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ASERTTI

The Future of Sustainable Transportation Fuels Webinar
Webinar 1: Anchoring Themes
May 29, 2015

Gary Dirks
Director of ASU LightWorks and
Director of the Julie Ann Wrigley
Global Institute of Sustainability

The Future of Sustainable Transportation Fuels Series
Part one of a four-part series

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Edward Saltzberg
Security & Sustainability Forum
Managing Director

ACORE American Council On Renewable Energy

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The Future of Sustainable Transportation Fuels Series

Series Organizer and Leader:
Dr. Ellen Stechel

Deputy Director, LightWorks
Managing Director, Light*Speed* Solutions

- Professor of Practice, Department of Chemistry and Biochemistry, College of Liberal Arts and Sciences
- Senior Sustainability Scientist, Julie Ann Wrigley Global Institute of Sustainability

ellen.stechel@asu.edu

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- **The Future of Sustainable Transportation Fuels**
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Agenda

- Overview and Introductions: Dr. Gary Dirks
- Presentations
  - Dr. Paul Bryan, UC-Berkeley
  - Sharon Burke, New America Foundation
  - Dr. Kathryn Clay, American Gas Association
  - Dr. Mike Tamor, Ford Motor Company
- Panel Discussion led
- Audience Questions (submit through the side panel)

(Please Take the Brief Exit Survey)

The Future of Sustainable Transportation Fuels

LightSpeed Solutions
Secure Energy · Sustainable Fuels

ASU LightWorks
ARIZONA STATE UNIVERSITY
Light-Inspired Solutions

Moderator

Dr. Gary Dirks is the Director of the Julie Ann Wrigley Global Institute of Sustainability and of LightWorks, an Arizona State University initiative that capitalizes on ASU's strengths in solar energy and other light-inspired research. Before joining ASU, Dr. Dirks was the President of BP Asia Pacific and the President of BP China.

Webinar introduction

Our ability to solve a problem is limited [only] by our conception of what is feasible

— Russell L. Ackoff, The Art of Problem Solving: Accompanied by Ackoff's Fables

Our Goal

- Achieve a sustainable low net carbon transportation future
- Stimulate conversation about a broad innovation space
- Provide useful input for policy and regulation

Get involved

- Ask questions for the panelists
- Join the associated LinkedIn discussion group

Upcoming monthly webinars

Focus on new innovation spaces and assess promise of early stage technologies

- **Coupling the Electric Power & Transportation Sectors: Electric Vehicles and Beyond**
- **Recycling CO_2 to Liquid Hydrocarbon Fuels**
- **Challenges and Opportunities in Designing Good Metrics to Assess Promise**

Webinar goals

To further the conversation on achieving a sustainable low net carbon transportation future

- To accelerate the transition and promote economic efficiency
- Technical advances and better understanding are opening up opportunities to consider a broader range of options

To stimulate additional conversation and prove to be a starting point on exploring alternatives

- Won't be comprehensive, not going to provide "the "answer" and not debating perspectives
- To further innovation and to further the conversation from a wide range of viewpoints and expertise
- To provide useful guidance for decision-makers, including policy makers and regulators

Webinar panelists

Paul Bryan, Chemical & Bimolecular Engineering Dept, UC Berkeley

- Consultant in conventional and renewable fuels & chemicals
- Previously director of the now DOE Bioenergy Technologies Office
- Previously Chevron's VP for biofuels technologies

Sharon Burke, New America Foundation, Senior Advisor

- Security implications of energy, climate change, and other natural resource challenges
- Previously Assistant Secretary of Defense for Operational Energy

Kathryn Clay, American Gas Association, VP for Policy Strategy

- Previously VP of research and technology policy for the Alliance of Automobile Manufacturers
- Previously professional staff for the Energy and Natural Resources Senate Committee

Mike Tamor, Ford Research at Ford Motor Co., Technical Fellow

- Henry Ford Technical Fellow for Energy Systems and Sustainability
- Senior research leadership : global electrification, renewable fuels, hybrid vehicle and fuel cells

