

Fuels for Advanced Combustion Engines



Bradley T. Zigler
National Renewable Energy Laboratory
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Fuels for Advanced Combustion Engines (FACE)

William Pitz, Nick Killingsworth, Daniel Flowers, Salvador Aceves, –
Lawrence Livermore National Laboratory (LLNL)

Bradley Zigler, Matthew Ratcliff – National Renewable Energy Laboratory
(NREL)

Robert Wagner, Scott Sluder, Bruce Bunting – Oak Ridge National
Laboratory (ORNL)

Tim Bays, David King – Pacific Northwest National Laboratory (PNNL)

Charles Mueller – Sandia National Laboratories (SNL)

Craig Fairbridge, Darcy Hager, Heather Dettman – CanmetENERGY,
Natural Resources Canada

This presentation represents a collective effort of several DOE and Canadian national laboratories on a Coordinating Research Council-led working group.

Overview

Timeline

Project Start Date: January 2006

Project End Date: TBD

Percent Complete: N/A

Budget

Total Project Funding:

DOE Share: Not calculated

Contractor Share: Not calculated

Funding Received in FY11: Varied by DOE lab annual operating plans (AOPs)

Funding for FY12: Varies by DOE lab AOPs

Barriers

- **VTP 2011-1015 MYPP Goals (cross-cut w/ Advanced Combustion Engines)**
 - By 2015, improve the fuel economy of light-duty gasoline vehicles by 25% and of light-duty diesel vehicles by 40% compared to the baseline 2009 gasoline vehicle.
 - By 2012, improve heavy truck efficiency to 50% with demonstration in commercial vehicle platforms. This represents about a 20% improvement over current engine technology.

Partners

- **CRC FACE Working Group, reporting to Advanced Vehicle, Fuel, & Lubricants Committee**
- **Many active collaborative partners:**
 - Industrial partners via CRC
 - National laboratories coordinate DOE resources
 - Canadian national laboratories also contribute significantly

Relevance/Objective(s)

Objective: To develop, characterize, and recommend research fuel sets that can be used broadly in research efforts to provide tie-points between these efforts that will further increase the understanding of fuel property impacts on advanced combustion processes, their efficiency and their emissions.

1. Continue analysis of diesel research fuels and publish results
 - Enable correlation of experimental data from combustion studies to physical and chemical properties of fuels
 - Demonstrate improved tools for fuels characterization
2. Complete formulation of gasoline research matrix
 - Monitor production of initial fuel batches
3. Complete analyses of gasoline research fuels and publish results
 - Initiate characterization effort as initial batches become available
4. Encourage use of the fuels by interested organizations to enable comparisons of fuel-effects data from a breadth of advanced combustion designs

FACE working group activities are governed by the FACE mission statement approved by the CRC Board of Directors.

Milestones

These are not formal milestones to DOE, but represent approximate timing for FACE activities.

Date	Milestone or Go/No-Go Decision	Status
~2012	Complete formulation of gasoline research fuels matrix. Plans include availability for public purchase through 3 rd party blender, CPChem (1-800-858-4327; sc@cpchem.com)	5 of 10 gasoline fuels are available for purchase as of March 2012.
~2012	Complete initial analysis of gasoline fuels matrix and publish results.	In progress as final blends become available and approved by FACE Working Group.
~2012+	Correlate available engine-based data to fuel physical and chemical properties.	ORNL is leading effort to consolidate FACE diesel data. FACE gasoline plans not yet fully defined.

Milestones

These are not formal milestones to DOE, but represent approximate timing for FACE activities.

