

The VW Story and Its Impact on Future In-use Emissions Compliance and Control Technologies

6th International PEMS Conference & Workshop

University of California, Riverside
College of Engineering - Center for Environmental Research and Technology (CE-CERT)
March 17 - 18, 2016

Dan Carder, Marc Besch, Arvind Thiruvengadam, Hemanth Kappanna, and Gregory Thompson

Center for Alternative Fuels, Engines, and Emissions
West Virginia University



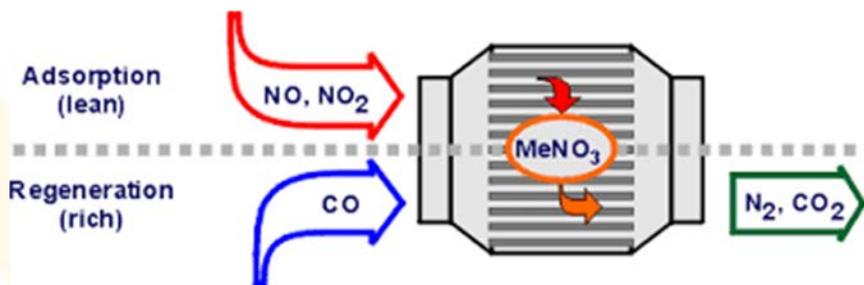
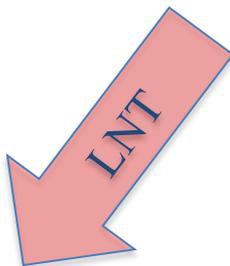
ICCT Light-Duty Diesel Project

- Initial Request by ICCT
 - Initial Contact by Representatives from Horiba Ltd. on 11/15/2012
 - Identify European-based Diesel Engines Sold in the United States Meeting at Least Tier 2 Bin 5, LEV II Emissions
 - Propose a Plan to Evaluate the In-use Emissions from a Representative Selection of Suggested Vehicles – Request Specified Two SCR-Equipped and One Lean NOx Trapped-Equipped Vehicles
 - Proposed Budget ~\$193,662 with Multiple Options
 - Project Award ~ \$69,387

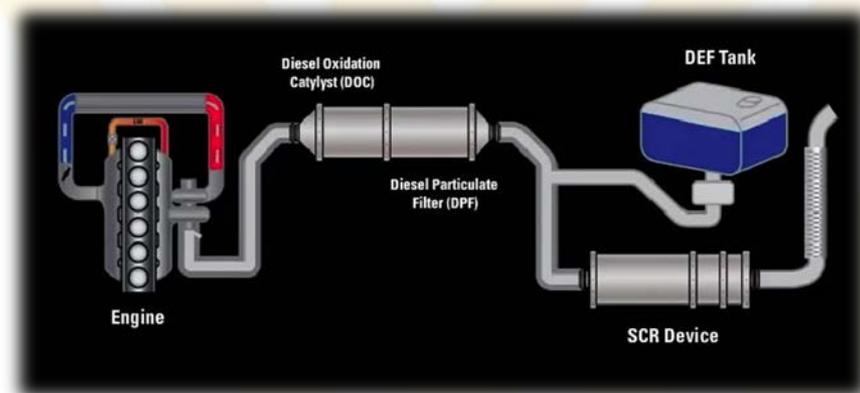


Emissions Control

- Typical Diesel OEM Solutions
- Exhaust Gas Recirculation (EGR)
- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- And:



https://www.dieselnet.com/tech/cat_diesel.php



<https://www.demanddetroit.com/performance/emissions.aspx>

Richard Dorenkamp



12th Diesel Engine-Efficiency and Emissions Research (DEER) Conference
August 20-24, 2006, Detroit, Michigan

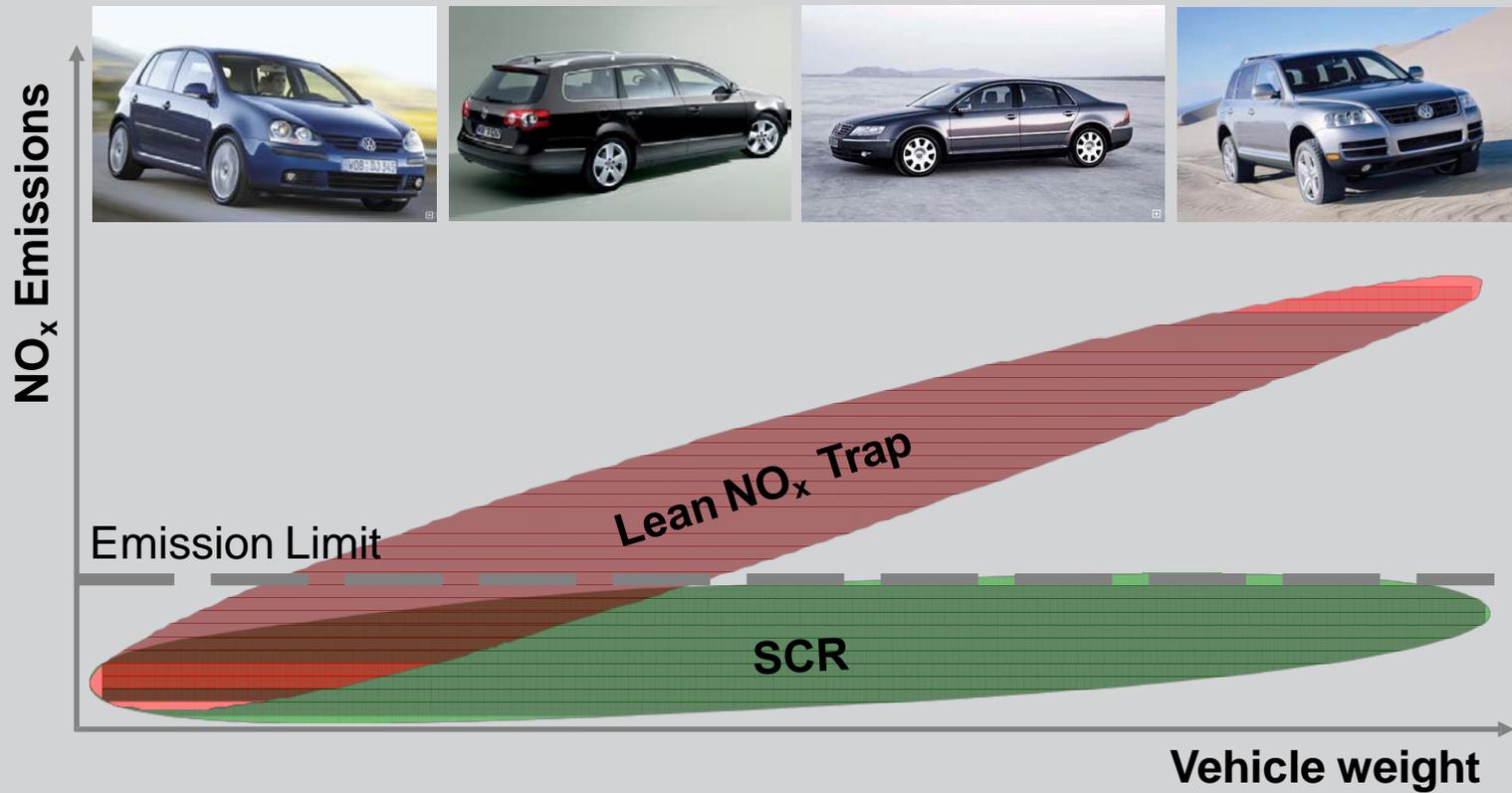
LNT or Urea SCR Technology:

Which is the right technology for TIER 2 BIN 5 passenger vehicles?

**Diesel Engine Development, Volkswagen AG,
Wolfsburg**



System Applicability

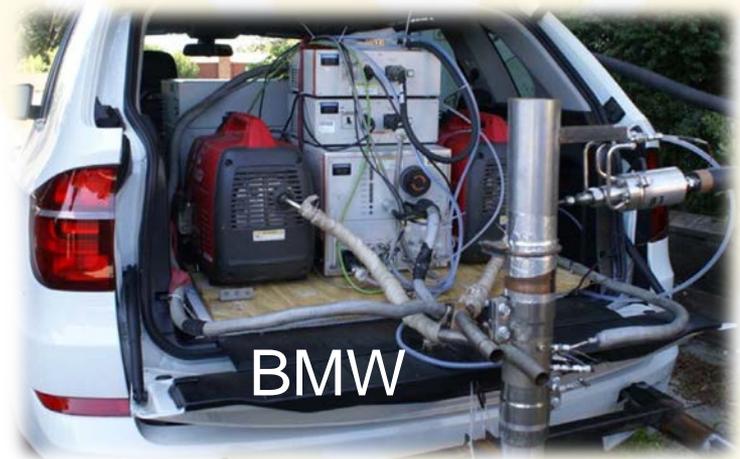


ICCT Light-Duty Diesel Project Protocol

- Initial Proposal Planned Work Around Morgantown, WV, and North Florida
- Vehicle Recruitment Resulted in Location Change to Southern California
- Incorporated CARB Chassis Dynamometer Test Facility to Provide Baseline Data
- Routes Selected to Provide Representative In-use Operation of City, Suburban, and Highway Driving
- Part of the 1970's Route in Los Angeles used to Generate the UDDS Included
- Grade Included for Aftertreatment Effects
- Extended Highway Driving to study PM Regeneration Events



Methodology - Test Vehicles



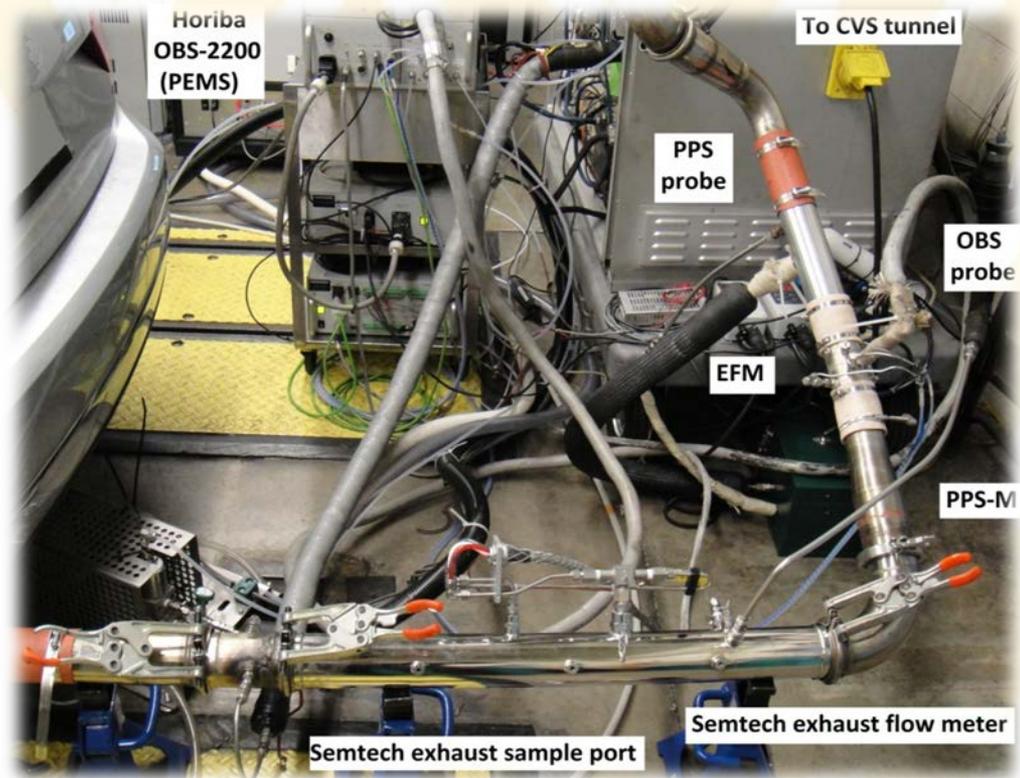
Methodology - Test Routes

- Route 1: highway driving in Los Angeles
- Route 2: urban driving in downtown Los Angeles
- Route 3: rural and uphill/downhill driving in LA's foothills
- Route 4: urban driving in downtown San Diego
- Route 5: urban driving in downtown San Francisco