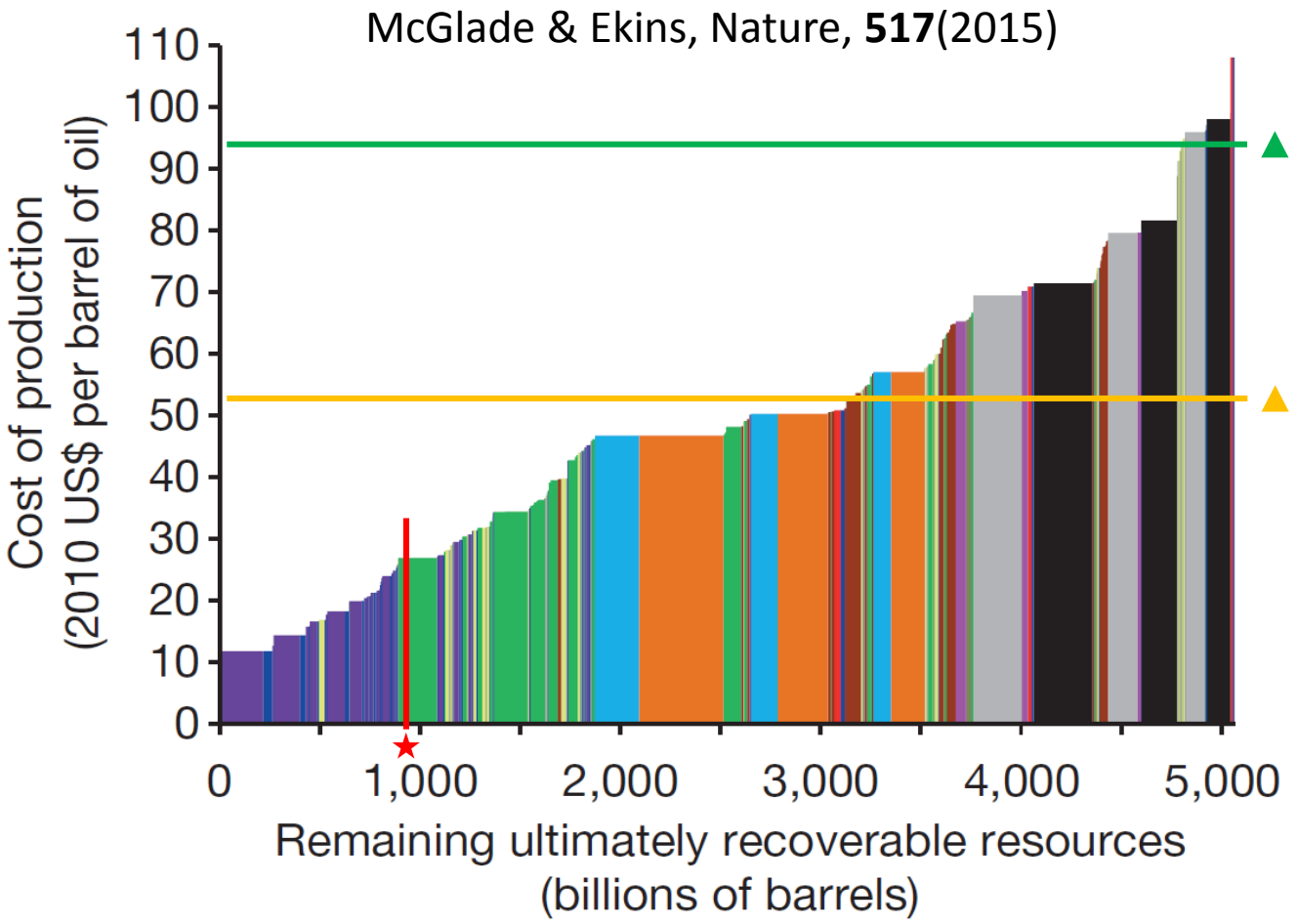
The *Sine Qua None** of Alternative Transportation Fuels

- Renewable Alternatives ***will not compete with fossil fuels on production cost at any point in the 21st Century***

* (sort of) Latin for: “Without which there ain’t gonna be any”

Paul Bryan, Ph.D.

separ8r@gmail.com



★ Total oil produced 1870 – 2009 (Jones, et al., Int. J. Oil, Gas & Coal Technol., **2**(2) (2009))

▲ Net Cost of Production of Corn & Cane Ethanol (2008 – 13; various sources; avg.)

▲ Net Cost of Production of Cellulosic Ethanol (NREL (2014-2015))

The *Sine Qua None** of Alternative Transportation Fuels

- Renewable Alternatives ***will not compete with fossil fuels on production cost at any point in the 21st Century***
- Renewable Alternatives offer many important benefits, but as of today, ***<u>none of them</u> profit the private investors whose capital we hope to attract to the field***

* (sort of) Latin for: “Without which there ain’t gonna be any”

The Many (Worthless) Benefits of Biofuels

- Widespread use of Biofuels has the Potential to:
  - Significantly reduce the GHG Footprint of the Transportation Sector
  - Create jobs, increase the tax base, and in general revitalize the economics of rural America
  - Improve the U.S. Balance of Trade by reducing petroleum imports
  - Improve our energy security by reducing dependence on imported oil
  - Remove military and diplomatic costs and constraints associated with protecting crude oil production & trade routes
  - Support technology leadership in biotechnology & advanced materials
- Bottom line: At present, not one of these benefits will put a dime in the pocket of the private-sector investors we are hoping to attract to the biofuels business!

The *Sine Qua None** of Alternative Transportation Fuels

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- Renewable Alternatives offer many important benefits, but as of today, ***none of them profit the private investors whose capital we hope to attract to the field***
- Biotechnology, which represents much of current investment and activity for biofuels, ***is unlikely ever to be competitive as a means of producing fuels***

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Cellulosic Ethanol = “Lignin-to-Coal”

- Lignocellulosic (non-food) biomass is 20-30% lignin by mass
- Lignin has ~1.5x more energy per unit mass than cellulose
- Therefore ~one-third of the energy in LCBM is lignin
- LCBM is likely to be available in quantity at $5-6/MMBtu
- Coal is worth ~$2/MMBtu
- Biological conversion of LCBM converts the lignin in the feedstock to a fuel with ***less than coal value***
- Bottom line: Biological conversion will be a great way to make ***chemicals***, but thermochemical conversion, which ***upgrades*** lignin to liquid-fuel value, will be the best way to make ***fuels***

The *Sine Qua None** of Alternative Transportation Fuels

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- Renewable Alternatives offer many important benefits, but as of today, ***none of them profit the private investors whose capital we hope to attract to the field***
- Biotechnology, which represents much of current investment and activity for biofuels, ***is unlikely ever to be competitive as a means of producing fuels***
- Bio-gas and Electric Vehicles are promising, but ***only if we decarbonize the natural gas and electric grids faster than we create new demand from the transportation sector***

* (sort of) Latin for: “Without which there ain’t gonna be any”