Date	Milestone or Go/No-Go Decision	Status
2011	W.J. Pitz and C.J. Mueller published “Recent Progress in the Development of Diesel Surrogate Fuels” in <i>Progress in Energy and Combustion Science</i> . Report related to AVFL-18, originally derived from FACE.	
2011	R. Gieleciak, C. Fairbridge, C. Lay, and D. Hager, published “Comparative Hydrocarbon Analysis of Cosdenol 180, RB Solvent 200B, and CPChem Naphthalene Samples” as CanmetENERGY Division Report 2011-044-INT. This work supported a reformulation of some diesel FACE fuels.	Available at http://www.crcao.com/publications/advancedVehiclesFuelsLubricants/FACE/index.html
2010	R. Gieleciak, D. Hager, C. Lay, and C. Fairbridge published “Hydrocarbon Characterization of FACE Aromatic Streams” as CanmetENERGY Division Report 2010-082-INT. This work complemented existing FACE diesel fuel analysis.	Also available at above CRC website

Approach/Strategy

- **Bring together a coalition of stakeholders to define matrices of research fuels**
 - Automakers
 - Engine Manufacturers
 - Energy Companies
 - R&D Organizations

CRC working group structure provided the environment needed to bring stakeholders together for information exchange.

- **Engage a specialty fuel blender to manufacture the designed fuels for sale to interested organizations**

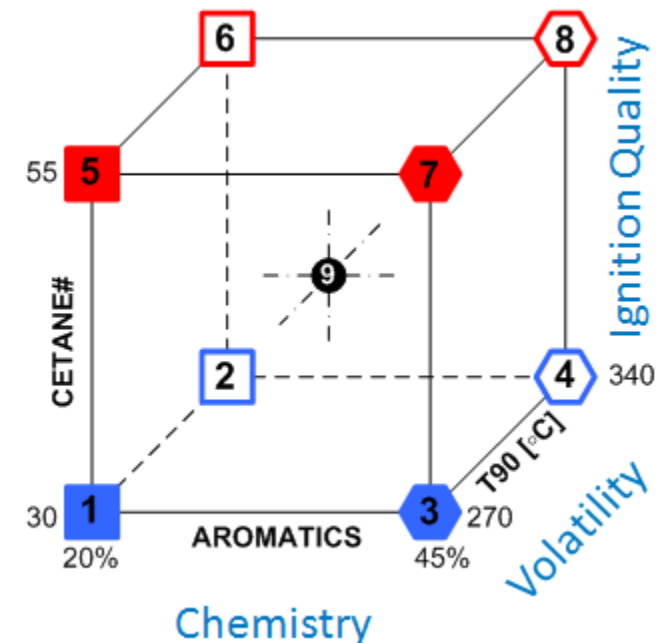
End-users can purchase the fuels directly from CPChem, a well-known supplier of specialty fuels. FACE research fuel characterization will be freely published.

- **Encourage interested R&D activities to make use of the fuels**
 - DOE-funded activities
 - Universities
 - Industry

Sharing of results encouraged, with correlation enabled by FACE research fuels.

Technical Accomplishments and Progress

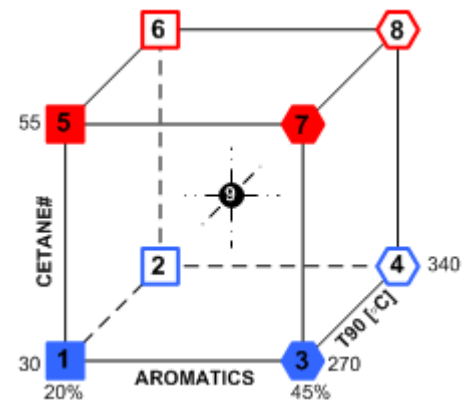
- Diesel FACE fuel matrix fully blended and available
 - First batch of fuels nearly expended; second batch being blended for purchase
 - Three fuels were reformulated to enable international sales (FACE diesel #2B, 4B, 7B)
 - Detailed characterization of affected blends in progress, piggy-backed on AVFL-19 project (Advanced Alternatives and Renewable Fuels)
- Analytical characterization of diesel fuels
 - Initial characterization published on CRC's website in late 2008
 - Brief of full characterization published as SAE 2010-01-2769, "Fuels for Advanced Combustion Engines Research Diesel Fuels: Analysis of Physical and Chemical Properties"; paper also served to introduce FACE diesel matrix to broader engine and fuel research community
 - Full characterization published on CRC's website July 2010, "Chemical and Physical Properties of the Fuels for Advanced Combustion Engines (FACE) Research Diesel Fuels," 242 pgs
 - Additional characterization (from reformulation) will be posted on CRC website



FACE diesel fuel matrix is available for purchase, and characterization data are publicly available.