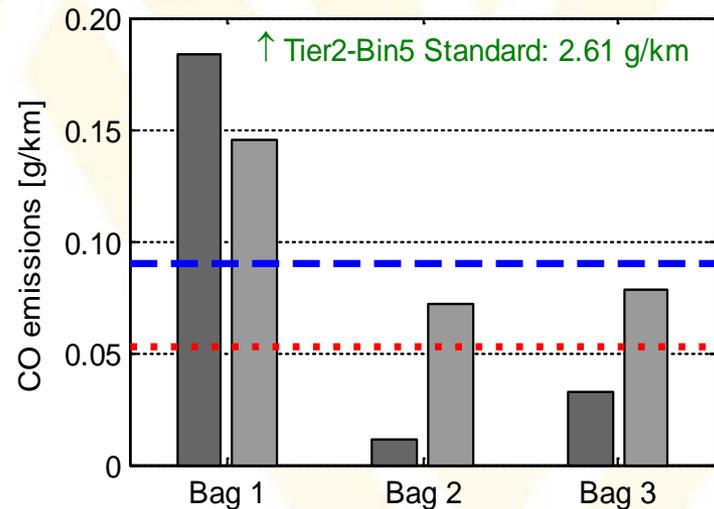
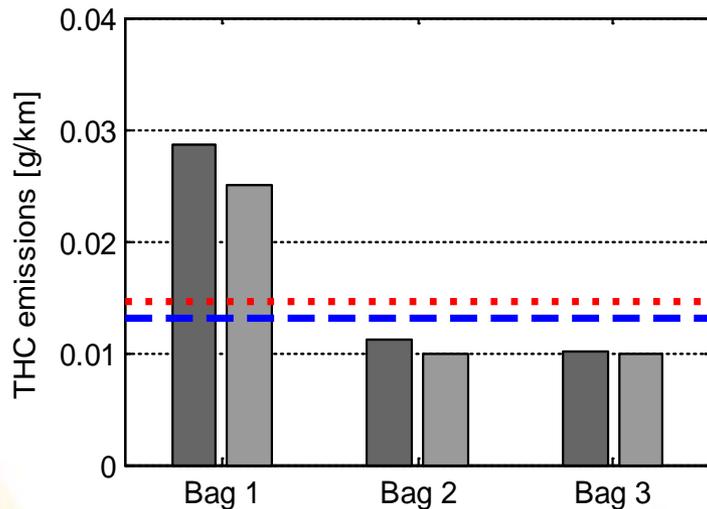
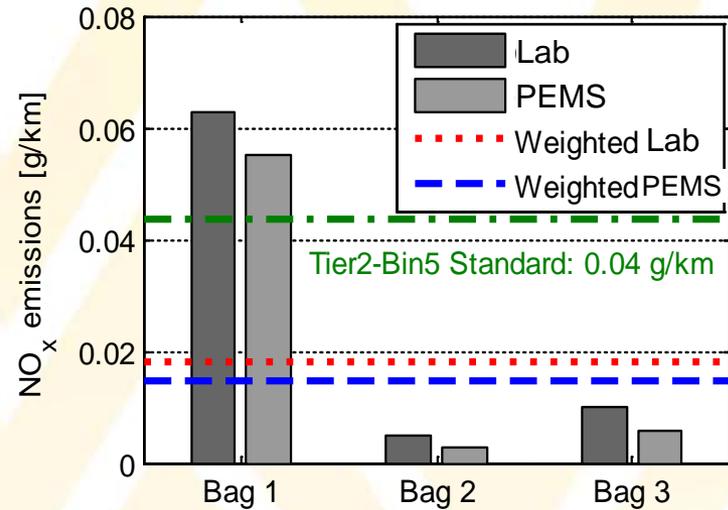
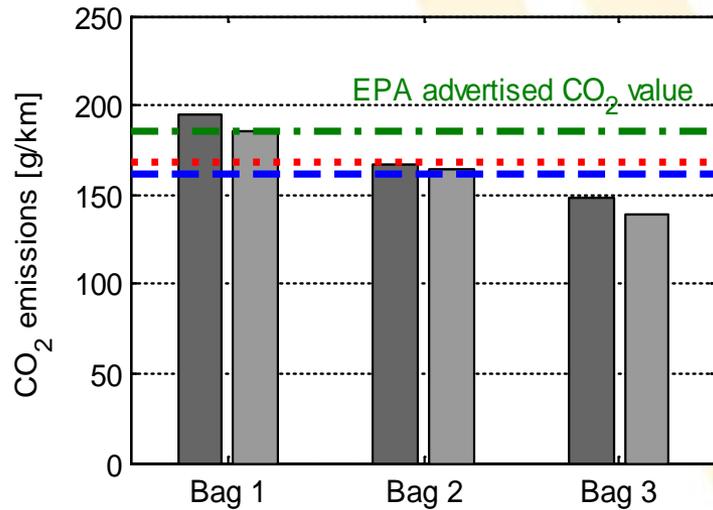