The Future of Sustainable Transportation Fuels
A Customer View

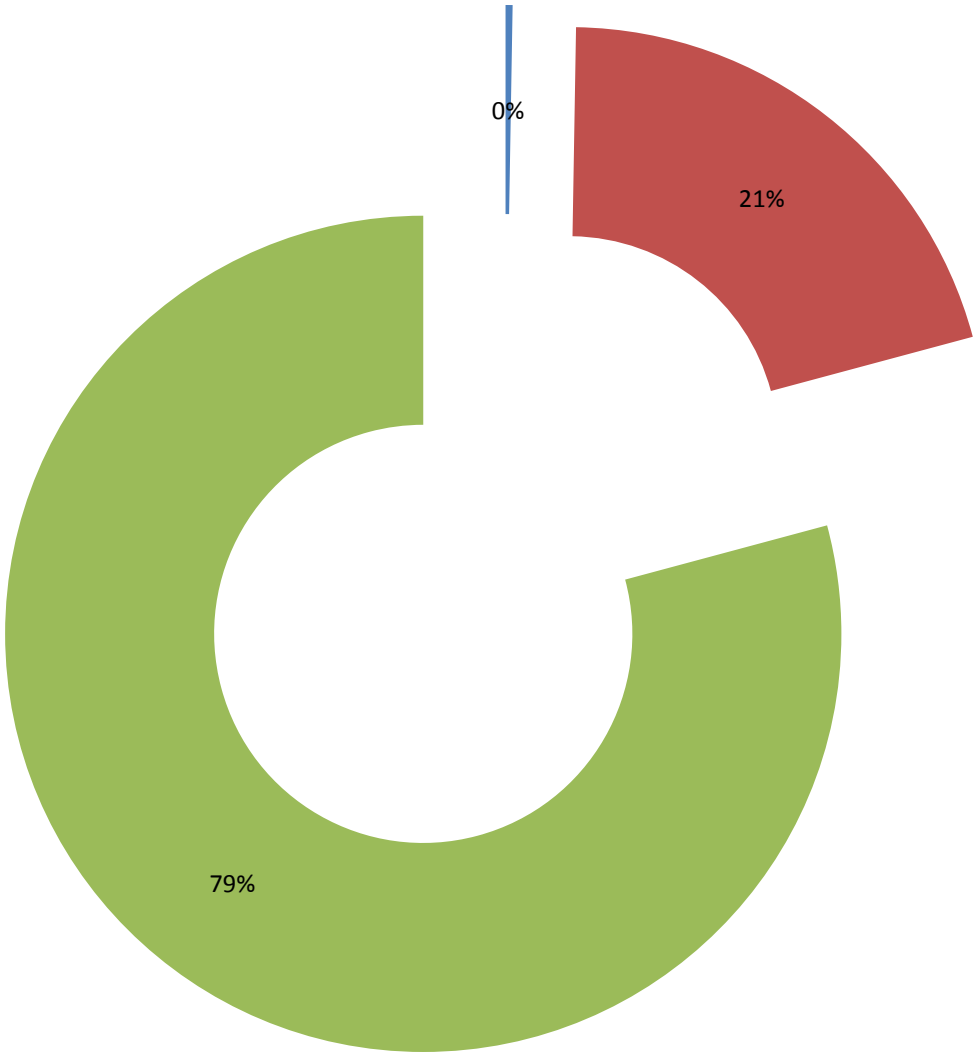
NEW AMERICA

Hon. Sharon E. Burke
Senior Advisor, New America

U.S. Department of Defense: A Major Customer for Liquid Fuels

Selected Countries	Global Oil Consumption in 2013 (Thousand of barrels/day)
Finland	198.4433
Morocco	209.37
Romania	215.25
Qatar	220
Norway	222.8332
Israel	238.091
Portugal	240.9753
U.S. Department of Defense	246.027
Libya	248
Ecuador	255
Kazakhstan	258.18
Austria	263.3436
Switzerland	263.6312
Ukraine	268
Greece	284.0151

DoD in Perspective



Total Global Daily Fuel Use 2013:

91 million barrels

- US 21%
- DoD .3% of global

1.3% of U.S.

53% USAF of DoD Consumption

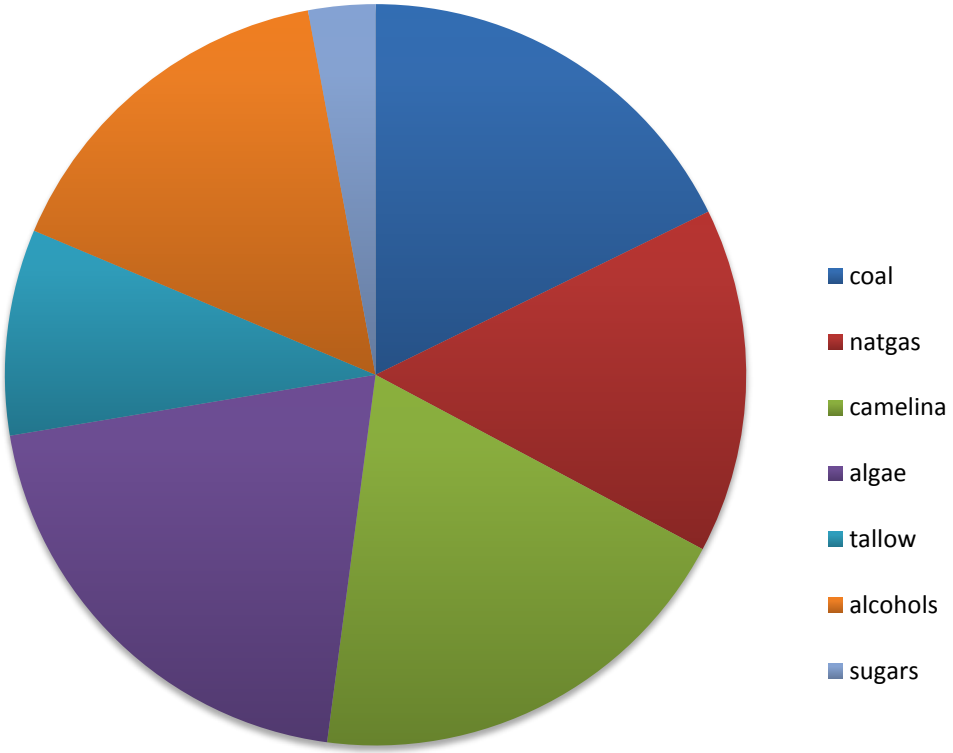
DoD Alternative Fuels Investments

DoD Alternative Fuels Purchases 2007-2012:

TOTAL: 1.9 million gallons

COST: $48 million

SOURCE: Congressional Research Service



Defense Production Act Title III Advanced Biofuels Project:

- DOD, USDA, DOE
- 2014 Award of $210M for 3 biofuel refineries
- Tallow/HEFA, MSW/FT, woody biomass/FT

How DoD Innovation Works: GPS Market Proliferation

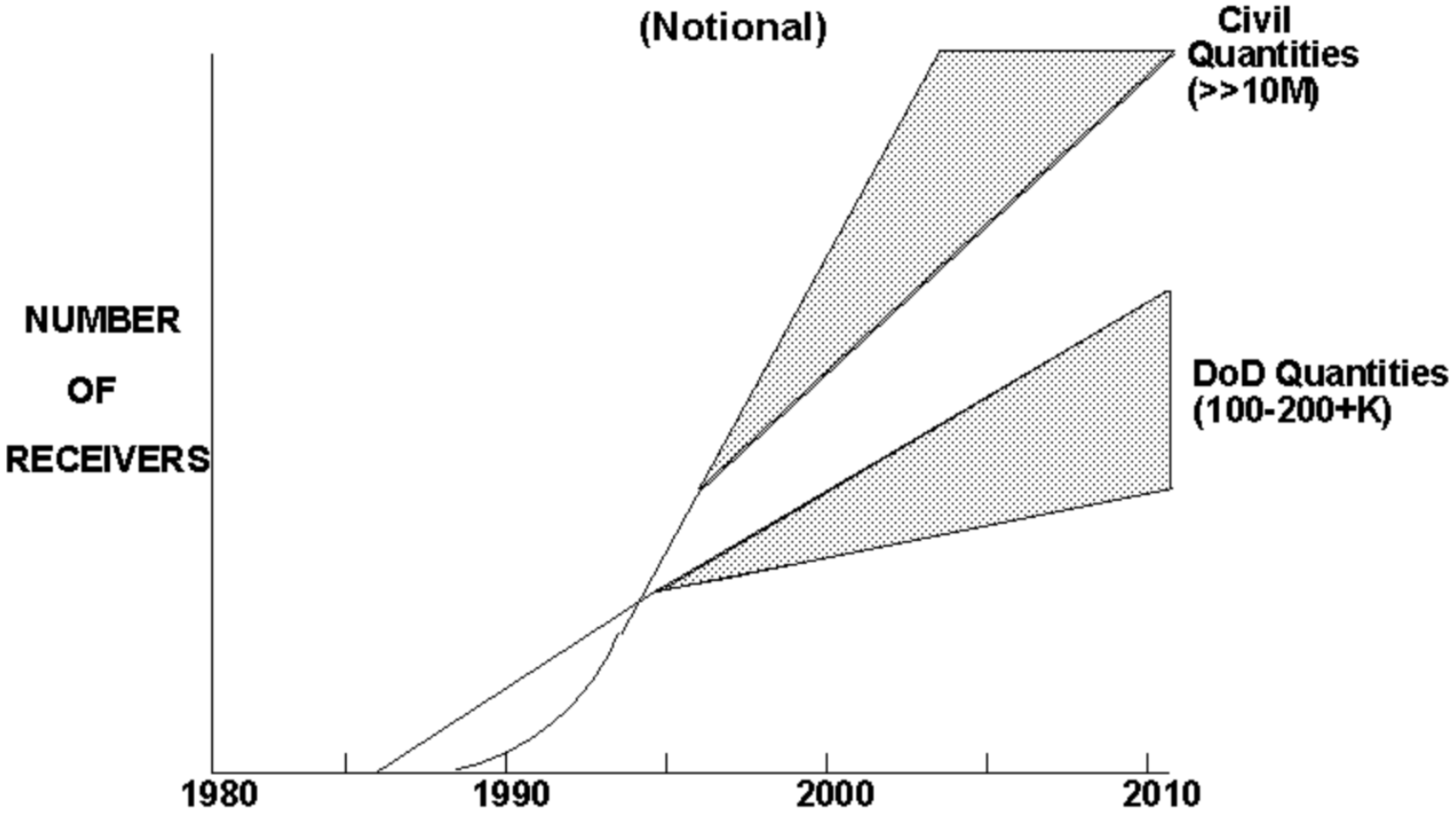


Figure 2-1: Civil Use of GPS vs. DoD

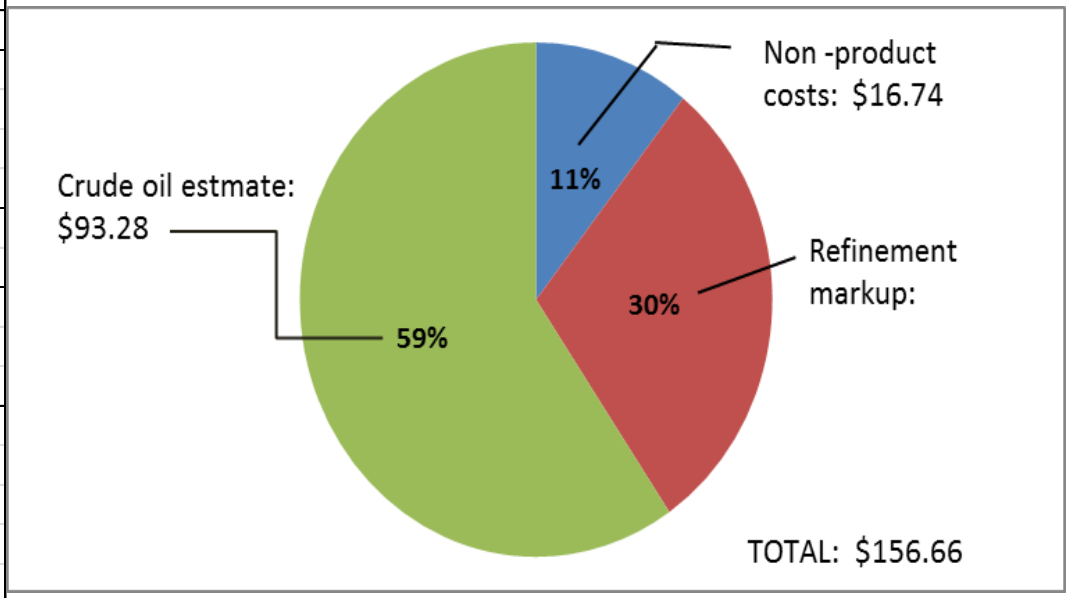
Backup Slides

Standard Price of Oil for DoD Customers

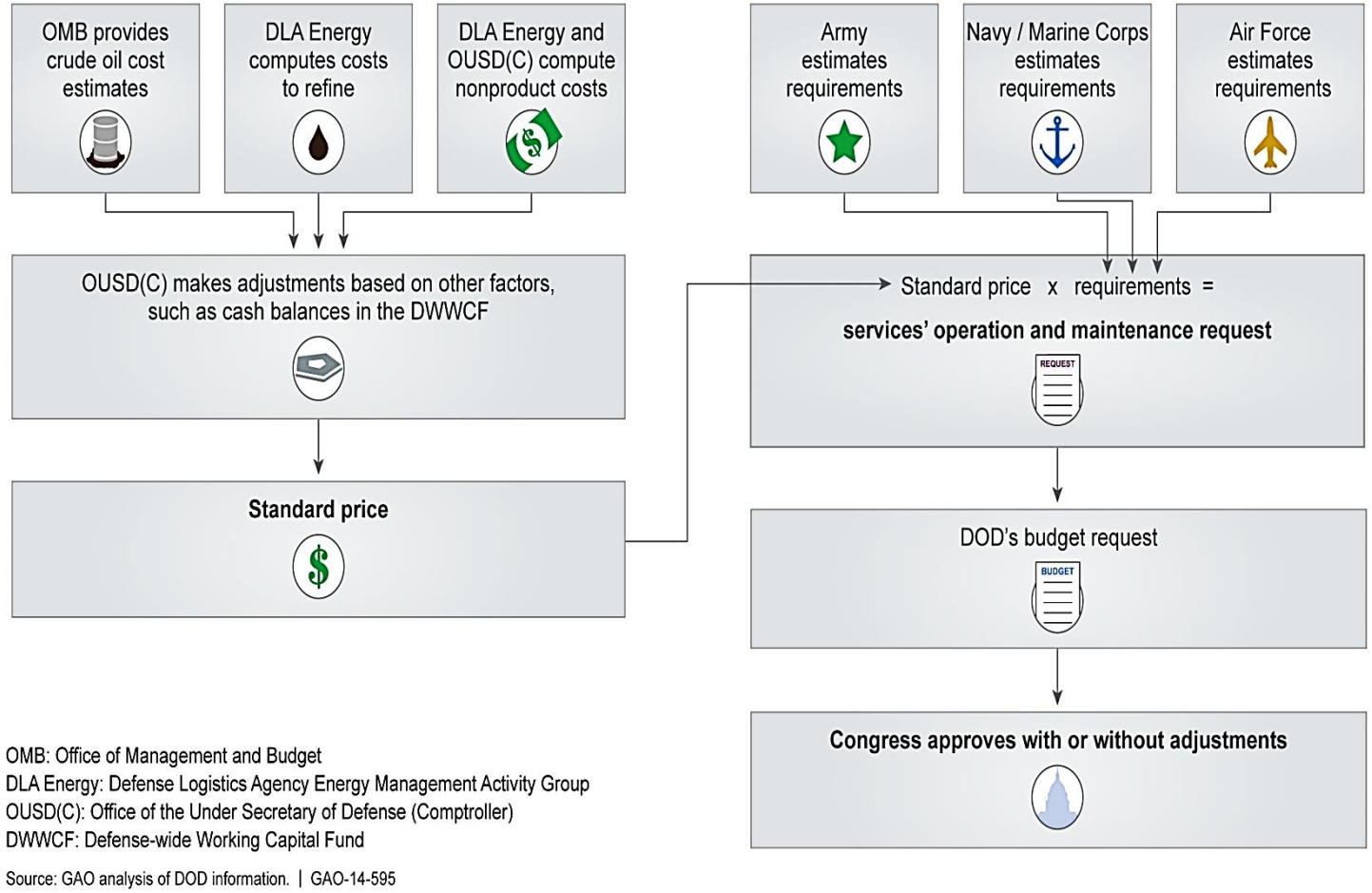
Fiscal Year	Effective Date of Standard Price	Standard Price (Per Barrel)
2016	President's budget	$144.06
2015	2/1/2015	$136.92
	10/1/2014	$155.40
2014	1/1/2014	$152.04
2013	10/1/2012	$156.66
2012	7/1/2012	$97.02
	6/1/2012	$151.20
	1/1/2012	$160.44
	10/1/2011	$165.90
2011	6/1/2011	$165.90
	10/1/2009	$116.76
2010	7/1/2010	$98.28
	1/1/2010	$118.44
	10/1/2009	$116.76
2009	9/1/2009	$89.46
	4/1/2009	$60.48
	2/1/2009	$69.72
	12/1/2008	$104.58
	10/1/2008	$170.94
2008	7/1/2008	$170.94
	12/19/2007	$127.68
	10/1/2007	$97.02

Source: DLA-Energy

Notes: Because of oil price volatility in the years following 2008 - and a decrease in avaliable supplemental funding - the Standard Price has seen large mid-year revisions to restore balance to the Defense Capital Working Fund.



