National Renewable Energy Laboratory
Innovation for Our Energy Future

Intermediate Ethanol Blends Test Program

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NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC

Agenda

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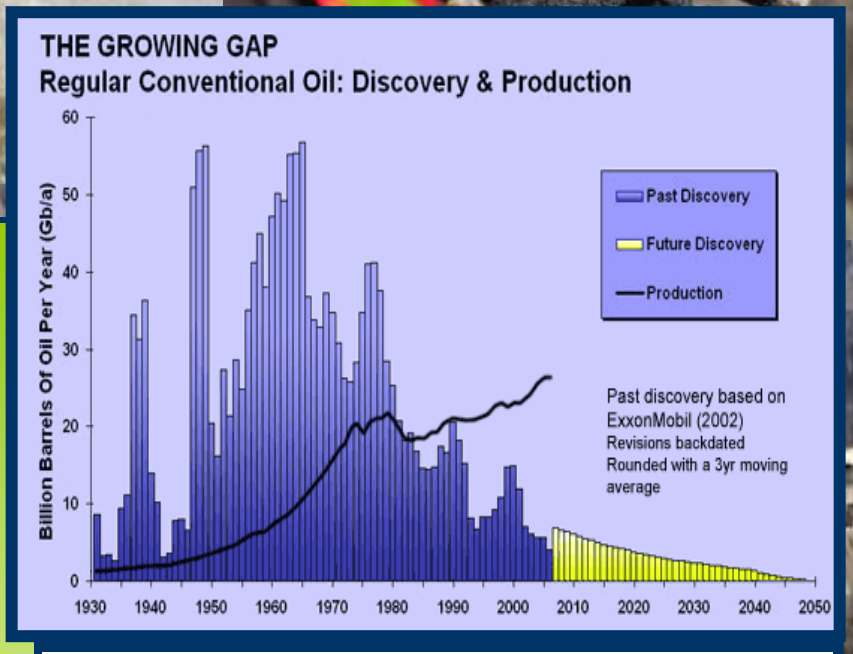
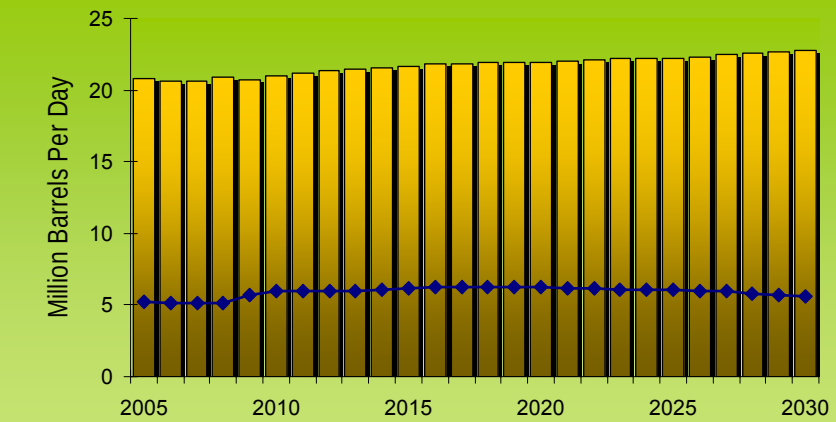
- Background
- Meeting the EISA Renewable Fuels Challenge with Ethanol – RFS
- Intermediate Ethanol Blends Test Program
  - Overview
  - Project descriptions & status
  - Sample results from small engines
- Information Resources