Chassis Dynamometer Testing at CARB

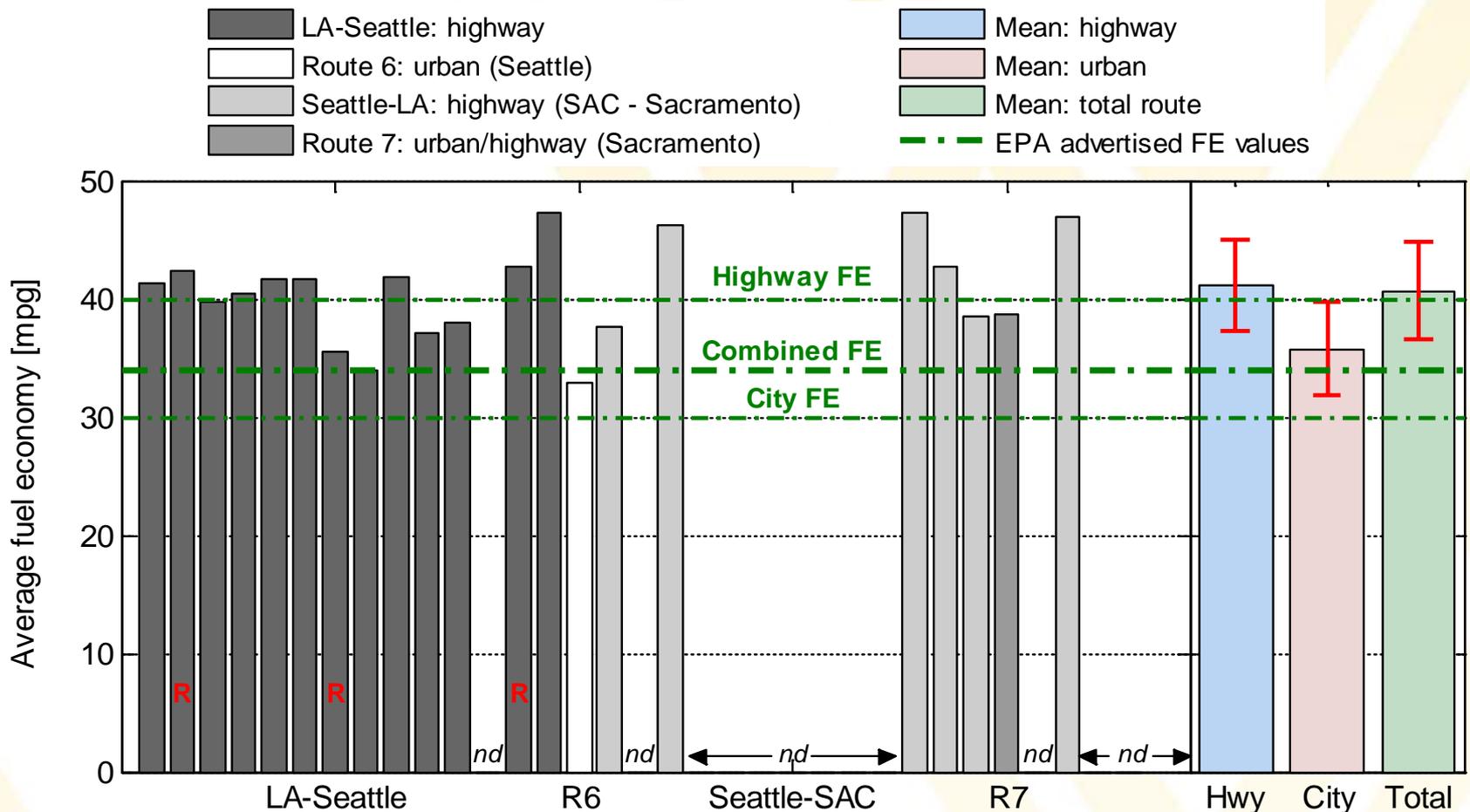
- Volkswagen Jetta and Passat Tested in CARB's El Monte Chassis Dynamometer Laboratory
- Passat Used to Compare PEMS to Lab – Ensure Confidence in PEMS Data
- Integrated (g/mile) and Continuous (g/s) Data Comparison
- Three Different Test Cycles
 - FTP75
 - NEDC
 - US06
- Cold, Warm, and Hot Starts



PEMS vs. CARB Laboratory

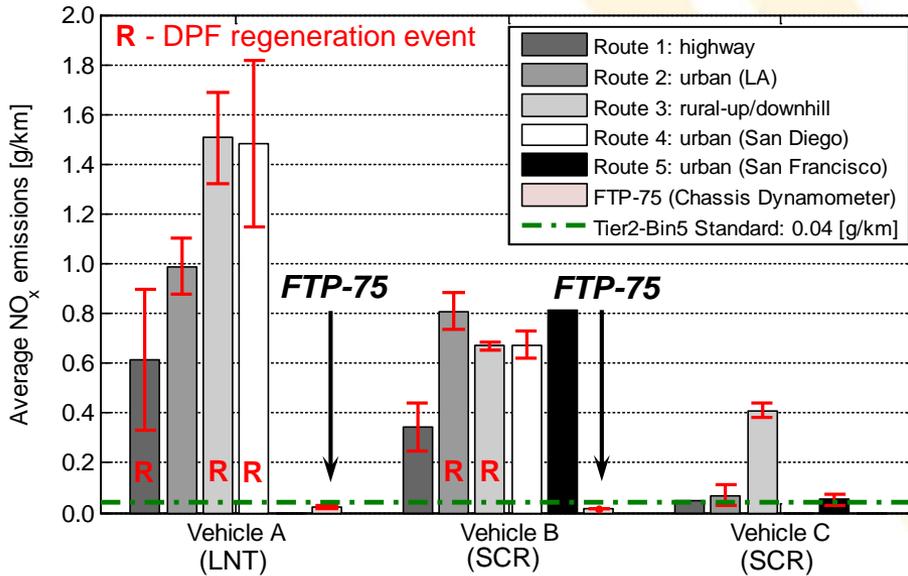


On-Road Fuel Economy Results



Average fuel economy of Passat over cross-multi-state driving route portions expressed as mpg; repeat test variations are presented as $\pm 1\sigma$, 'R' designates segments including a DPF regeneration event, 'nd' - no data available.