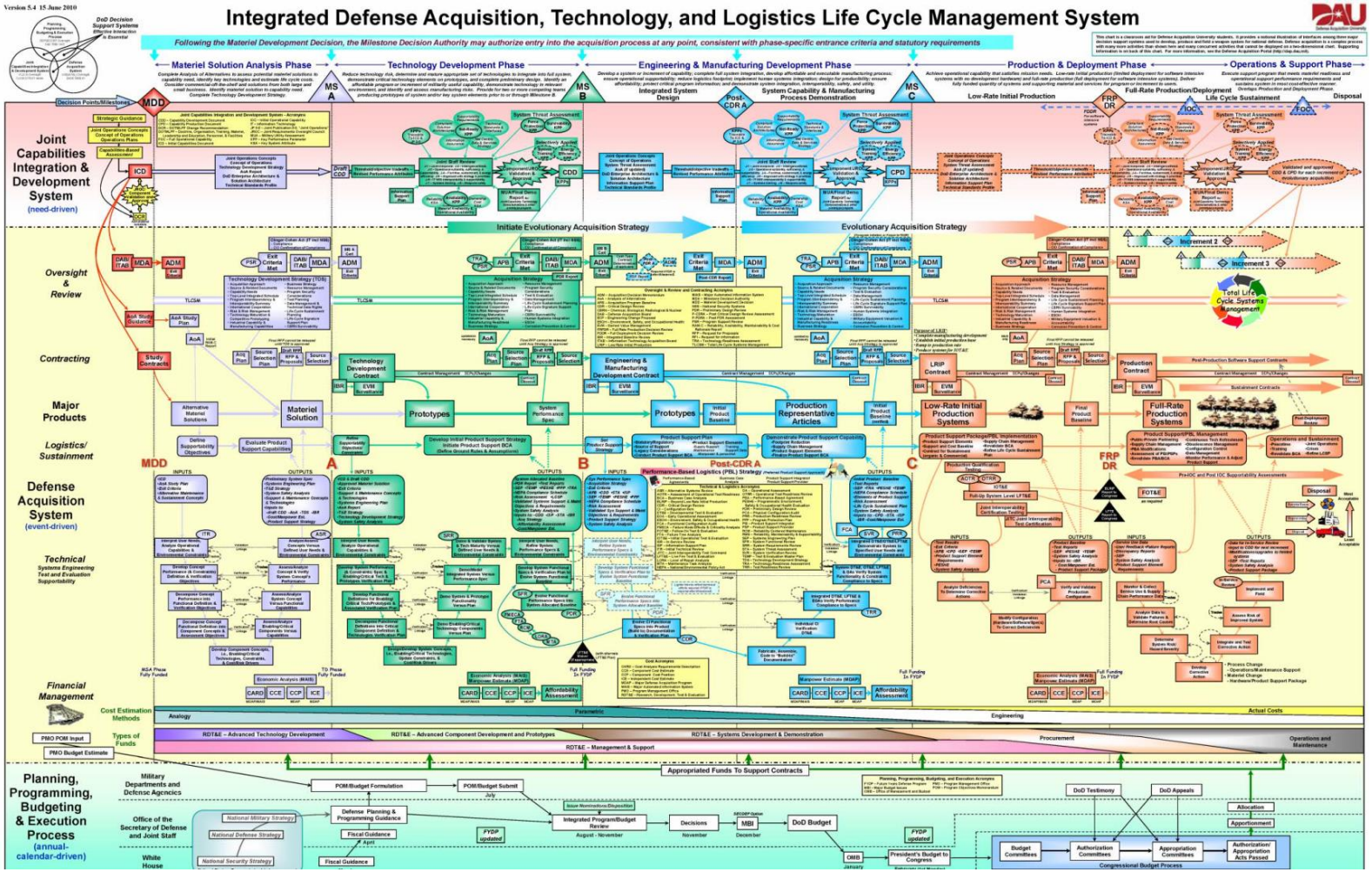
How DoD Buys Fuel



OMB: Office of Management and Budget
DLA Energy: Defense Logistics Agency Energy Management Activity Group
OUSD(C): Office of the Under Secretary of Defense (Comptroller)
DWWCF: Defense-wide Working Capital Fund

Source: GAO analysis of DOD information. | GAO-14-595

How DoD Buys Items that Consume Fuel



National Outlook for Natural Gas Vehicles

Helping to Transform the Transportation Sector

Kathryn Clay, Ph.D.
Vice President,
Policy Strategy
American Gas Association

Arizona State University
LightWorks Webinar
May 29, 2015

Shale Gas Resources

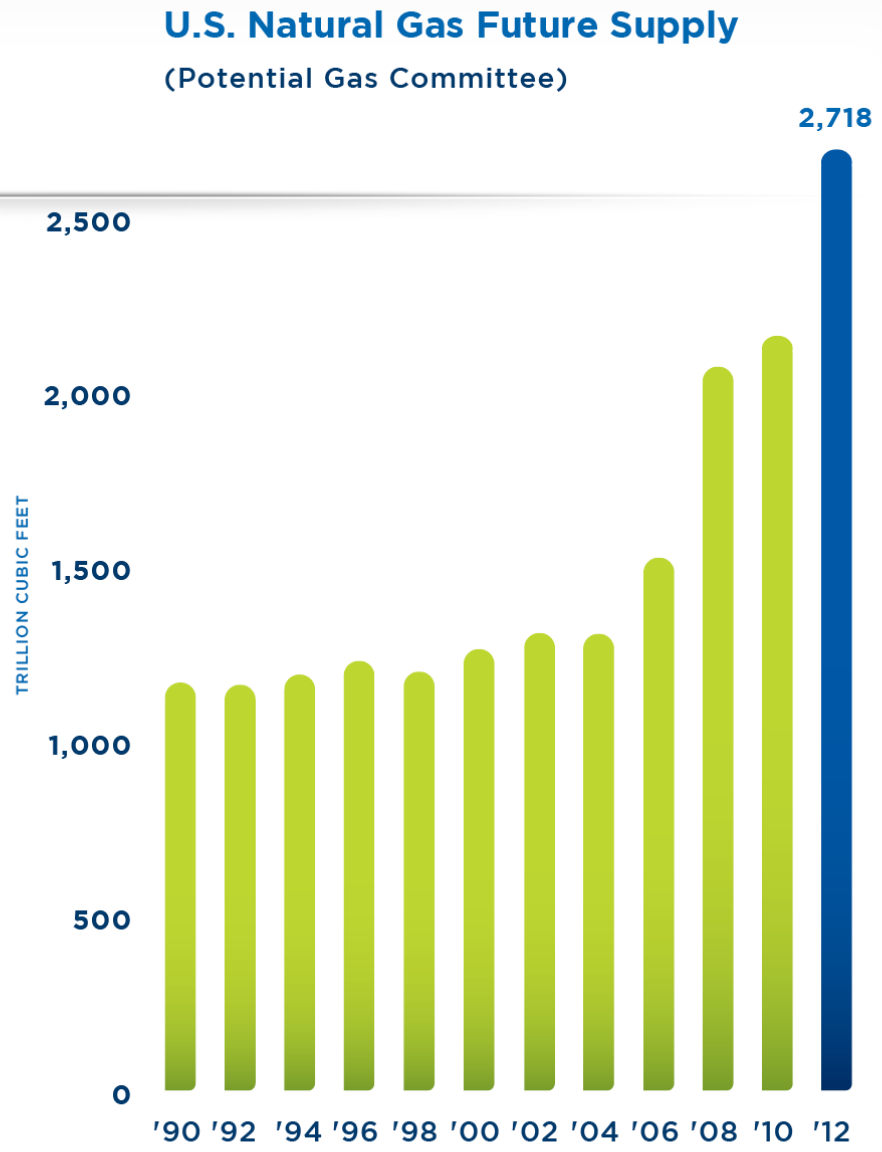
- 33 states are now producing or have produced natural gas.
- The United States produces approximately 14 Bcf per day more natural gas than 12 years ago.

