The Future of Transportation Significant Progress ...And the challenges Looking Ahead

> Dan Greenbaum, President Health Effects Institute

HEI Annual Conference Alexandria, Virginia April 30, 2017



The Future of Transportation

- We've come a long way...
 - With significant improvement in air quality and health
- The Challenges ahead:
 - Fine-tuning the newest internal combustion technologies and accelerating replacement
 - Making way for the newest technologies, especially electric drive
 - Taking a broader look at mobility solutions
- Looking Ahead... and our Session Today

We've Come a Long Way...



We've Come a Long Way...





We've Come a Long Way:

Improvements in PM and NO_x Diesel Emission Standards

EPA Heavy-Duty Engine Emission Standards





We've Come a Long Way:

ACES: Dramatic Progress on Mass and Particle Number

(A) Mass Emissions (B) Particle Number Emissions 0.07 Average Brake-Specific Particle Number 350 10¹²) 0.06 0.0016 300 Emissions (particles/hp-hr imes0.05 0.0012 250 g/bhp-hr g/bhp-hr 0.0008 0.04 200 0.0004 0.03 150 0.0000 2007 2010 0.02 100 Model Year 0.01 50 0 0 2007 2010 2004 2007 2010 2007 2010 2004 FTP FTP FTP 16-hr 16-hr Model Year

7

Model Year / Testing Cycle

ACES = Advanced Collaborative Emissions Study



We've Come a Long Way

More new technology clean diesel trucks and buses on the road Over 40% now meet at least 2007 Standards

Percent Fleet Penetration



We've Come a Long Way: Effect of Diesel Rules in Southern California



- On-road measurements show diesel rules reducing PM and NO_x on a truck-dominated freeway near the Ports of Los Angeles and Long Beach
- Continued reductions expected as the Truck and Bus Rule is implemented

Kozawa et al. (2014) Environmental Science & Technology, 48, 1475-1483

And even recent VW on-road tests demonstrate progress... PM emissions were dramatically below US EPA Tier 2 – Bin 5 emissions standard (ICCT/WVU tests)

(there were, of course, NOx emission in-use issues...)

Figure 4.11: Average PM emissions of test vehicles over the five test routes compared to US-EPA Tier2-Bin5 emissions standard; repeat test variation intervals are presented as ±1σ; Route 1 for Vehicle A includes rush-hour/non rush-hour driving, no PM data collected for Vehicle C, 'R' designates routes including a test with DPF regeneration event, 'nd' - no data available



10

We've Come a Long Way: Greenhouse gas (GHG) and Fuel Economy Standards



* Note that Japan has already exceeded its 2020 statutory target, as of 2013.





With Progress in Nearly Every Country Largely Enhanced Technology Internal Combustion (IC) Engines: Gasoline Direct Injection, Diesel, Hybrids

Figure 1 • Average new LDV fuel economy by country, normalised to the WLTC, 2005-15



Improved Fuel Economy 2005 – 2015 (Source: GFEI)



The Future of Transportation

- We've come a long way...
 - With significant improvement in air quality and health
- The Challenges ahead:
 - Fine-tuning the newest internal combustion technologies and accelerating replacement
 - Making way for the newest technologies, especially electric drive
 - Taking a broader look at mobility solutions
- Looking Ahead... and our Session Today

Continued Challenges with Ozone



Source: Gauderman, et al NEJM 2015

Figure 1. Levels of Four Air Pollutants from 1994 to 2011 in Five Southern California Communities.

Colored bands represent the relevant 4-year averaging period for the analysis of lung-function growth in each of the three cohorts, C, D, and E. $PM_{2.5}$ denotes particulate matter with an aerodynamic diameter of less than 2.5 μ m, and PM_{10} particulate matter with an aerodynamic diameter of less than 10 μ m.



Challenge: Real World Emissions Compliance High Europe Light Duty Diesel NO_x In Use Emissions (Beyond VW) NO_x emissions of selected diesel vehicles sold in Europe, average ratio of actual emissions to EU regulatory limit

180 mg/km, for cars sold 2009-14 (Euro 5) **80 mg**

80 mg/km, for cars sold 2014-current (Euro 6)



Economist.com

European Cities, EU respond

Mayors of Paris, London, Seoul Call for action, new consumer Websites Tougher EU Real Driving Emissions (RDE)



Next Steps: Fine-Tuning, Enhancing Internal Combustion (IC) Technology

- NO_x Controls:
 - Under certain conditions, selective catalytic reduction (SCR) may be too cool to work efficiently
 - Manufacturers and others are developing new technologies
 - Strong push in California (and Northeast) to lower the current heavy duty 2010 NO_x standard
 - Session at this conference on the science of NO_x contributions to Ozone Tuesday Morning
- Diesel Particulate Matter (PM) Filters:
 - Seem to work well under a variety of conditions
 - Robust technology, but some early evidence of failure in a relatively small number
- Gasoline Direct Injection (GDI)
 - Do particle numbers raise possibility of filters?
- Fuels...
 - What are the best fuels to support enhanced IC technology?
- Need to find ways to accelerate replacement



The Future of Transportation

- We've come a long way...
 - With significant improvement in air quality and health
- The Challenges ahead:
 - Fine-tuning the newest internal combustion technologies and accelerating replacement
 - Making way for the newest technologies, especially electric drive
 - Taking a broader look at mobility solutions
- Looking Ahead...and our Session Today

The Challenge: Thinking beyond 2025 GHG and Fuel Economy Standards





* Note that Japan has already exceeded its 2020 statutory target, as of 2013.