Results - Routes NO_x Emissions

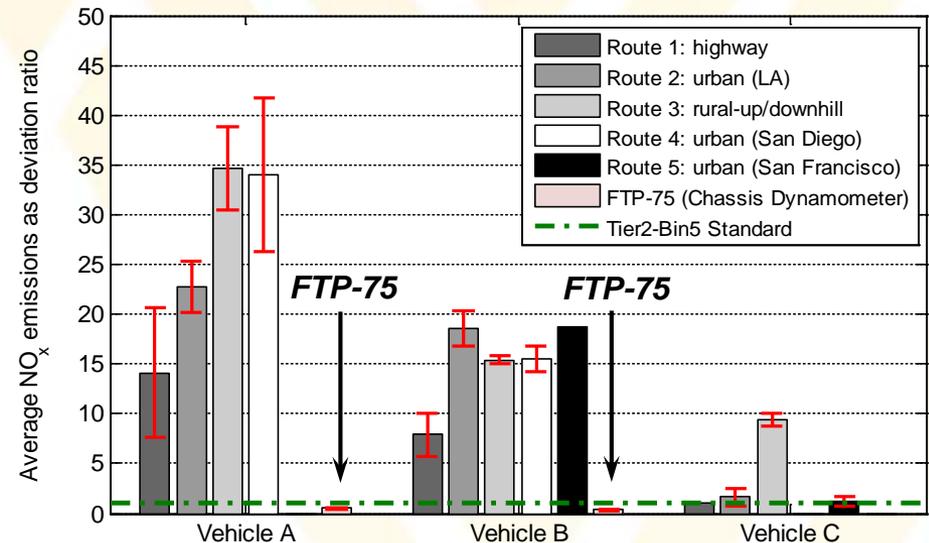


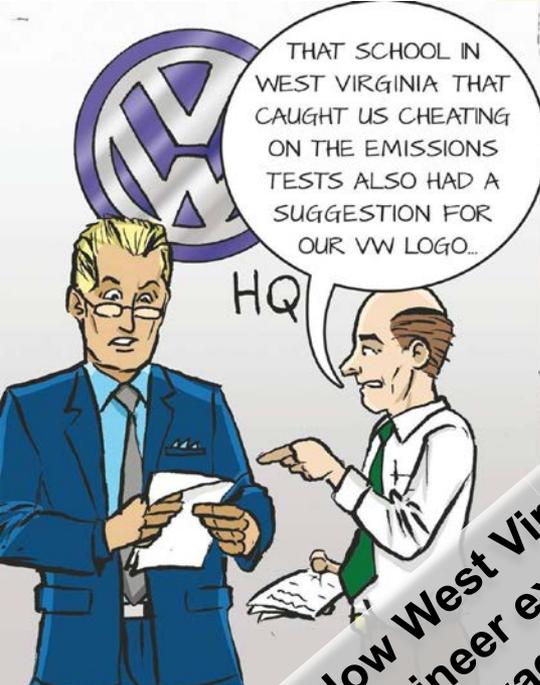
- Highest NO_x emissions during rural/up-downhill and lowest NO_x during highway driving
- LNT shows deficiencies in NO_x reduction over urea-SCR system
- Increase in NO_x emissions during tests with DPF regeneration event => especially pronounced for *Vehicle A* (LNT)
- Route 1, Vehicle A contains rush-hour and non-rush-hour traffic conditions

Chassis dynamometer test results for NO_x

Vehicle	NO _x over FTP-75 [g/km]	Rel. to Tier2-Bin5 [%]
Vehicle A	0.022 ±0.006	50.4
Vehicle B	0.016 ±0.002	64.1
Vehicle C	(no data)	(no data)

NO_x standard EPA Tier2-Bin5, CARB LEV-II ULEV over FTP-75: **0.044 g/km**





~~How A Little Lab In West Virginia Caught Volkswagen's Big Cheat~~
September 24, 2015 5:04 AM ET



Das Liars?

EPA's notice of violation of the Clean Air Act to Volkswagen [press statement]

Investigation into "defeat device" alleged emissions tests began with ICCT emissions from diesel passenger cars

Highlights the global laws by regulatory agencies

Volkswagen swung to a \$1.9 billion dollar third-quarter net loss and issued a full-year profit warning Wednesday, as VW's emissions-cheating crisis continues.

How West Virginia engineer exposed Volkswagen's catastrophic environmental fraud and wiped BILLIONS off company's shares

By [Reuters](#) and [Daily Mail Reporter](#)
Published: 20:36 EST, 22 September 2015 |
Updated: 18:50 EST, 23 September 2015



Volkswagen Shares Plunge On Emissions Scandal

[VW CEO Issues Statement on EPA Emissions Violations, Apologizes for Wrongdoing](#)

Media Coverage of CAFEE Research/ VW Diesel Emissions (Jan. 2016)

Global locations of note:

- / Dohar, Qatar
- / Brisbane, Australia
- / Jakarta, Indonesia
- / London, England
- / Alberta & Toronto, Canada
- / Mumbai, India
- / Norway
- / Germany
- / France
- / Portugal
- / Japan
- / Italy

Television interviews:

- / I-View
- / NPR-DC
- / MSNBC
- / All In With Chris Hayes/ MSNBC
- / Bloomberg TV
- / German TV ARD
- / The State Journal's Decision Makers with Bray Cary
- / Danish Broadcast Corporation
- / TF-1 French Television
- / La Repubblica
- / NHK Japan Broadcasting Corporation
- / RTS Swiss Public Broadcasting