The Future of Oil





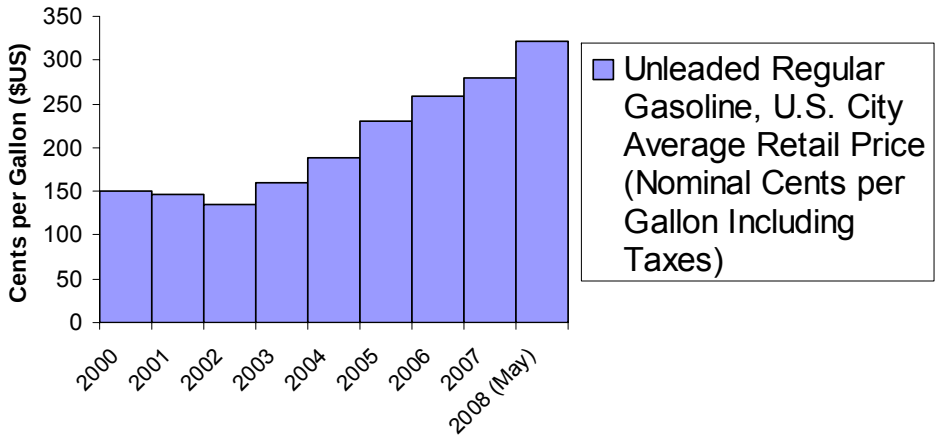
Source: Energy Information Administration

"Oil prices would be at least 15% higher than they are, if not for today's output of ethanol."

- Francisco Blanch, head of global commodity research at Merrill Lynch, as quoted in "Is Ethanol Getting a Bum Rap?" BusinessWeek, May 1, 2008

Unleaded Regular Gasoline
U.S. City Annual Average Retail Price
(Nominal Cents per Gallon Including Taxes)

Source: Energy Information Administration



Legislation

January 2007 – State of Union Address

- **President announces 20 in 10 initiative: Focused on reducing gasoline demand by 20% in 10 years (2017)**
  - **¼ from improved fuel economy**
  - **¾ from increased use of alternative fuels**

December 2007 – Congress Passes and President Signs the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140)

- **Key elements**
  - **Increased Corporate Average Fuel Economy (CAFE) Standard**
  - **Expanded Renewable Fuel Standard (RFS)**

National Biofuels Targets

New Renewable Fuel Standard

- Expand use of renewable fuels to 36 billion gallons annually by 2022 (vs. 7.5B gal/yr by 2012 in EPAct 2005)
- Limits corn based RIN credits to 15 bgy
- Cellulosic biofuels component
  - 0.5 billion gallons by **2012**
  - 3 billion gallons by **2015**
  - 16 billion gallons by **2022**
- Includes Significant Safeguards
  - Ethanol production from corn is capped
  - EPA developing regulations to implement
  - EPA authorized to waive targets annually
  - Requires GHG reductions, which include land use impact
  - Requires studies on environmental impacts

DOE Longer-Term Goal (30 X 30)

- Displace 30% of US gasoline consumption by 2030 with biofuels (60 billion gallons)

Best short-term option to alleviate gasoline prices and heating oil costs - Ethanol

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Challenges Across Entire Supply Chain

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Feedstock Production → Feedstock Logistics → Biofuels Production → Biofuels Distribution → Biofuels End Use




Cellulosic Ethanol: Primary focus of the DOE biofuels program.

Alternative Light-Duty and Diesel Replacement Fuels: A scoping study is underway to help prioritize future work on additional alternate fuels that require governmental support and can significantly contribute to achieving the President's goal.

Best short-term option would be to use ethanol blends greater than 10% - only if it makes sense

Developing End-Use Market for Ethanol

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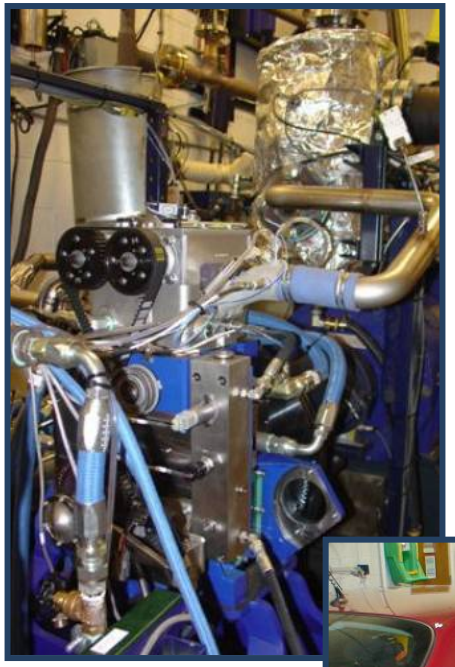
- An estimated 9 billion gallons of ethanol will be used in the U.S. in 2008
  - More than 99% is used in the form of E10
  - E10 market will be saturated at about 14 billion gallons
- DOE strategy for expanding ethanol use
  - Expand E85
  - Determine feasibility of using intermediate ethanol blends (e.g., E15, E20) in conventional vehicles (non-flex fuel vehicles)
- EPA has authority to issue a "substantially similar" waiver to allow alternative fuels to be used in place of gasoline
  - Evaluated in terms of effects on durability, driveability, materials, and emissions

