankcase Start
- Leaks
- Venting
- Permeation
- Displacement
- Spillage

Based on MOVES2014a

NC STATE UNIVERSITY
Trends in NO$_x$ Emission Factors: 1990 to 2050

Based on MOVES2014a
Trends in NO$_x$ Emissions Source Distribution: 1990 to 2050

Based on MOVES2014a
Measurement Methods

• Chassis dynamometer
• Engine dynamometer
• Tunnel studies
• Remote sensing
• Chase vehicles
• Portable emission measurement systems

• Mobile emissions laboratories
• Automotive sensors
• Twin site ambient measurements
• Inverse modeling
• Evaporative emissions
• Low cost sensors

Discussed in more detail in the Critical Review paper and its Supplemental Material
Transportation, Exposure, and Health

• Evidence for and estimates of the health effects of traffic-related air pollution
• Empirical evidence regarding near-road exposure concentrations
• Empirical evidence regarding in-vehicle exposures
• Methods for modeling human exposure

Discussed in more detail in the Critical Review Supplemental Material

Source: Grieshop, Saha (NCSU), Khlystov (DRI)
Emissions

• Areas for ongoing assessment:
  • Durability and operational limitations of diesel post-combustion controls
  • Life cycle inventories of alternative fuels/energy sources
  • Mobile Source Air Toxics (MSATs)
  • Speciated PM
  • Ultrafine PM
  • Secondary Organic Aerosols
Wear Emissions

• Tire wear is relevant to any vehicle with tires
• Brake and tire wear emissions relatively weakly quantified
Greenhouse Gas Emissions

• Growth in vehicle stock, VMT, and fossil fuel consumption will lead to increase in GHG emissions

• Unless… priorities to reduce carbon intensity of transportation energy consumption are pursued – e.g.,
  • Increasingly stringent fuel economy standards
  • Increased vehicle electrification coupled with lower carbon power generation
Exposure and Health

More work is needed to characterize spatial and temporal variability in emissions, exposure, and adverse effects related to transportation.
Related Project: Exposure Measurement and Modeling in Hong Kong
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Acknowledgments

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