Technical Accomplishments and Progress

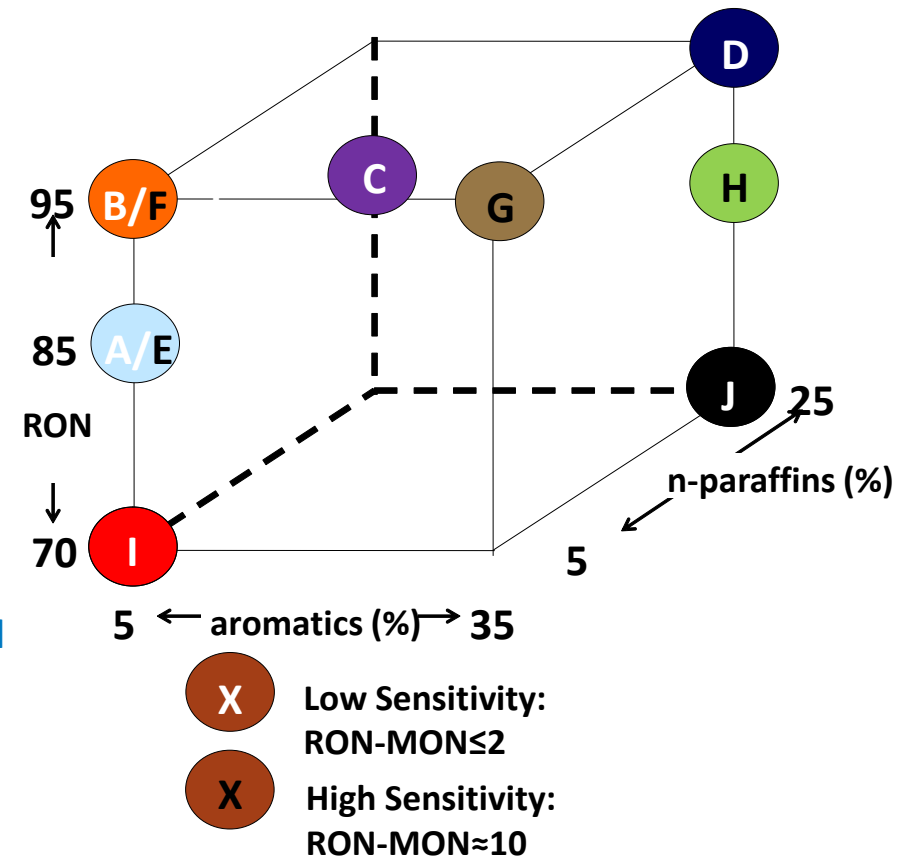
- Encouraged R&D activities to use diesel FACE matrix
 - ORNL employed full set in fuel effects studies
 - High Efficiency Clean Combustion, SAE 2010-01-2669 (Cho et al.)
 - Homogeneous Charge Compression Ignition (HCCI), SAE 2010-01-2645 (Bunting et al.)
 - CRC is directing a study using set to enable advanced combustion regimes via AVFL-16 project in progress at West Virginia University
 - NRC-Canada employed full set in single-cylinder engine studies
 - Premixed Charge Compression Ignition (PCCI) combustion, ASME ICEF2010-35194 (Dumitrescu et al.)
 - HCCI combustion, SAE 2010-01-2168 (Hosseini, et al.)
 - Navistar employed set in low-temperature combustion
 - SAE 2011-01-0329 (Ojeda, et al.)
- ORNL has been compiling available engine data generated with FACE diesel fuels and is conducting correlation for publication (Kim, Sluder, and Wagner)



Researchers have been employing FACE diesel fuel matrix in advanced engine studies and cross-correlation is in progress.