Expanded FFV Usage

- Support expanded use for FFVs for markets in which they make sense
- Five awards to industry teams to increase efficiency and fuel economy of next-generation FFVs
  - Teams led by Delphi, Ford, GM, Mahle, Bosch
- National Lab projects
  - Delphi-ORNL
  - St. of CO E85 emissions speciation, NREL
  - Lean-burn study, Saab BioPower benchmarking, ORNL



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I-Blends Program History

- DOE initiated study ~ 18 months ago
- Organizational meetings – DOE, National Labs, EPA, USDA, State of MN – March & June 2007
- Literature review April – July 2007
- Small, non-road engines (SNRE) given priority in summer 2007 at EPA request
- Established leveraging with CRC and EPA
- Vehicle evaluations underway late CY 2007
- First report issued Oct 7, 2008

June 2007 Literature Review

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- **Very little data on E20**
- **Almost no data on E15**
- **Credible studies reported NO_x emission increases and long-term catalyst degradation with E20**
- **Prior studies found materials compatibility issues with E20, and evidence of fuel filter plugging even with E10**
- **Average driver might not initially detect driveability problems (stumble, hesitation, etc) in late-model vehicles using E20**
  - **No long-term information available on driveability**
- **Drivers of older vehicles could notice driveability problems (potential tampering concern)**

Completed Testing

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Vehicles

Emissions and Catalyst Temperature Pilot Study (DOE) (16 vehicles)

- Tests of 13 vehicles complete – First report published October 7, 2008 (Report #1)
- Full 16 vehicle completed December 2008 – to be reported February 2009 (Report #2)

Small Non-Road Engines (SNRE) (lawn equipment, generators)

Emissions and Exhaust Temperature Pilot Study (6 engines)

- Testing completed May 2008 – First Report Published October 7, 2008 (Report #1)

Full Useful Life Emissions and Durability (17 / 22 engines aged to full life)

- Testing completed May 2008 – First Report Published October 7, 2008 (Report #1)

Ongoing Vehicle Testing

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Tailpipe Emissions (DOE and EPA) (22 vehicles, 31 different fuels)

- Phase 1 (75°F) of EPAct project completed.
- Phase 2 (50°F) begun Sep 2008

Evaporative Emissions (DOE, EPA, CRC) (8 vehicles)

- E-77-2 complete, report expected Nov 2008
- E-77-2b expected start Oct 2008, expect report March 2010

Full Useful Life Emissions Study (DOE and CRC) (up to 80 vehicles)

- Full results expected 2010-2011
- Includes some evaporative emissions tests

Cold Start and Driveability (DOE and CRC) (6 vehicles)

- Initial testing completed

Fuel System Materials Compatibility (DOE and CRC)

- Testing underway – full results expected by October 2009

RIT fleet study (10 vehicles)

- NREL is analyzing fleet data such as fuel economy, maintenance costs, etc
- Analysis of emissions results pending baseline tests by NREL

Effects of Intermediate Ethanol Blends on Legacy Engines: Report #1

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Tested E0, E10, E15, and E20 on --

- 13 popular late model vehicles
- 28 small non-road engines

Collected data on –

- Vehicle emissions and catalyst temperatures
- Small non-road engine emissions; engine/component temperatures; durability testing

Peer Reviewed

- Group chaired by Joseph M. Colucci, retired from GM R&D
- Peer comments not in report but are public and available upon request

Published as a laboratory technical memorandum (ORNL/NREL).

