Co-Optimization of
Fuels & Engines

Co-Optima Market Transformation Team

Team Lead: Doug Longman
Argonne National Laboratory

8 March 2017

Goal and Relevance

Co-Optima MT Goal Statement

Identify and mitigate the challenges of moving new fuels and vehicles into markets

1. Engaging with all critical stakeholders (OEM's, fuel producers, distribution networks, gas station owners, UL, regulators, consumers, etc.)
2. Understanding and addressing impacts, concerns, opportunities, and barriers

Relevance

The MT team enables the introduction of new, co-optimized fuels and engines that will result in expanded markets for renewable fuels through:

- Facilitating new fuel standards needed for introduction into the marketplace
- Identifying vehicle, distribution, and infrastructure compatibility of new candidate bio-blendstocks
- Interact with all market sector stakeholders for technology transfer from the national labs to the industries that produce and market fuels and vehicles.

Quad Chart Overview

Timeline

Project Start Date:	10.1.2015
Project End Date:	9.30.2018
Percent Complete:	42%

Budget ($K)

	FY16	FY17	FY18
BETO	$1,300	$1,400	$1,400
VTO	$125	$100	$0

Partners

ANL, INL, NREL, ORNL

Barriers

Im-C: Codes, standards, and approval for use. MT is providing technical information to regulatory agencies and standards organizations.

Im-G: Biofuels distribution infrastructure. MT is collating and co-leading developing key data required to assess backward compatibility and infrastructure use.

It-D: Engines not optimized for biofuel. MT engages with stakeholders from all market sectors to identify the engine-biofuel co-optimization

1 Project Overview

Project Overview

Historical new fuel and vehicle introductions “Lessons Learned” reports were generated to provide past success and failure perspective.

- New fuels successfully introduced to the U.S. marketplace since the 1970s have had societal need, technical solution, and policy or regulatory drivers

Stakeholder engagement activity has initiated two-way communication with all market sectors potentially affected by Co-Optima.

- Listening Day feedback has guided AOP development and future plans
- External Advisory Board used for quick feedback on technical hurdles/progress

New fuel/vehicle misfueling mitigation measures may require industry standards to be established, which the Co-Optima MT team is facilitating.

- OEMs will not “get credit” for fuel economy certification on the new fuel if they cannot ensure that the fuel is actually used in the marketplace

The ability to introduce a second new fuel into the marketplace will require significant benefits.

- Fuel properties approach is a key focus of Co-Optima, which allows consideration of backward compatibility of components that meet fuel properties.
- Analysis is underway to quantify the amount of improvement required to justify a change in the marketplace if backward compatibility is achieved and if it is not achieved.

2 Approach (Management)

Approach (Management)

FY17 Team Lab Leads and PIs

Argonne NATIONAL LABORATORY	***Doug Longman***, Andy Burnham, Mike Duoba, Marianne Mintz , Marcy Rood , Dan Santini
INL Idaho National Laboratory	***Jason Hansen***, Shyam Nair
NREL NATIONAL RENEWABLE ENERGY LABORATORY	***Teresa Alleman,*** *Caley Johnson, Kristi Moriarty, Justin Sluiter*
OAK RIDGE National Laboratory	***Brian West,*** Mike Kass, Scott Sluder

Team Lead: Doug Longman (ANL)

Co-Lead: Teresa Alleman (NREL)

Approach (Management)

Team Engagement

MT Team Management

- Bi-weekly team conference calls are conducted by the team lead or deputy to check progress and status of active tasks
- Resources available for critical activities are assessed, and resulting actions needed are identified
- Meeting minutes are recorded and posted on Co-Optima's SharePoint site

MT Task Leaders conduct calls as needed to coordinate inter-lab activities

- Stakeholder Engagement – Doug Longman, ANL
- Lessons Learned Reports – Teresa Alleman, NREL
- Misfueling Mitigation – Scott Sluder, ORNL
- Co-Optimizer Algorithm Metrics – Teresa Alleman, NREL
- Market Introduction Scenario Analysis – Caley Johnson, NREL

Approach (Management)

Team Interactions

Interactions with other Co-Optima teams

- Coordinate with all team leads for making monthly stakeholder conference call presentations
- High Performance Fuels materials compatibility closely linked (two members with dual team membership)
- Fuel Properties team provides the Fuel Property Database, which MT uses to inform MT metrics
- Close interactions with the ASSERT team for market analysis; weekly meeting between team leads

Leadership Team interactions

- MT lead and deputy have monthly calls with the Co-Optima leadership
- Quarterly face-to-face meetings between leadership and team leads