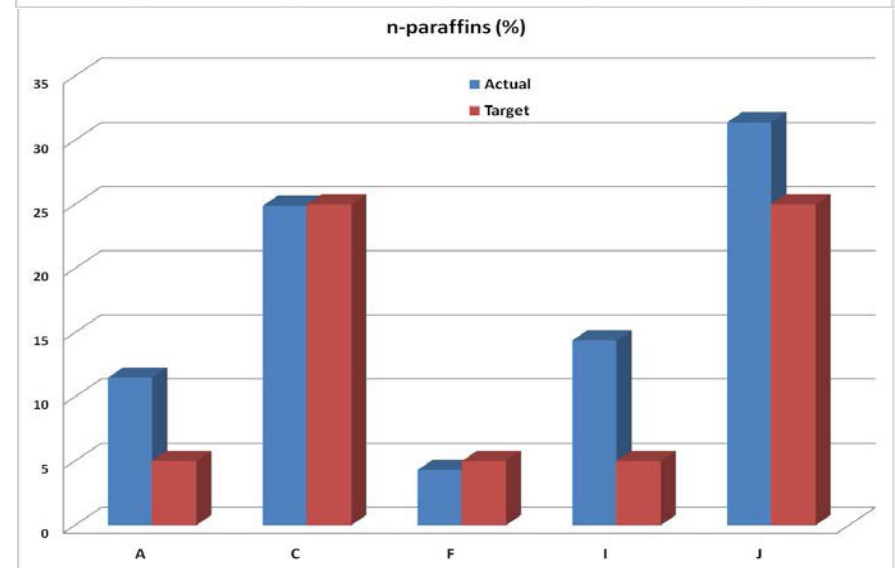
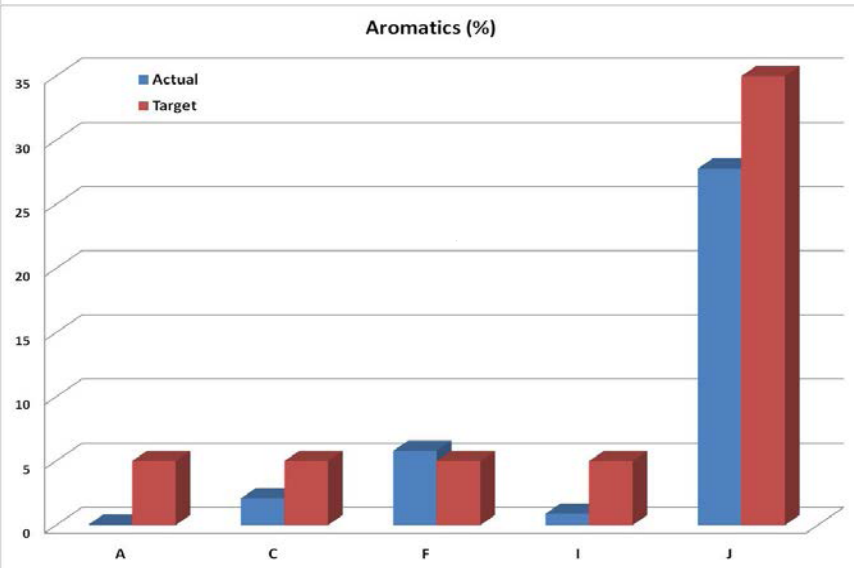