Results: Vehicle Emissions & Fuel Economy

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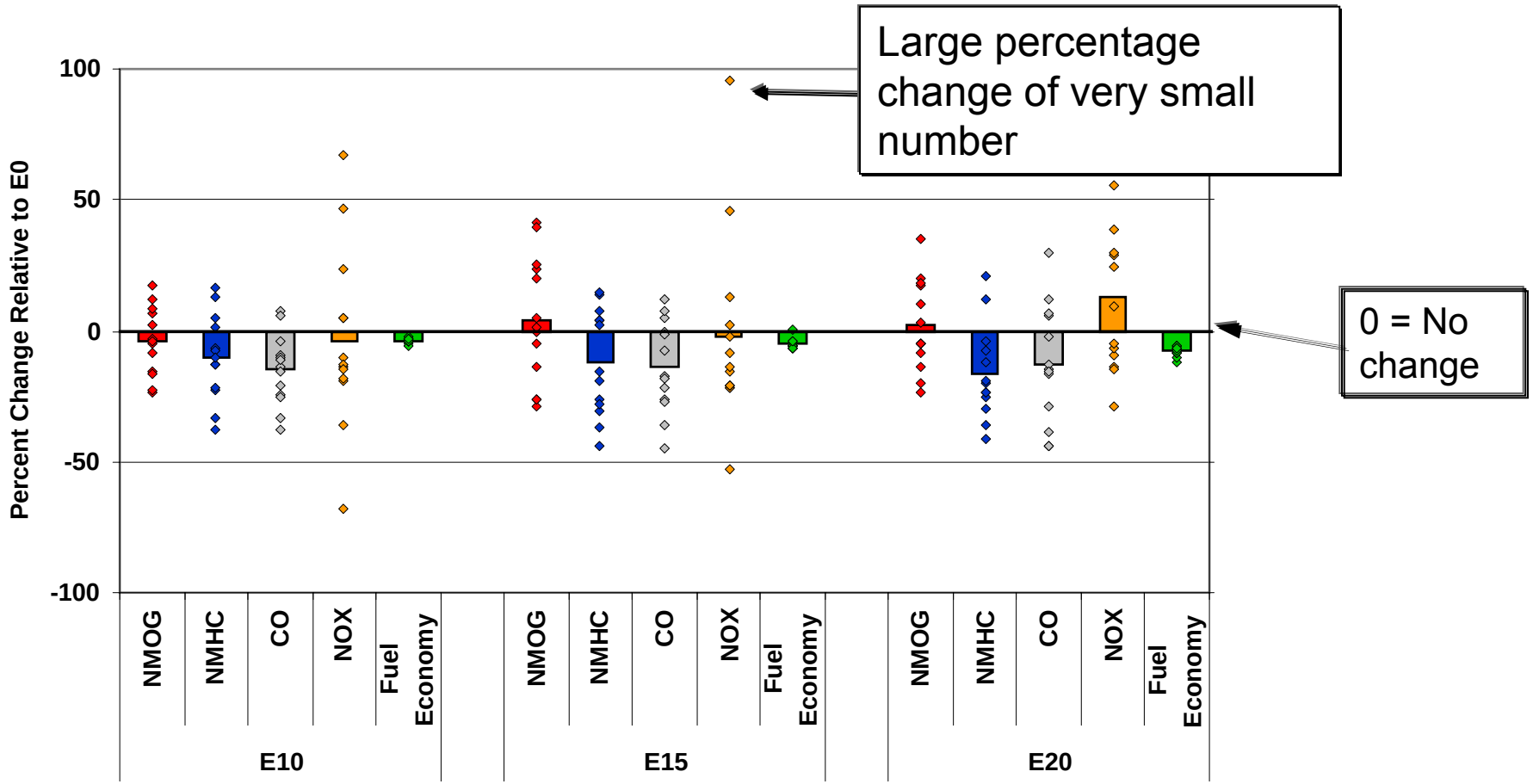
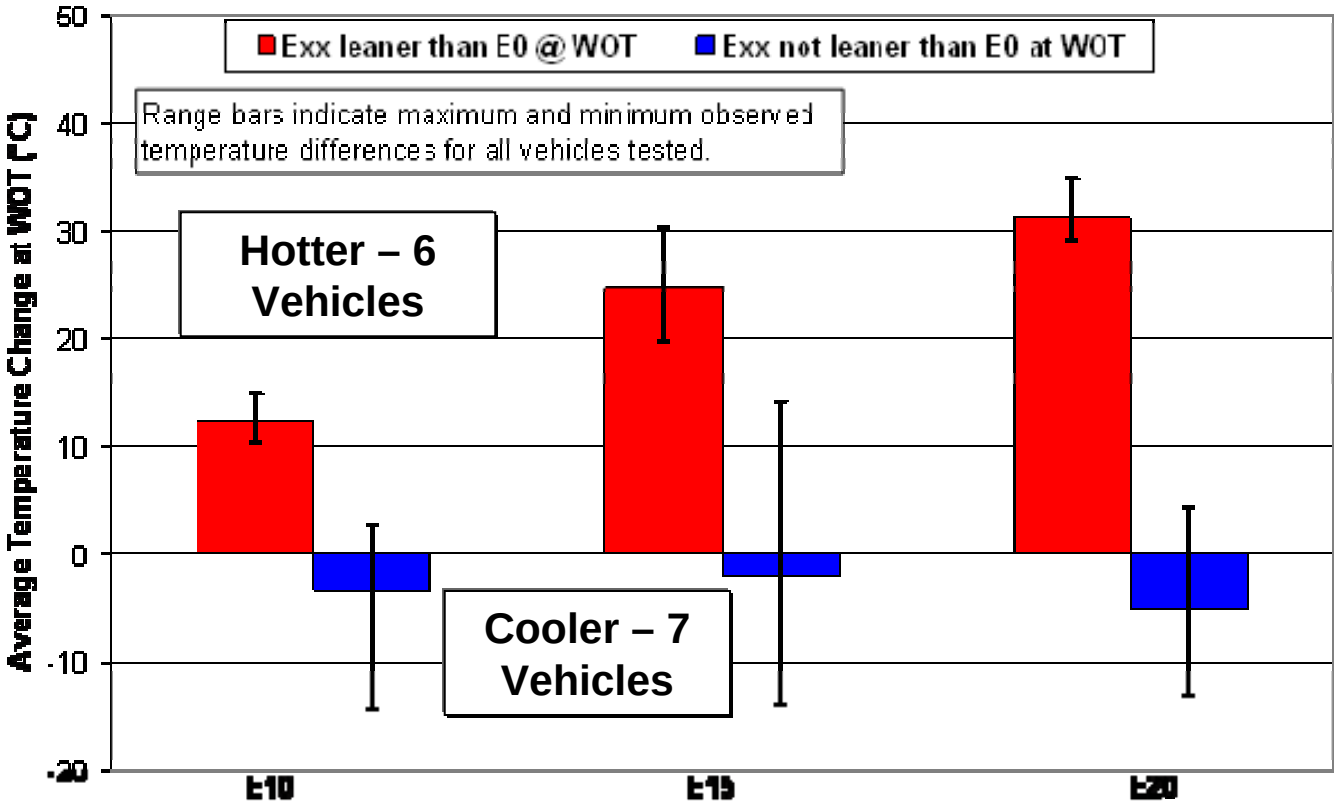
- **Given the scatter in the testing, the average emissions were relatively unchanged from E0.**
- **The reduction in fuel economy due to ethanol was predictable and statistically significant.**