2 Approach (Technical)

Approach (Technical)

Approach - **Engage with critical stakeholders**

- Communicate Co-Optima goals
- Understand their technical needs
- Understand their value propositions

- External Advisory Board – Early feedback on priorities of market sectors
- Monthly stakeholder conference calls – Inform technical accomplishments
- One-on-one visits – Contact reports generated with key takeaways
- Listening Day events – Detailed feedback and 2-way interactions
- Identify the financial incentives necessary for industry to change their fuels and/or vehicles

Approach - **Complete critical assessments**

- Working with ASSERT
- Working with AED, FP, and HPF

Focus on requirements to get new fuels and engines to market

- Identify critical problems that other teams miss
- Execute analysis to define solutions
- Execute analysis to determine “size of the lift”
- Determine value propositions

Approach (Technical)

Top Challenges

- Balance the benefits among multiple stakeholders to bring co-optimized new fuels & vehicles to consumers, emphasizing market-driven solutions over policy-driven solutions
- Infrastructure compatibility for new fuel introduction
  - Seek new fuel Co-Optima solutions that minimize the disruption to the infrastructure, particularly the retail sector which is 60% individually owned/operated with limited capital for investment
- Vehicle backwards compatibility
  - Ensure that new Co-Optima fuel solutions maximize the level of existing fleet compatibility where possible, and understand the potential unintended consequences when it's not
- Completing codes and standards
  - Develop the specification for a Co-Optima led new fuel, as well as a new industry standard for misfueling mitigation

Critical Success Factors

- Market Transformation success is gauged by the willingness of industry to "carry the ball" following tech transfer from the labs.
- Do not pick market sector winners or losers – let the marketplace decide using science provided by the Co-Optima team
- Support informed decision making by the Co-Optima team
- Coordinate & facilitate introducing a new fuel specification to the market

3 Technical Accomplishments

Lessons Learned

"Lessons Learned" Reports on new fuel and vehicle introductions

- Fuel & Vehicle Introduction
- Fuel & Vehicle Distribution & Infrastructure
- Feedstock Effects
- Laws & Incentives

Summary Report

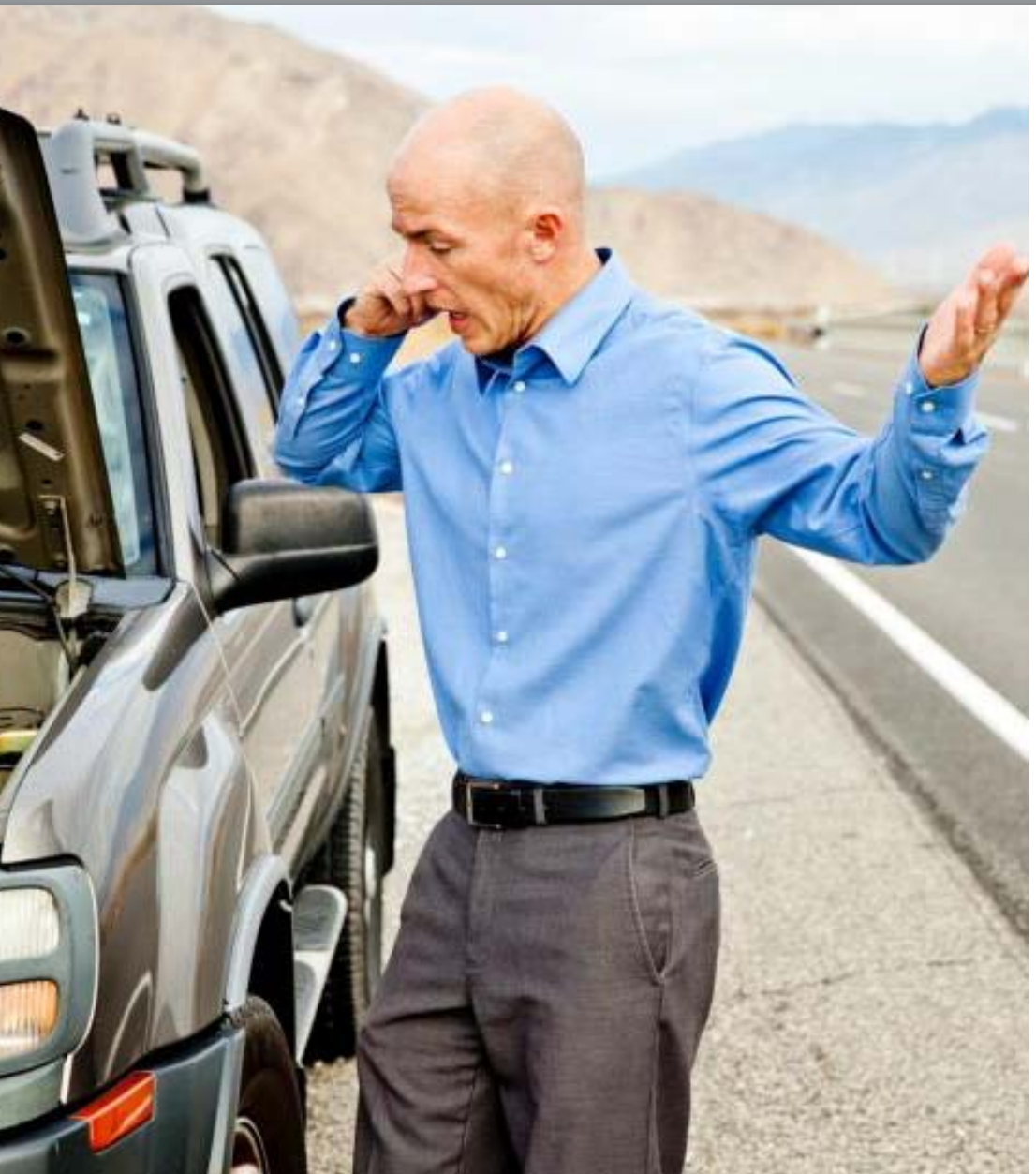
- New fuels successfully introduced to the U.S. marketplace since the 1970s have all had a societal need, a technical solution, and a champion. Consistent policy and regulatory environment is critical!
- Examples: removing lead from gasoline and sulfur from diesel—societal need was clean air (lead by CARB). Pb and S damage the catalytic systems required to remove tailpipe emissions. A consistent policy and regulatory environment enabled oil & auto/heavy-duty OEMs to work together on the solutions.