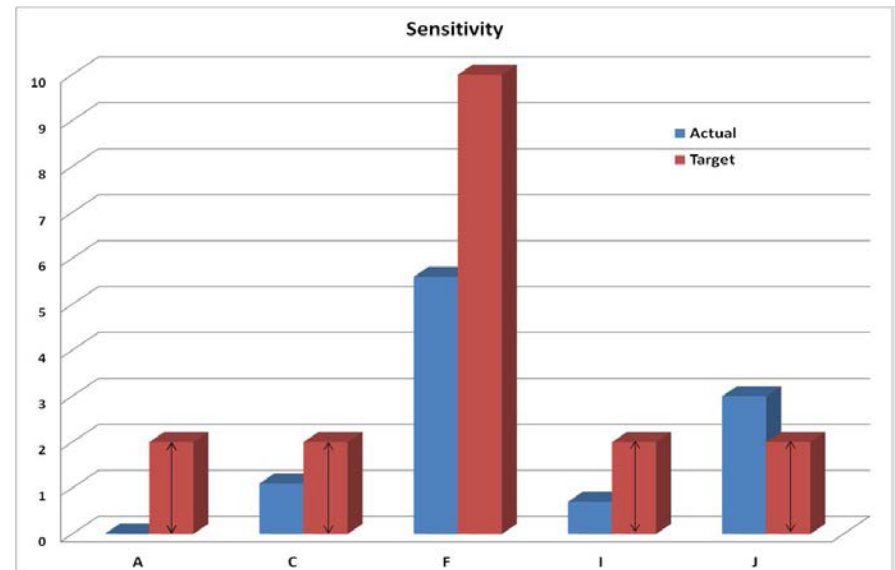
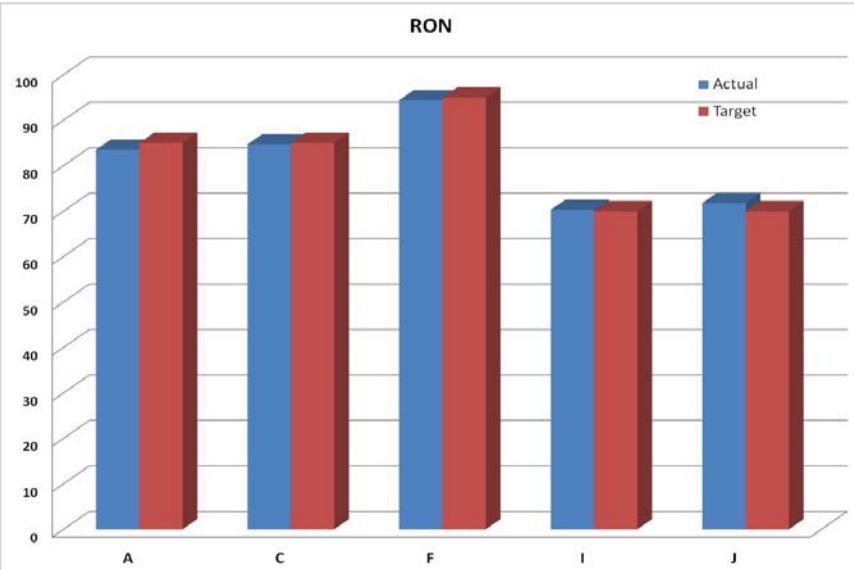
Technical Accomplishments and Progress