Source: Energy Information Administration based on data from various published studies.

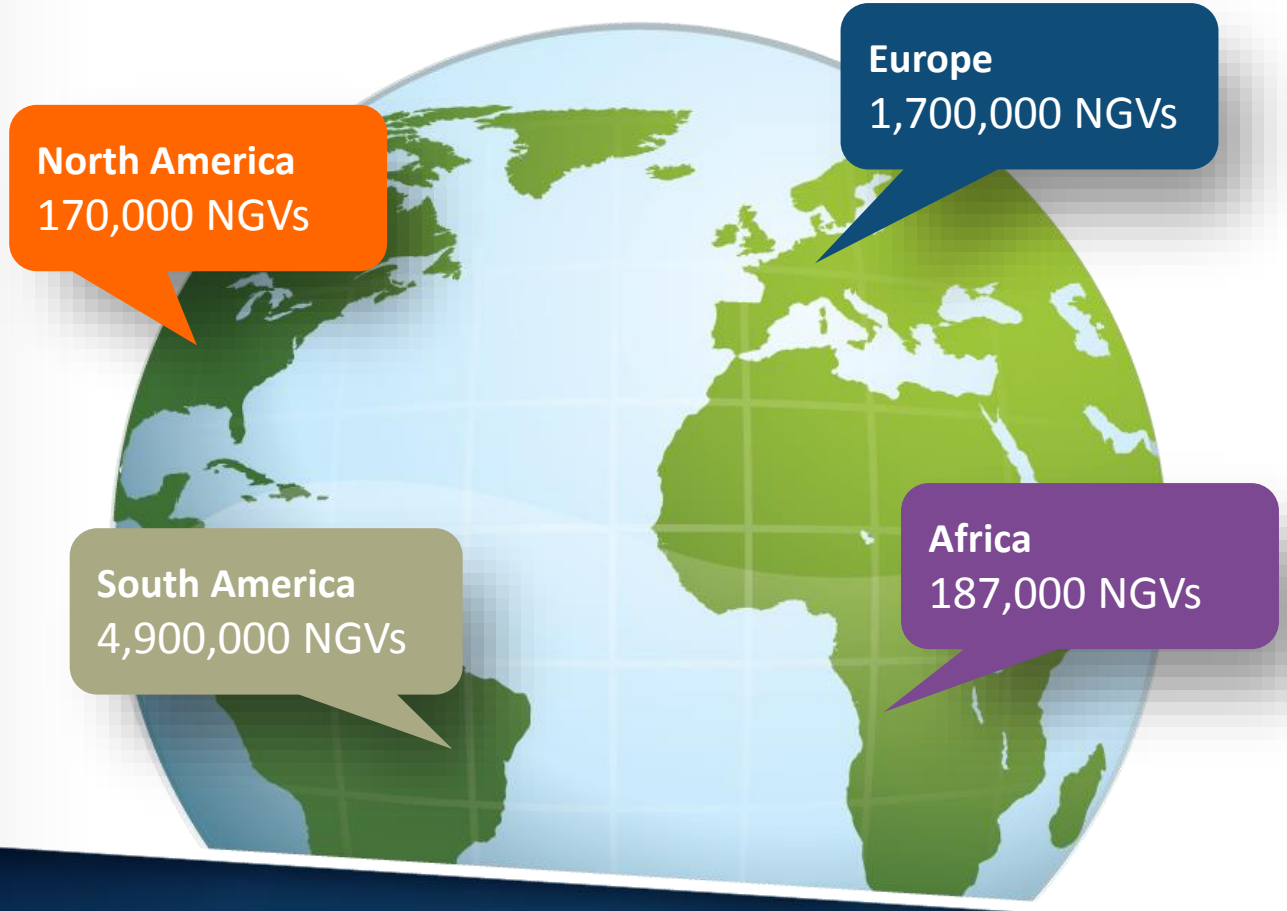
Natural Gas

Stable and affordable prices well into the future

Our nation's abundance of home-grown natural gas provides an opportunity to satisfy significant new demand at affordable prices well into the future.