National publications of note:

- / The New York Times
- / The Washington Post
- / CBS News
- / ABC News
- / NBC & MSNBC
- / CNN & CNN International
- / The Discovery Channel
- / NPR (Los Angeles and Washington, D.C.)
- / Associated Press
- / Reuters
- / Al Jazeera (America and UK)
- / USA Today
- / Huffington Post
- / AOL
- / Bloomberg
- / TIME

State/local publications of note:

- / The Dominion Post
- / WV MetroNews
- / Charleston Gazette-Mail
- / WV Public Broadcasting
- / WBOY-TV
- / The State Journal
- / Pittsburgh-Tribune Review

150+ DIRECT MEDIA INQUIRIES

since the story broke from international, national, state and local media outlets.



100+ INTERVIEWS CONDUCTED (AND COUNTING)

in person, by phone, satellite uplink, radio and Skype, and continue with today's scheduled in-person live interview on NBC's Today Show.



Thousands of **SOCIAL MEDIA IMPRESSIONS**



WV Public News @wvpublicnews - Sep 21
WVU Researchers Help Bust Volkswagen for Pollution Violations
wvpublic.org/post/wvu-resea...

View summary

TribLIVE.com @TribLIVE - Sep 21
West Virginia University uncovers VW's emission-rigging plot. bit.ly/1t8Scub
#TribFrontPage

View photo



Over **3,500 STORIES** appeared in news outlets from as far away as Qatar, Australia, Indonesia, England, Canada, India, South Korea, Norway, Germany, France and Japan.

The Washington Post



Japan Broadcasting Corporation



THOMSON REUTERS



ABC



ALJAZEERA

GESTIONARADIO

Los Angeles Times



ARD
GERMAN TV

Timeline

Increased on-road (i.e. off-cycle) NOx emissions measured in EU

Nov. 7th 2012
RFP by ICCT

March – May 2013

Testing of three vehicles (on-road and laboratory)

May 15th 2014
Submission of final report to ICCT

Sept. 3rd 2015
VW Engineers admit to CARB of use of “defeat device”

Sep. 25th 2015
CEO Winterkorn resigns, VW names Müller C.E.O.

ICCT wants to test Diesel LDVs sold in US to demonstrate EU legislator the feasibility of low NOx emissions

Nov. 22th 2012
Submission of proposal

March 30th 2014
Presentation of data at 24th CRC Real-World Emissions Workshop

Dec. 2014
Notification of voluntary recall by VW

Sept. 18th 2015
First Notice of Violation by U.S. EPA and CARB

Timeline....cont'd

Nov. 2nd 2015
Second Notice of Violation by U.S. EPA and CARB

Jan. 4th 2016
DOJ files complaint on behalf of EPA against Volkswagen Group for alleged violations of the Clean Air Act. Fines estimated up to \$46 Billion

Jan. 22nd 2016
Elizabeth Cabraser appointed sole lead class counsel in MDL against Volkswagen

Mar. 24th 2016
U.S. District Judge Charles Breyer requests definitive answer on the status of a fix

Dec. 10th 2015
Internal VW inquiry reports decision to cheat was made more than a decade ago

Jan. 12th 2016
EPA & CARB rejected VW's proposed fix

Mar. 9th 2016
Horn steps down as president and CEO of Volkswagen Group of America. Woebcken named president and CEO on an interim basis.

History in the making

Can Diesels be “Clean”?

- “Clean-diesel” Technology is REAL and AVAILABLE
- Volkswagen is the problem, NOT the diesel engine
- WVU has a long history – We are “diesel guys”
- Some history...
 - 1974: Volkswagen was sued by US EPA for emissions defeat devices on four MY1973 vehicles. Settled for \$120,000. Ref: <http://brandilawblog.com/2015/10/01/history-repeats-itself-volkswagen-was-sued-by-the-epa-for-cheating-on-emissions-in-1974>
 - 2005: Failure to promptly notify EPA and to correct a defective oxygen sensor At least 329,000 of 1999, 2000, 2001 Golfs, Jettas, and New Beetles. \$1.1 Million fine.

Ref: <http://www.cnn.com/2015/09/23/vw-had-previous-run-in-over-defeat-devices.html>