- Gasoline FACE fuels matrix
 - Matrix development
 - 4-D matrix targets selected
 - 58 different fuel designs modeled by John Orban (Battelle)
 - Reduced to 37 candidates
 - Down-selection to 20 blendable recipes
 - Hand blends of 20 recipes analyzed and studied by Battelle's statistical analysis group
 - Final matrix of 10 fuels identified
 - Ken Wright and Bill Leppard leading effort with CPChem to blend matrix and compare to targets
 - Five fuels have been made commercially to date and are available for sale from CPChem (A, C, F, I, & J)
 - Others in progress



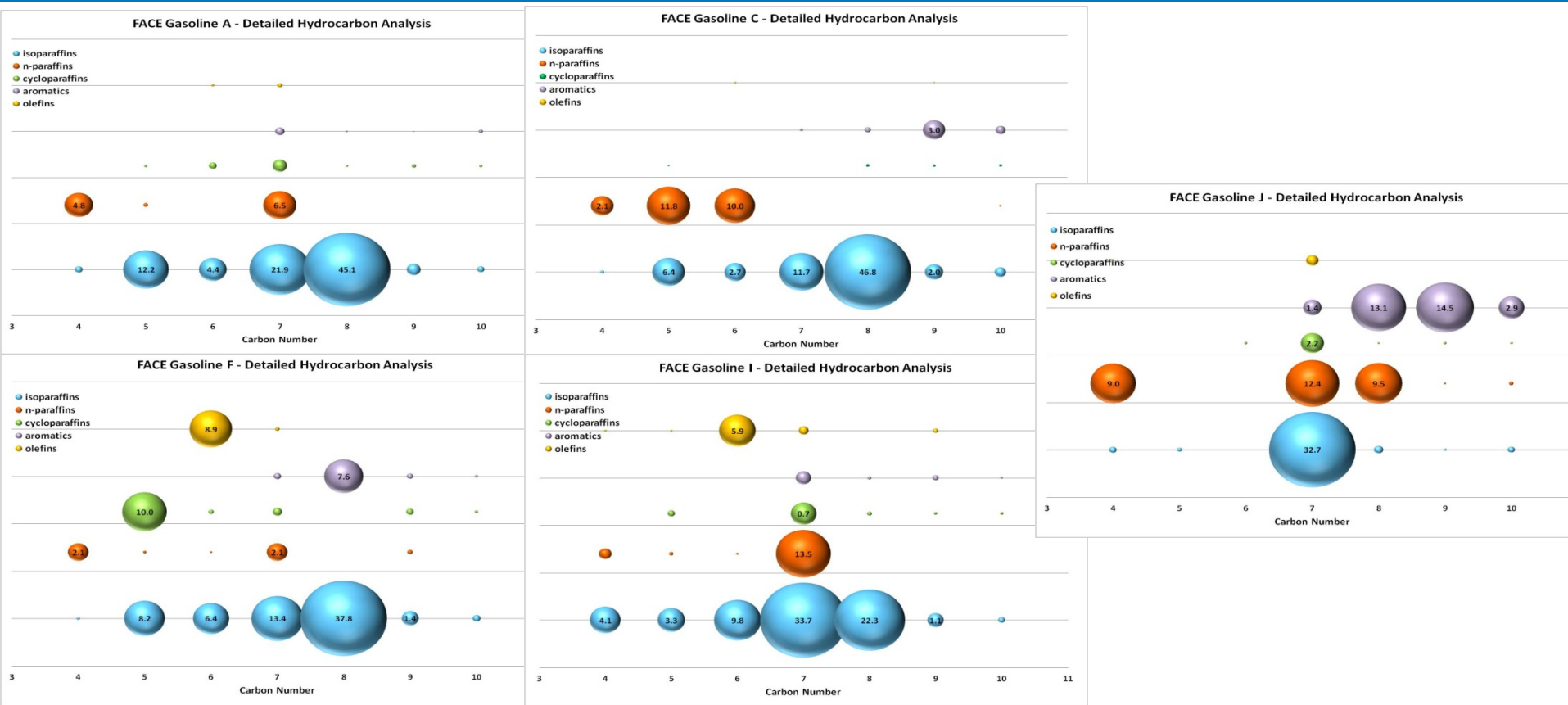
Half of the gasoline FACE matrix is now available for purchase, with the remainder coming soon.

Technical Accomplishments and Progress



Available gasoline FACE matrix blends are close to targets.

Technical Accomplishments and Progress



Detailed hydrocarbon analysis by gas chromatography has been conducted by Chevron (Bill Cannella) and ConocoPhillips (Ken Wright).