All 5 reports are in the publication "pipeline" for public domain

"Those who fail to learn from history are doomed to repeat it."
Sir Winston Churchill

https://upload.wikimedia.org/wikipedia/commons/9/9c/Sir_Winston_S_Churchill.jpg

Misfueling Mitigation



SAE committee activity initiated to establish an industry standard

- FY16 activity report in publication process

As long as any lower grade fuel exists in the marketplace, ***OEMs will not "get credit" for fuel economy certification on the new fuel if they cannot ensure that the fuel is actually used in the marketplace.***

Technologies are available today that can facilitate this with electronic communication to fuel dispensers, but the landscape is changing quickly.

Stakeholder Engagement – 1 on 1

Summary of CY2014-15 Contacts

- Three engine / auto OEMs & trade organizations
- Six energy companies and trade organizations with petroleum interests
- Four biofuel-producing companies
- Two infrastructure and retail-related companies
- One regulatory organization
- Two general-interest organizations
- 18 TOTAL

Summary of CY2016-17 Contacts

- Eight engine / auto OEMs & trade organizations
- Five energy companies and trade organizations with petroleum interests
- Four biofuel producing companies
- Eight infrastructure and retail-related companies
- Four regulatory organizations
- Six general interest organizations
- 35 TOTAL

Technical Accomplishments/ Progress/Results

We have met with these companies/orgs

- AAA
- Abengoa
- ADM
- Afton Chemical
- ARAMCO
- ARPA-E
- Auto Alliance
- CARB
- Caterpillar
- Chevron
- DuPont
- EPA
- ExxonMobil
- FCA
- Ford
- Fuels Institute
- General Motors
- Global Automakers
- Growth Energy
- ILTA
- LanzaTech
- Marathon
- NACS
- PACCAR
- Petroleum Equipment Institute
- Phillips 66
- Poet
- SCAQMD
- Shell
- Tesoro
- Total
- Toyota
- UL
- Union of Concerned Scientists
- UOP
- USDA
- Valero
- Virent
- Volvo
- Wayne Fueling Systems

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- Chevron
- DuPont
- EPA
- ExxonMobil
- FCA
- Ford
- Fuels Institute
- General Motors
- Global Automakers
- Growth Energy
- ILTA
- LanzaTech
- Marathon
- NACS
- PACCAR
- Petroleum Equipment
- Toyota
- UL
- Union of Concerned Scientists
- UOP
- USDA
- Valero
- Virent
- Volvo
- Wayne Fueling Systems

One-On-Ones provide organizational specific perspective into the market impact of new fuel and vehicles. This is not always revealed in larger, trade organization settings

Stakeholder Listening Days

http://energy.gov/eere/bioenergy/downloads/co-optima-stakeholder-listening-day-summary-report

June 2015 Listening Day

- Golden, CO
- 22 stakeholders in person
- 4 stakeholders via webinar
- ThinkTank used to capture feedback
- Public report on DOE Website

July 2016 Bioenergy 2016

- MT & ASSERT teams
- Evaluation metrics focused

January 2017 Listening Day

- Livermore, CA
- 18 stakeholders in person
- ThinkTank used to capture feedback

Stakeholder Listening Days

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- Golden, CO
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WHAT THEY TELL US:
Stakeholders want Co-Optima to coordinate and facilitate the development of new fuel specifications.