Challenge: Making Progress on Electric Drive Battery Electric, Fuel Cells



Figure 1 • Evolution of the global electric car stock, 2010-15



Note: the EV stock shown here is primarily estimated on the basis of cumulative sales since 2005.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2016), IHS Polk (2014), MarkLines (2016), ACEA (2016a), EEA (2015) and IA-HEV (2015). Source: International Energy Agency (IEA) 2016

The Future of Transportation

- We've come a long way...
 - With significant improvement in air quality and health
- The Challenges ahead:
 - Fine-tuning the newest internal combustion technologies and accelerating replacement
 - Making way for the newest technologies, especially electric drive
 - Taking a broader look at mobility solutions
- Looking Ahead... and our Session Today

Challenge: How Do We Travel in 2050? The Third Ring Road in Beijing....Today





The Third Ring Road – of many!



The Challenge (and Opportunity): New Ways of Travel

CAR SHARING



The Challenge (and Opportunity): Driverless Cars



A world of driverless cars

Fully autonomous vehicles are developing faster than anyone would have thought a few years ago, with many experts predicting that they will become widely available in the next 5-10 years. Many questions remain, but it is already possible to imagine how this new world of driverless cars will work.

PERCEPTION Vehicles use radar to detect obstacles, a laser ranging system to map the surround-ings in three dimensions, and video cameras to identify objects such as traffic lights, construction signs, pedestrians and other vehicles.

DECISION AND ACTION To make the appropriate responses to rare events — such as a ball bouncing in from a playground, or a plastic bag blowing down the roadway — the cars rely on algorithms refined through millions of kilometres of test drives.

ADAPTIVE TRAFFIC FLOW Smart infrastructure integrates V2V signals from the moving cars to optimize speed limits, traffic-light timing and the number of flanes in each direction on the basis of the actual traffic load. The result is a smoother flow, shorter

travel time and less energy wasted at traffic lights or in traffic jams.

ROUTE PLANNING An on-board computer uses sensor data to plot a route that gets the car

where it needs to go, while avoiding people, potholes and other vehicles.

LOCATION Mapping software uses Global Positioning System data to tell the car where it is in relation to roads, traffic signals, and other landmarks.

The decade when driverless cars are predicted to become widespread.

ILLUSTRATION BY DON FOLEY; TEXT BY N. MITCHELL WANDROP; DESIGN BY KELLY KRAUSE

ROAD TRAINS Vehicles can take Fuel savings for cars that travel in formation. time.

advantage of aerodynamics and save fuel by following one another almost bumper to bumper They are protected from catastrophic pile-ups by their V2V radios, which allow all the cars in line to hit their brakes at the same

COMMUNICATION (V2V) radios send signals between cars, trucks and infrastructure items such as traffic lights.

CITIES TRANSFORMED

ASS TRANSPORT People increasingly give up owning cars in favour of calling companies to pick them up wherever they are and drop them off wherever they need to go — a driverless version of a ride-sharing service.

/11

101

LAND USE Urban centres begin to undo the many accommodations they have made for personal vehicles — starting with the vast quantities of real estate devoted to parking, which could be adapted to more productive uses.

One estimate of the number of US parking spaces. Many could be used for other purposes if people ride-share more.

Source: Nature

The Challenge (and Opportunity): Putting it All Together (NYC DOT 2013)

How do we consider the many different choices for transportation to ensure sustainable mobility and access well into the future?

Sustainable Streets: 2013 and Beyond

New York City Department of Transportation

Putting it All Together





Putting it All Together

UBERATC.COM/CAR

UBER

0









And maybe there is an even better solution???



Looking Ahead...

- We HAVE come a long way!
 - Vehicle air pollution is down substantially even with increased vehicles, travel
 - Enhanced internal combustion (IC) is improving fuel economy, GHG emissions
- There IS still work to do:
 - To fine-tune and enhance the IC technologies
 - And accelerate replacement of the older technologies
 - To build the technology and market for Electric Drive
 - And to put it "all together" for enhanced mobility

Our Session Today

- The GDI Engine: Features, Emissions, and Effect of Fuel Composition
 - Allen Robinson, Carnegie Mellon University
- Looking Ahead: Electric Drive
 - Nic Lutsey, International Council on Clean Transportation
- The Future of Mobility in the Urban Context
 - Susan Zielinski, Former head of the Sustainable Mobility and Accessibility Research and Transformation initiative, University of Michigan
- Wrap-Up: The Way Forward

Thank You

Dan Greenbaum dgreenbaum@healtheffects.org