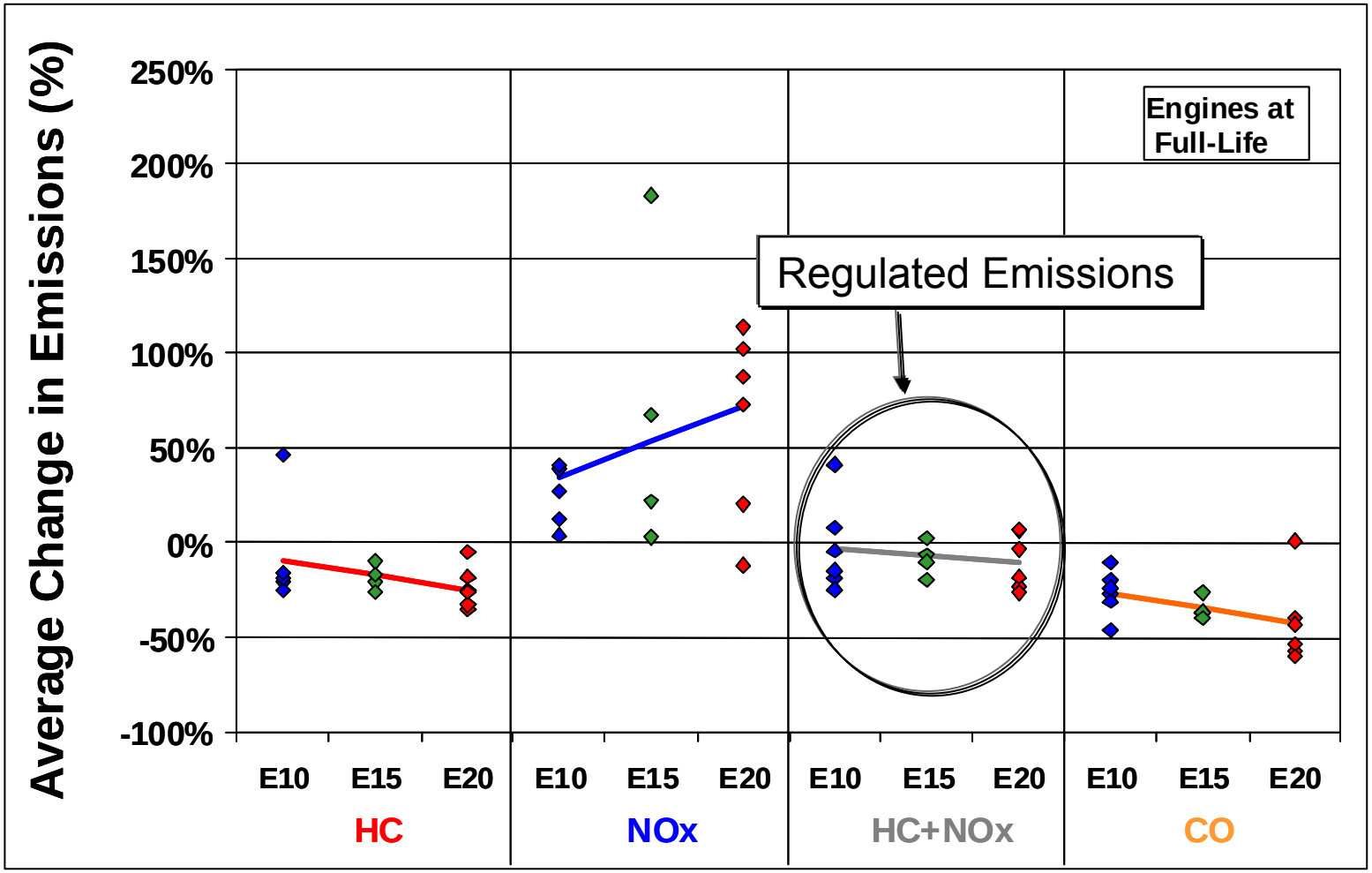
Results: Vehicle Catalyst Temperatures

- **Approximately half the vehicles had an increase in catalyst temperature at full power. Otherwise, the catalyst temperatures were lower for all vehicles under all other driving conditions.**
- **The effect of higher temperatures at full power is still unclear and being tested by DOE.**