- Evaluation metrics focused

January 2017 Listening Day

- Livermore, CA
- 18 stakeholders in person
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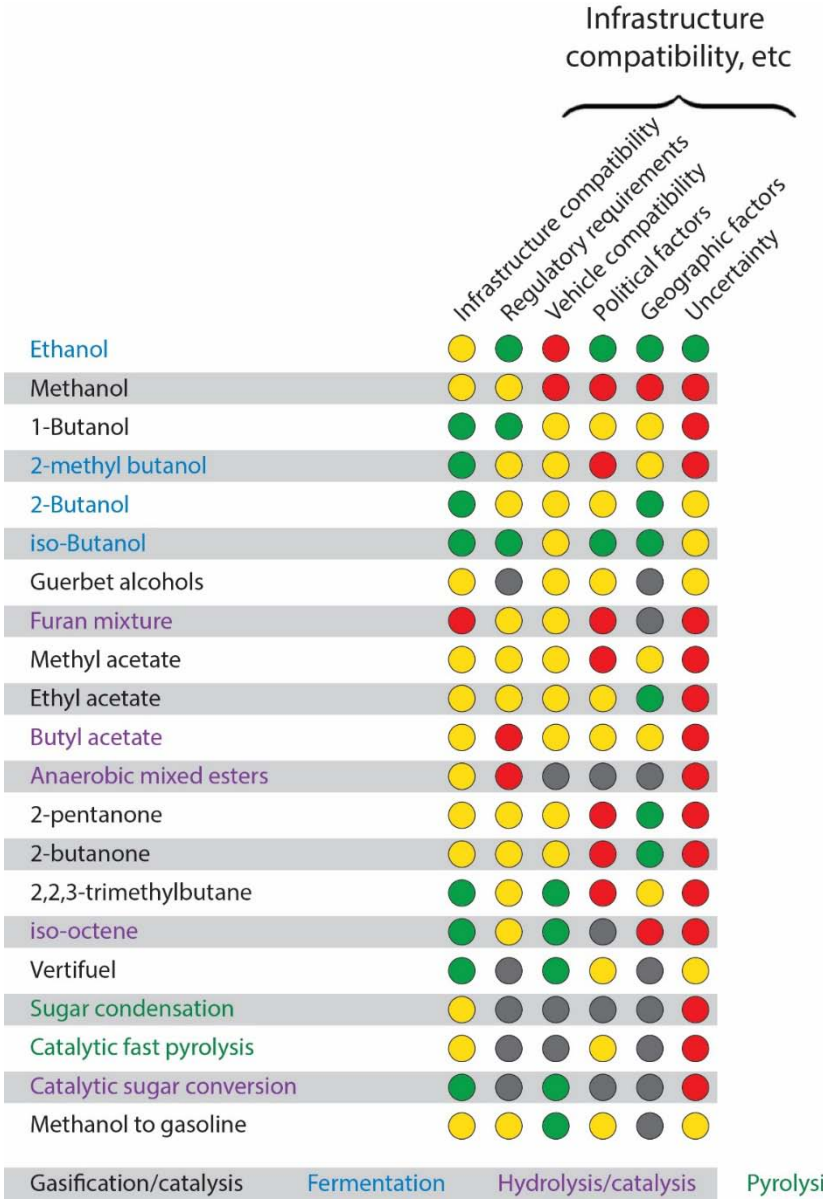
MT Co-Optimizer Metrics

MT Co-Optimizer Metrics

Infrastructure Compatibility	Compatibility of common elastomers and plastics used in fueling infrastructure across range of blend levels
Regulatory Requirements	Fuel registration, Chemical safety, odor criteria, ASTM certification, Tax & Trade Bureau registration, California multi-mode assessment, other regulatory
Vehicle Compatibility	Polymer compatibility across range of blend levels. Backward compatibility – Legacy vehicle Malfunction Indicator Light (MIL) likelihood across range of blend levels
Political Factors	Champion industries, key constituencies
Geographic Factors	Regional deployment, non-attainment areas
Uncertainty	Oil prices, deployment/adoption of connected/automated vehicles