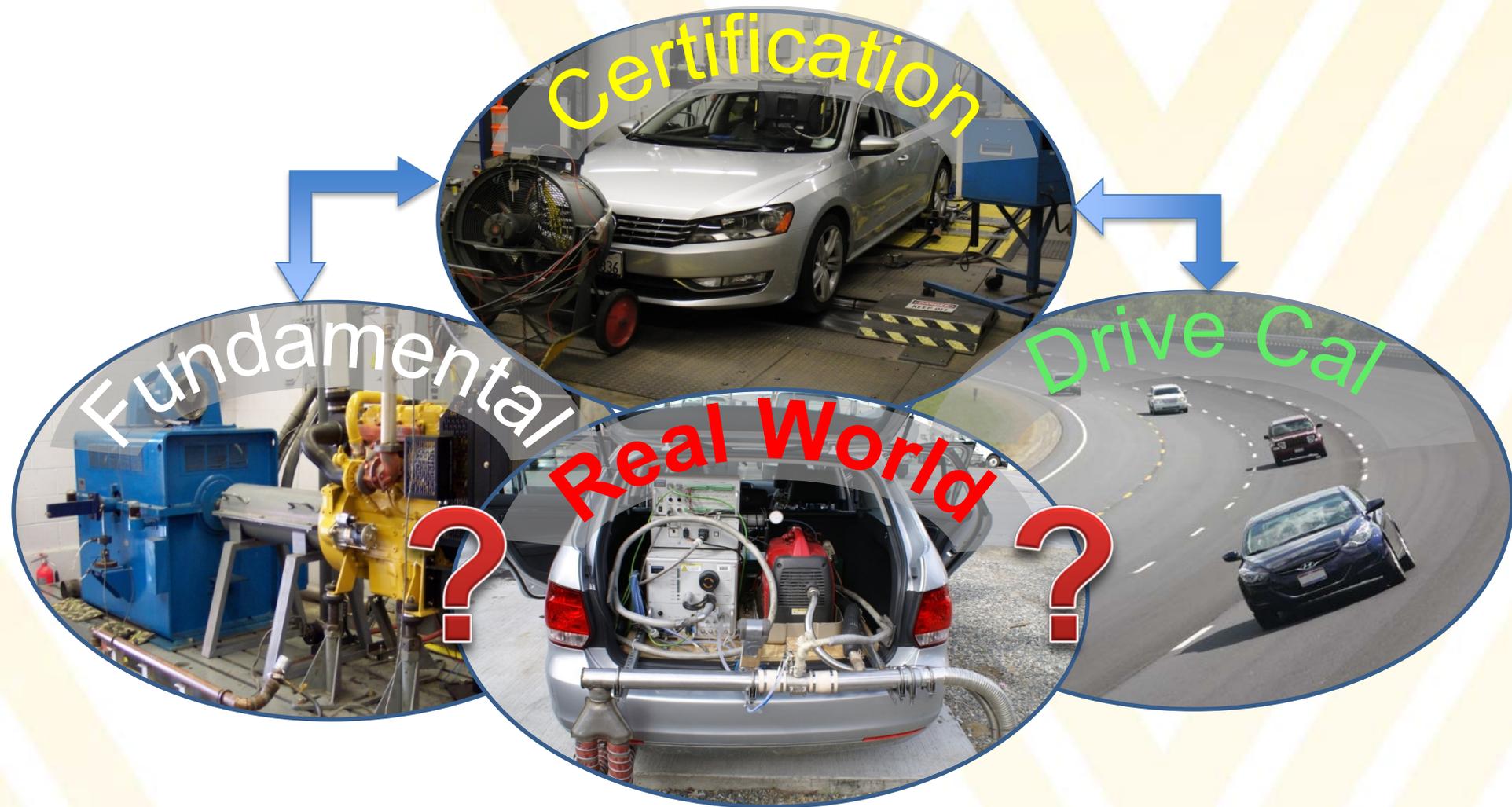


<http://www.roadandtravel.com/roadtests/buyersguides/2012-buyers-guide/green-suv-buyers-guide/bmw-x5--xdrive-35d-clean-diesel.html>



http://clean-green-cars.blogspot.com/2010_01_01_archive.html

Development and Compliance



<http://www.trcpg.com/facility-tour/75-mile-test-track.aspx>

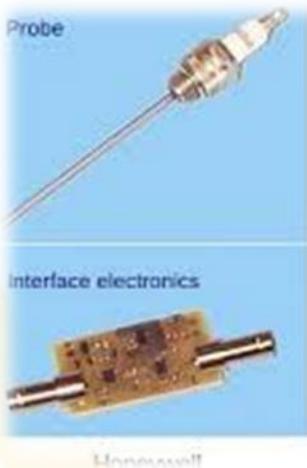
Regulatory Action?

- Increased Certification Procedures to Identify Off-Cycle Emissions
- On-Road Emissions Measurements
 - Similar to HDD Requirements
- Expand Certification Test Ambient Conditions
 - Low/High Temperature, Humidity, Elevation
- Real-world Certification/Compliance
 - Geofencing
 - Incentivize Future Reductions
- Drive Cycles
 - More Representative of “Real-World” Driving
 - “Surprise” Cycles or “Periodically Refreshed”
- NTE and ?-Based Windows
- OBD....I/M....??



Technology Acceleration?

- Aftertreatment Development
- Sensor Development
- Advanced Combustion Techniques
- Advanced Driveline Strategies
- Fuel Alternatives
- Connected Vehicle
- Enhanced Integration



Ref: www.dieselnet.com



You Like Us...You Really Like Us



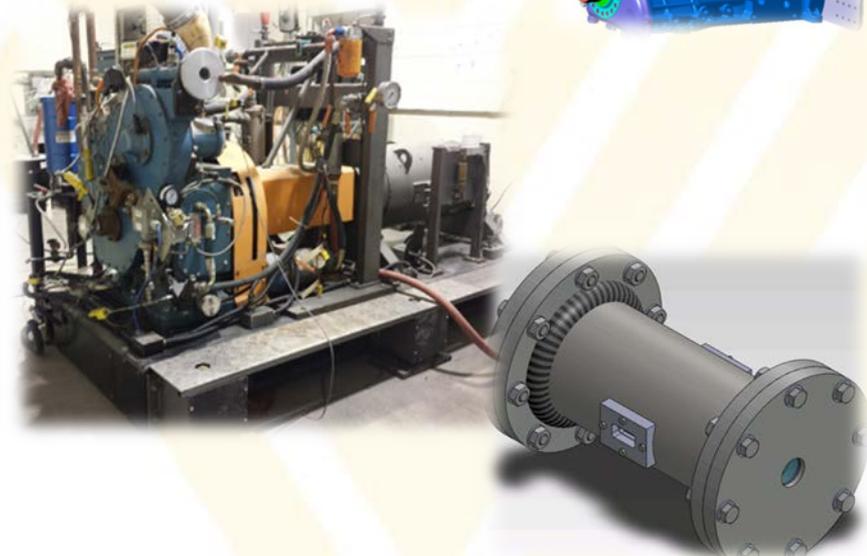
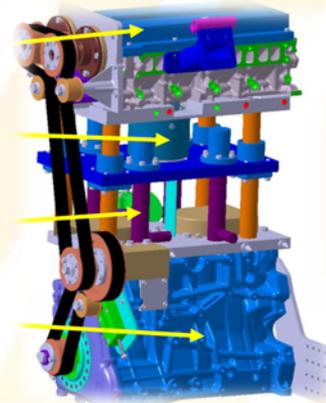
- Advanced Combustion Laboratory
- Engine and Emissions Research Laboratory
- Vehicle and Engine Testing Laboratory