Characterization of gasoline FACE matrix has begun, and data will be publicly available.

Technical Accomplishments and Progress

- The lessons learned from the FACE working group effort also enabled other related research projects:
 - Further development of non-traditional fuel analyses is continuing through collaborations between LLNL, NREL, ORNL, PNNL, SNL, CanmetENERGY and other CRC members
 - Development of multi-component diesel surrogate with supporting kinetic model, complementing FACE diesel matrix: AVFL-18
 - Apply advanced characterization techniques to formerly Advanced Alternative and Renewable Fuels (AARF) feedstocks: AVFL-19
 - While the list is not finalized, the AARF team is considering:
 - 2nd generation biofuels
 - Non-food sources
 - Jatropha
 - Algae
 - Lignocellulose
 - Other biomass-to-liquid
 - Advanced processing of edible feedstocks
 - Hydrotreated animal fat
 - Hydrotreated soy oil
 - Oil shale
 - Oil sands
 - Other processing, including Fischer-Tropsch

Collaboration and Coordination

- DOE laboratories
 - LLNL, NREL, ORNL, PNNL, SNL
- Canadian laboratories
 - CanmetENERGY Natural Resources Canada, National Research Council - Canada
- Other research organizations
 - Battelle, National Institute of Standards and Technology, independent consultants
- Coordinating Research Council member companies, including autos and oils
 - AVL
 - BP
 - Chevron
 - ConocoPhillips
 - ExxonMobil
 - Ford
 - General Motors
 - Marathon
 - Mitsubishi
 - Nissan
 - Ricardo
 - Saudi Aramco
- Active collaboration of national laboratories and industry partners via CRC has been critical to the success of this project
- Past Annual Merit Review feedback has indicated FACE should be a model for other DOE programs

Proposed Future Work

- Finalize remaining FACE gasoline matrix blends, then enable CPChem to manufacture and sell them
- Perform characterization of FACE gasoline fuels and publish results
- Continue to encourage use of FACE diesel and gasoline research matrix fuels
 - CRC-directed study using FACE diesel matrix to enable advanced combustion regimes in a light-duty engine: AVFL-16 project
- Continue correlation of available engine-based data with FACE fuels to physical and chemical properties. ORNL is leading this effort. NRC-Canada and industry have contributed data.
- Continue to apply techniques developed in FACE diesel advanced characterization effort to related research projects:
 - Address paucity of combustion-related physicochemical data for AARF: AVFL-19 project
 - Continue development of multi-component diesel surrogate with full kinetic model, complementing FACE diesel fuel matrix: AVFL-18 project

Summary

- FACE Working Group objective: *To develop, characterize, and recommend research fuel sets that can be used broadly in research efforts to provide tie-points between these efforts that will further increase the understanding of fuel property impacts on advanced combustion processes, their efficiency, and their emissions.*
- FACE Working Group is composed of a wide range of industry and national laboratory experts and is facilitated by the CRC
- U.S. DOE and Canadian national laboratories continue to make significant contributions to CRC FACE Working Group:
 - FACE diesel matrix developed, characterized, and being utilized for combustion / fuels research studies
 - Knowledge gained from FACE diesel matrix characterization effort enabled other related studies:
 - AVFL-18: multi-component diesel surrogates with supporting kinetic models
 - AVFL-19: advanced alternatives and renewable fuels
 - FACE gasoline matrix development nearly completed, with five fuels currently available from CPChem. Plans set for extensive characterization.
 - These parametric fuel sets have created common experimental tie-points and provide researchers both research fuels and a wealth of data with which to correlate advanced combustion to chemistry. ORNL has begun initial engine data correlation work.

Acknowledgements

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CRC FACE Working Group Members

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- Robert Wagner (co-chair)
- Brad Zigler (co-chair)

Chevron Energy Technology Co.

ORNL

NREL

- | | | | |
|----------------------|-------------------------------|-------------------|-------------------------------|
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