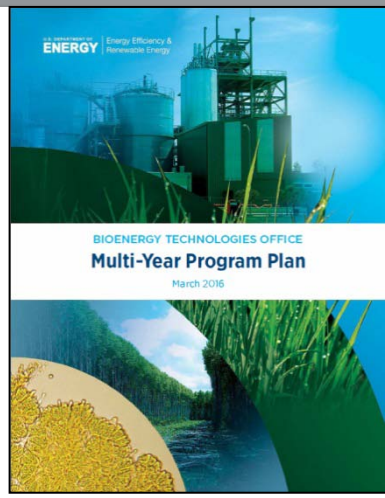
MT Co-Optimizer Metrics (cont.)

- 3 Rating Levels
  - **Red** – unfavorable (work needed)
  - **Yellow** - neutral
  - **Green** – favorable
  - **Gray** – lack of information
- "ASSERT 20" Thrust I molecules completed
- The 40 High Potential molecules identified by HPF Team are in process
- Initial MT metrics not very "green," but quite a lot of yellow.



4 Relevance

Relevance to MYPP Goals and Barriers



BETO MYPP Goal: "Enable sustainable, nationwide production of biofuels that are *compatible with today's transportation infrastructure*, can reduce greenhouse gas emissions…displace… petroleum-derived fuels to reduce U.S. dependence on foreign oil."

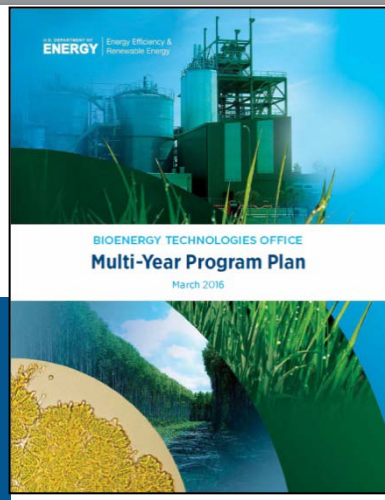
MT inputs to the Co-Optimizer Algorithm rank fuel candidates' compatibility with 6 common elastomers and 19 common plastics in infrastructure and legacy vehicles.

Im-C: Codes, Standards, and Approval for Use "New biofuels and biofuel blends must comply with federal, state, and regional regulations before being introduced to the market… *Limited data and technical information can also delay approvals of technical codes and standards for biofuels and related infrastructure components*, including pipelines, storage tanks, and dispensers……"

MT is engaged with the regulatory agencies and standards organizations to clearly identify the data and technical information that Co-Optima can provide to coordinate stakeholders meeting these requirements. The biofuels industry has the potential to garner additional market share of the fuel market with the success of Co-Optima.

Relevance to MYPP Goals and Barriers

Im-G: Biofuels Distribution Infrastructure "…Most refueling stations are privately owned with relatively thin profit margins, and *owners have been reluctant to invest in new infrastructure until the market is more fully developed.* Petroleum-compatible biofuels may also require distribution infrastructure investment."

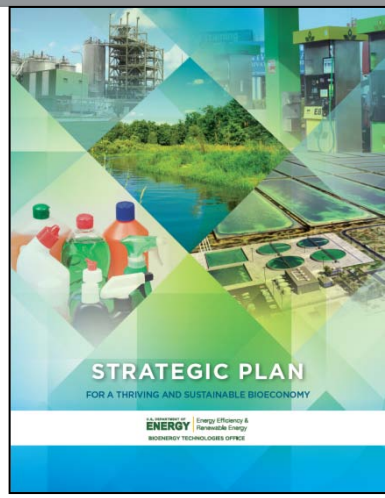


MT inputs to Optimizer Algorithm rank fuel candidates' compatibility with common infrastructure materials including 6 elastomers and 19 plastics. The "Lessons Learned" report validated the difficulty of these infrastructure modifications.

It-D: Engines not optimized for biofuel "…*Co-development of fuels and engines has … the potential to drive increased vehicle engine efficiency and reduced GHG emissions.* Vehicle manufacturers are considering the impact that the specification of new fuel mixtures and vehicle system optimizations can achieve,…."

Standard. As long as any lower grade fuel exists in the marketplace, OEMs will not "get credit" for fuel economy certification on the new fuel if they cannot ensure that the fuel is actually used in the marketplace.