Production-Based Head

Optical Combustion Chamber

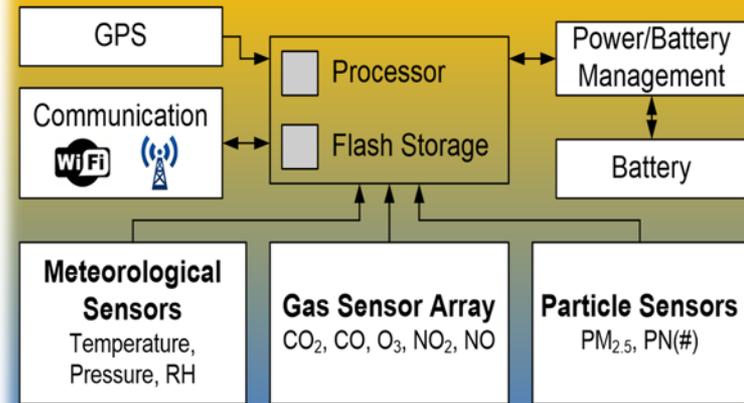
Hydraulic Assembly

Production-Based Bottom End



AirCom - Prototype

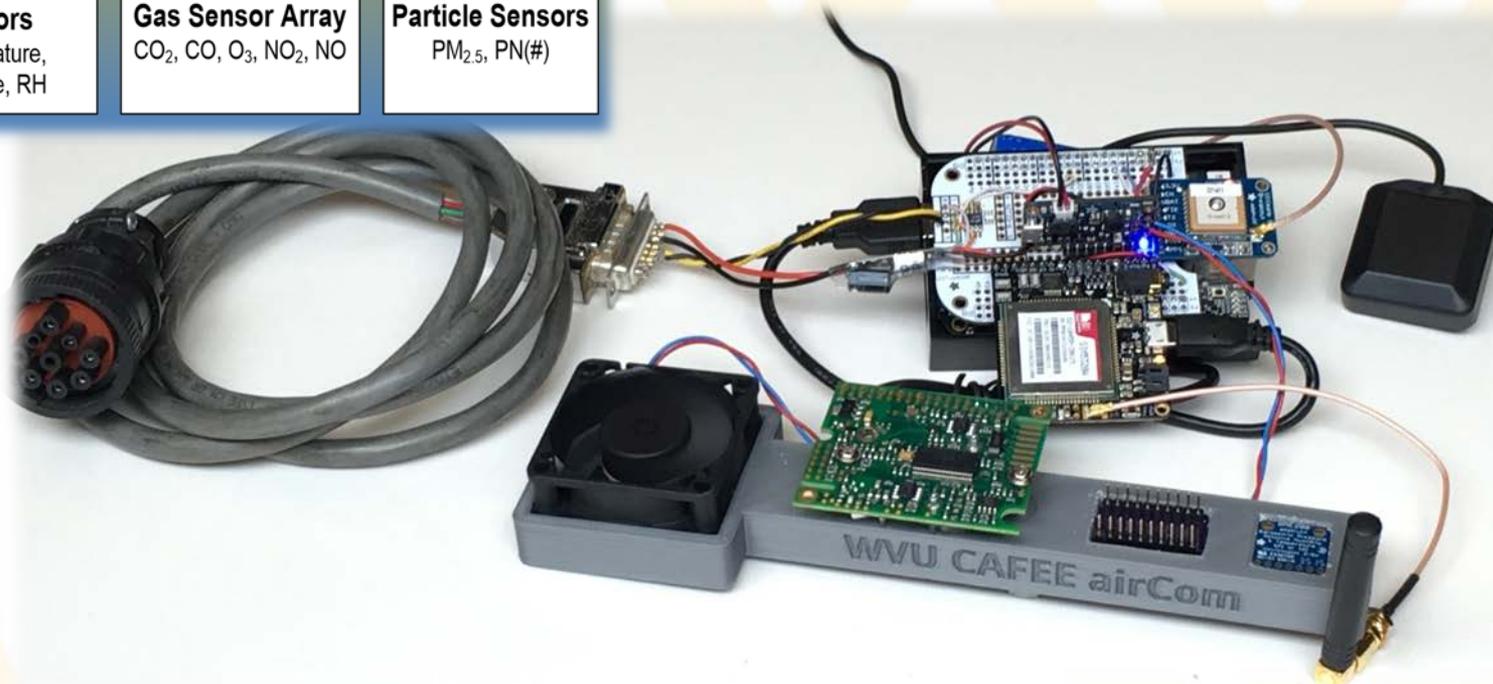
AirCom Sensor and Data Acquisition/Transmission Unit



- Barometric Pressure/Temperature Sensor
 - Bosch BMP180
 - Resolution: up to 0.03hPa / 0.25m (300-1100hPa)
 - T accuracy: $\pm 2^{\circ}\text{C}$ (Range: -40 to +85°C)

- CO₂ Sensor
 - NDIR K-30, 1% CO₂ range
 - Accuracy: $\pm 30\text{ppm}$, $\pm 3\%$ of measured value

- Humidity Sensor
 - Sensirion SHT21
 - Resolution: 0.04 %RH, Accuracy: $\pm 2\%$ RH



WVU Markov Drive Cycle



Thank You!

www.cafee.wvu.edu

Daniel.Carder@mail.wvu.edu

304-293-0650/304-288-7917

Acknowledgement