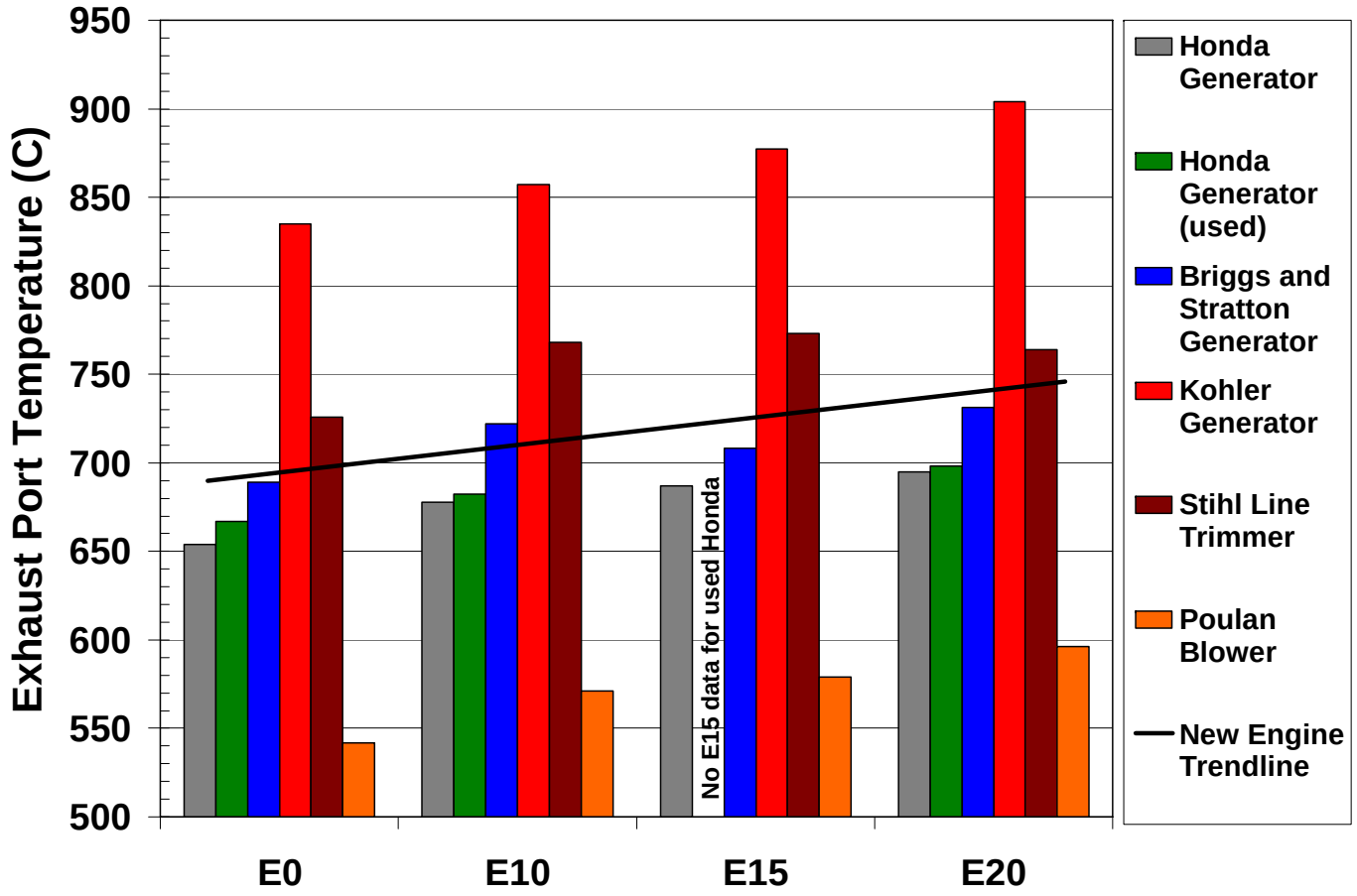
Sample Small Engine Emissions

- **Typically, HC and CO decrease while NOx increases for small engines.**
- **Regulated emissions (HC + NOx) decrease for most cases.**



Sample Small Engine Exhaust Temp.

- **Exhaust temperatures and cylinder head temperatures increased slightly.**
- **The effect of increased temperatures on engine durability is unknown, however no failures due to ethanol were encountered in full life testing.**



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NREL – http://www.nrel.gov

DOE Office of Biomass Program - http://www1.eere.energy.gov/biomass/

EERE Info Center - www1.eere.energy.gov/informationcenter

Alternative Fuels Data Center - http://www.eere.energy.gov/afdc/fuels/ethanol.html

Bioenergy Feedstock Information Network - http://bioenergy.ornl.gov/

Biomass R&D Initiative – www.biomass.govtools.us

Grant Solicitations - www.grants.gov

Office of Science - http://www.er.doe.gov/

Intermediate blends Report #1 - feerc.ornl.gov/publications/Int_**blends**_Rpt_**1**.pdf