Relevance to BETO's Strategic Plan



BETO Strategic Plan: "*Co-optimization of fuels and engines offers the potential to significantly improve vehicle engine efficiency, maximize engine performance and carbon efficiency, and reduce harmful emissions through accelerating the widespread deployment of improved fuels and engines.* BETO will work with the national laboratories and stakeholders to address technical barriers and facilitate eventual market entry of co-optimized fuels and engines."

MT engages with stakeholders from all market sectors to identify barriers to and solutions for bringing co-optimized technologies to market. Since neither DOE nor the national labs produce fuels or vehicles, the success of the Co-Optima program is dependent on this technology transfer to industry.

Relevance to Industry

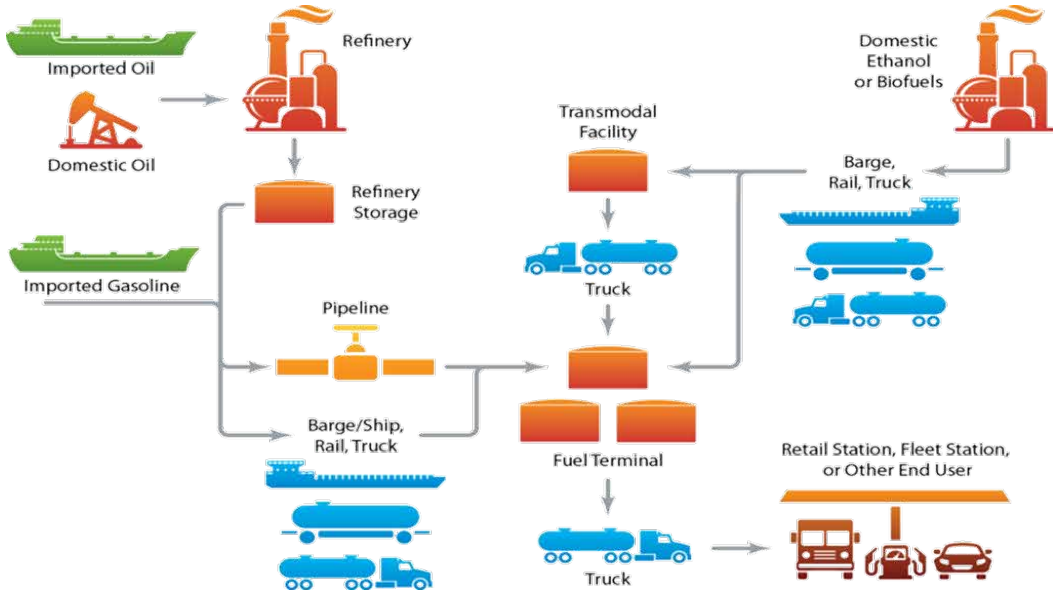
MT's engagement with stakeholders from all market sectors enables the marketplace to bring co-optimized fuel and engine technologies to market.

- Neither DOE nor the national labs produce fuels or vehicles
- Technology transfer to industry is essential for bringing new fuels and vehicles to consumers.
- Potential to create new market opportunities/US jobs in the biofuels industry

5 Future Work

Future Work – Stakeholder Engagement

- Analyze scenarios to maximize stakeholder value for all market segments
- Understand the business models for all of the fuel and vehicle market sectors
- Convene stakeholders to propose a new fuel specification based on Thrust I research
  - Request for this was received from stakeholders during Listening Day events
  - Anticipated ~ June 2017
- Our FY17 Stakeholder Engagement Plan expands Co-Optima outreach with:
  - Light-duty foreign OEMs
  - Medium- and heavy-duty OEMs
  - Biofuel producers
  - NGOs
  - Consumers
  - Retail
  - Infrastructure
  - Additive companies
  - Canadian regulatory agencies



Fuel Distribution Infrastructure

Market Insertion Scenario Analysis

Objective:

Assess the adoption and acceptance of two fuel / vehicle combinations into the light-duty market under various introduction scenarios, beginning in 2025 (Thrust I)

Q4FY17 Dashboard Milestone (VTO)

- Fuels to analyze
  - E40 – High-Octane Fuel Program update
  - Catalytic fast pyrolysis (pyrolysis gasoline)
- Thrust I Engine
  - Spark ignited
  - Downsized
  - Boosted

Closely work with ASSERT team – ADOPT/BSM models

- Automotive Deployment Options Projection Tool (ADOPT)
- Biomass Scenario Model (BSM)

Stakeholder interview guided

FY18 – Analyze Thrust II fuels / engines insertion

- 2030 target, adding medium duty and heavy duty markets

Future Work (cont.) – FY17+ Plans

- Co-Optimizer metrics
  - Regular re-assessment of candidate molecule blendstocks
  - Metric revision, addition, and update
- Steps required to introduce a new fuel & engine report
  - Coordinate industry standards organizations for a new fuel specification
- Publish “Lessons Learned” reports
  - Finish publications
- Misfueling Mitigation
  - Society of Automotive Engineers standards committee engagement
  - Convene stakeholder workshop
- Webinar Series – Tech2Market (VTO)
  - Fuel and blend-stock distribution from production to end use via truck, rail, barge, and pipeline
  - General EPA registration needs and process
  - ASTM and National Council on Weights & Measures process

Summary

Section	Summary
1	Lessons learned from new fuel introductions emphasizes the need to engage those who inform policy and regulation. The MT team has engaged those regulatory and policy informing organizations.
2	Biggest Challenges (barriers) facing Co-Optima that MT is addressing: • Infrastructure compatibility for new fuel introduction • Vehicle backwards compatibility • Misfueling mitigation
3	One-on-one visits with 40 organizations; in communication with 132 individual stakeholders from 74 organizations. Continuous, two-way communication needed to keep pace with constantly changing transportation landscape.
3	MT provides outreach to Co-Optima team and stakeholders to facilitate the technology transfer to industry necessary for Co-Optima success.
4	MT engages with stakeholders from all market sectors to identify barriers and solutions for bringing co-optimized technologies to market. Since neither DOE nor the National Labs produce fuels or vehicles, the success of the Co-Optima program is dependent on this technology transfer to industry.
5	Market introduction scenario analysis will provide guidance for the necessary Thrust II benefits.

Additional Slides

Publications, Patents, Presentations, Awards, and Commercialization

2016 Publications

- *Co-Optima Stakeholder Listening Day Summary Report*. Jointly sponsored by the EERE Vehicle Technologies Office and the EERE Bioenergy Technologies Office, June 16-17, 2015. http://www.energy.gov/sites/prod/files/2016/04/f30/co-optima_listening_day_summary_report_0.pdf

- Market Transformation: Identify and Mitigate Barriers to New Fuel Deployment for Thrust I and Thrust II, D. Longman. http://www.energy.gov/sites/prod/files/2016/09/f33/cooptima_webinar_6_market_transformation.pdf

Market Transformation - Lesson Learned Reports: In process/All under review

- *History of Significant Vehicle and Fuel Introductions in the United States*, B West
- *Fuel and Vehicle Distribution & Infrastructure*, M. Mintz
- *Summary of Lessons Learned from Corn Supply for Ethanol Production Applied to Logistics of Cellulosic Biofuels*, M. Shirk
- *The Role of Laws, Incentives, and Regulations in the Transformation of Markets for Fuels and Powertrains of Passenger Cars*, T. Alleman
- *New Fuel and Vehicle Introduction Lessons Learned Synopsis/Summary Report*, T. Alleman
- *Misfueling Mitigation*, S. Sluder

Stakeholder Interactions CY14 & CY15

OPTIMA Stakeholder Engagement FY15 Individual Meetings			
Stakeholder Name	Date of Visit	Location of Visit	Co-Optima Participants
ExxonMobil	12/10/2014	ExxonMobil Fairfax, VA	Farrell, Pontau
Ford	12/11/2014	Ford, Dearborn, MI	Farrell, Pontau
GM	12/13/2014	GM, Warren, MI	Farrell, Pontau
UOP	12/16/2014	Des Plaines, IL	Holladay
LanzaTech	12/16/2014	Skokie, IL	Holladay
Virent	12/18/2014	Madison, WI	Holladay
ExxonMobil	01/12/2015	Clinton, NJ	Farrell, Holladay, Pontau
Chrysler	01/13/2015	Chrysler, Auburn Hills, MI	Miles, Wagner
Dupont	01/14/2015	Wilmington, DE	Holladay
EPA	02/20/2015	Ann Arbor, MI	Farrell, Pontau
Chevron	02/26/2015	Houston, TX	Marrone, Miles
Union of Concerned Scientists	03/17/2015	Washington, DC	Farrell Wagner Dunn
TMFB UAachen	09/03/2015	Cambridge, UK	George
Phillips 66	09/14/2015	Houston, TX	Farrell, Pontau, Wagner
Shell	09/15/2015	Houston, TX	Farrell, Pontau
Tesoro	09/16/2015	Houston, TX	Farrell, Pontau
National Tanks Conference & Expo	09/14-16-2015	Phoenix, AZ	Moriarty
Net-Zero Drive Across Colorado	10/07/2015	Denver, CO	Johnson
NACS & PEI	10/12-14/2015	Las Vegas, NV	Moriarty
OPIS	10/15-16/2015	Chicago, IL	Johnson
ICM	11/20/2015	Colwich, KS	Farrell, Longman
Flint Hills Resources	11/20/2015	Wichita, KS	Farrell, Longman

Stakeholder Interactions (cont.) CY16

Co-OPTIMA Stakeholder Engagement CY16 Meetings			
Stakeholder Name	Date of Visit	Location of Visit	Co-Optima Participants
API	Jan 20, 2016	Washington, DC	Farrell, Pontau, Wagner
EPA	Feb 25, 2016	Ann Arbor, MI	Moriarty, West
ADM	Feb 25, 2016	Decatur, IL	Farrell, Longman
MPACT	Mar 24, 2016	Indianapolis, IN	Farrell
Wayne Technology Summit	April 6, 2016	Austin, TX	Longman, Moriarty
SAE High Efficiency ICE Symposium	April 11, 2016	Detroit, MI	Farrell, Wagner, Longman, Som
ARAMCO Services	April 15 2016	Novi, MI	Farrell, McCormick, Longman
Fuels Institute Annual Meeting	April 27-29, 2016	San Francisco, CA	Farrell, Pontau
PEI Board	April 29, 2016	Austin, TX	Longman
Cummins	May 3, 2016	Golden, CO	Farrell
BOSMAL	May 20, 2016	Bielsko, Poland	Wallner
ILTA	May 23-24, 2016	Houston, TX	Alleman
Texon	May 24, 2016	Houston, TX	Alleman
API Tech Subcommittee	June 14, 2016	Denver, CO	Farrell, Pontau
Governor's Biofuels Consortium	June 17, 2016	Teleconference	Farrell
ASTM D02 & E48	June 26-Jul1, 2016	Bellevue, WA,	Alleman

Co-OPTIMA Stakeholder Engagement CY16 Meetings			
Stakeholder Name	Date of Visit	Location of Visit	Co-Optima Participants
Fuels Institute Symposiums	June 29-30, 2016	Washington, DC	Sarkar, Longman, Moriarty, Sluder, Farrell
EIA Conference	July 11-12, 2016	Washington, DC	Alleman, Johnson
Sustainable Transportation Summit	July 12, 2016	Washington, DC	Farrell, Gaspar, Dunn, Miles, etc
Afton Chemical	July 13, 2016	Richmond, VA	Alleman, Longman
BioEnergy2016 & Stakeholder Meeting	July 14, 2016	Washington, DC	Farrell, Gaspar, Dunn, Miles, Longman, Alleman, Biddy
USCAR Crosscut Team	July 21, 2016	Southfield, MI	Wagner, Miles
NCWM	July 24-26, 2016	Denver, CO	Alleman
Nat'l Council of State Legislators	Aug 8, 2016	Chicago, IL	Farrell
FCA	August 15, 2016	Auburn Hills, MI	Farrell, Wagner, , Szybist
US DRIVE FWG	August 25, 2016	Teleconference	Farrell
Auto Alliance	August, 31, 2016	Southfield, MI	Longman, Schlenker
Global Automakers	Sept 20, 2016	Washington, DC	Longman
FISITA	Sept 28, 2016	Busan, Korea	Musculus
Auto-Ag Ethanol Annual Forum	Oct 5, 2016	Detroit, MI	McCormick
API	Oct 12, 2016	Teleconference	Gaspar, Farrell, Pontau
A3PS-"Eco-Mobility 2016"	Oct 17, 2016	Vienna, Austria	Farrell
PEI Show @ NACS	Oct 19, 2016	Atlanta, GA	Berube, Moriarty
Racetrac	Oct 19, 2016	Atlanta, GA	Moriarty
ASTM	Dec 4-8, 2016	Orlando, FL	Alleman

Stakeholder Engagement / External Advisory Board (EAB)

Members

• American Petroleum Institute	Bill Cannella
• Fuels Institute	John Eichberger
• Academic / Engine	David Foster
• Truck & Engine Manufacturers Assoc.	Roger Gault
• California Air Resources Board	James Guthrie
• U.S. Environmental Protection Agency	Paul Machiele
• American Bio-Fuels Association	Michael McAdams
• Underwriters Laboratory	Edgart Wolff-Klammer
• USCAR	David Brooks
• Academic / Fuel	Ralph Cavalieri
• Flint Hills Resources	Chris Pritchard
• General Advisor	John Wall

EAB has provided Co-Optima with early feedback on analysis results, insight on stakeholder issues, and Multi-Year Strategic Plan development.