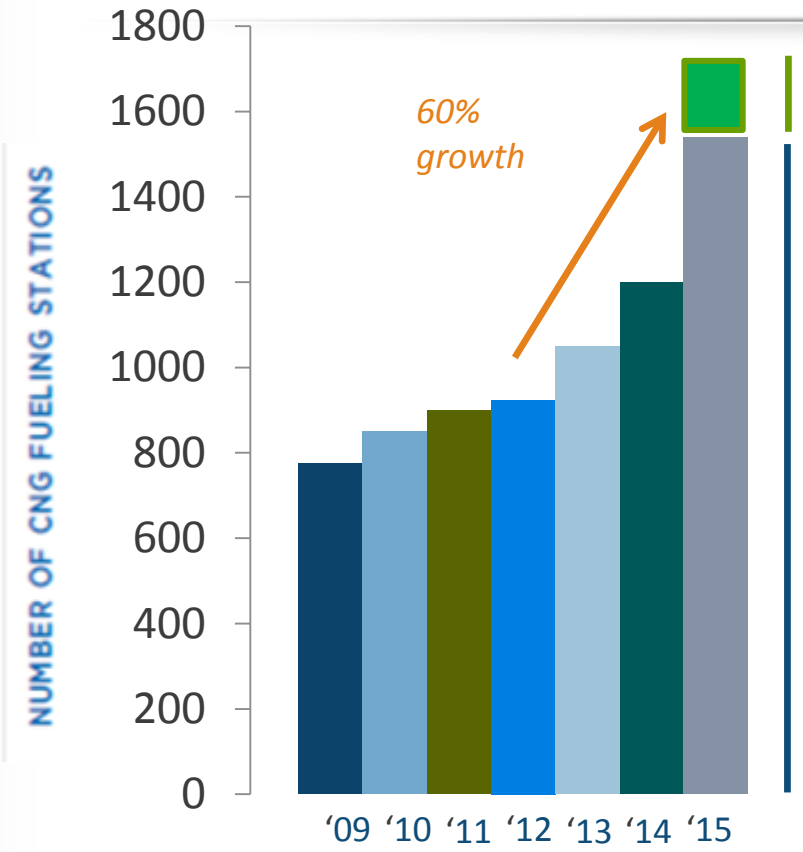


Other nations are realizing the potential of natural gas vehicles and moving forward.



There are over **16 million** natural gas vehicles on the road worldwide – but only about 150,000 are in the United States.

Our national CNG refueling infrastructure is growing each year.



Growth of 60% in number of stations over the period 2012 to 2015.

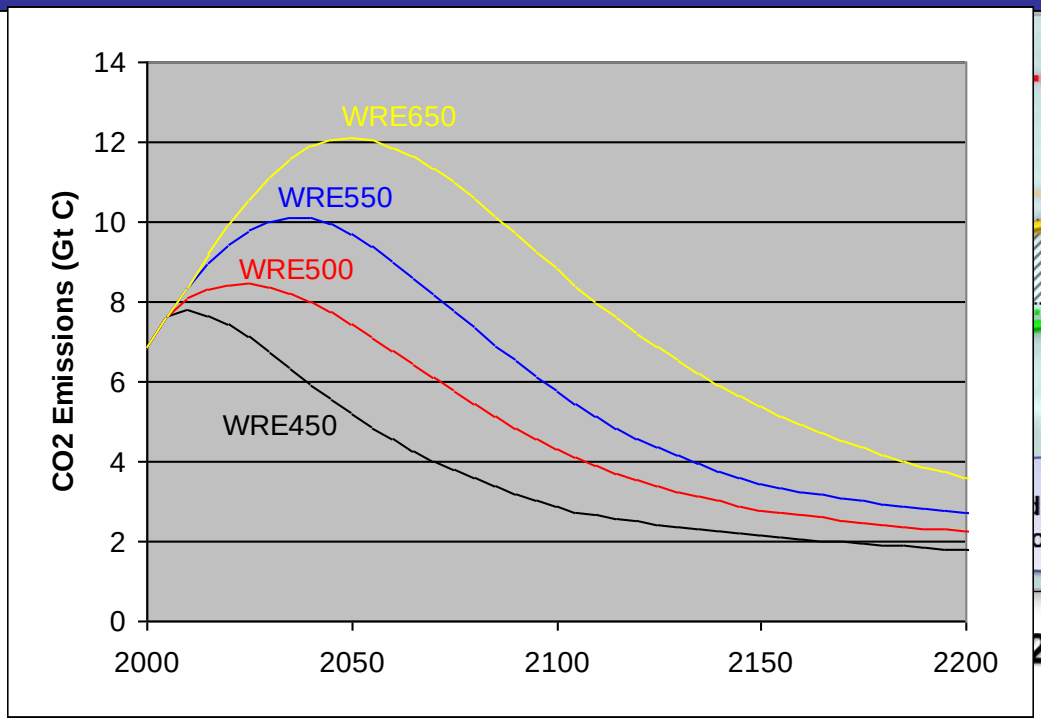
GHG Reduction After 2025: Road Transportation Without Oil

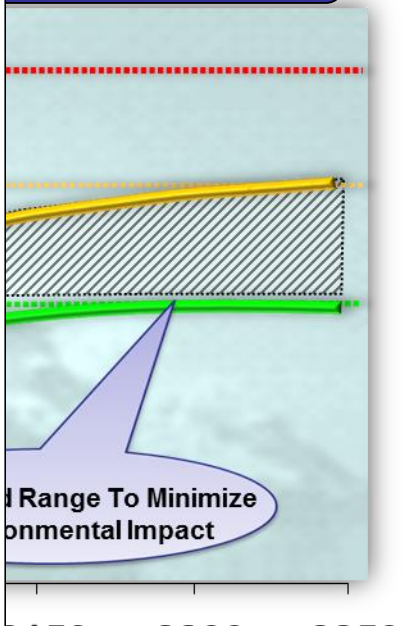
Mike Tamor

Henry Ford Technical Fellow, Energy Systems & Sustainability
Ford Research & Advanced Engineering

CO_2 Stabilization at 450 ppm Requires that:

Global emissions decrease 40% by 2050 …

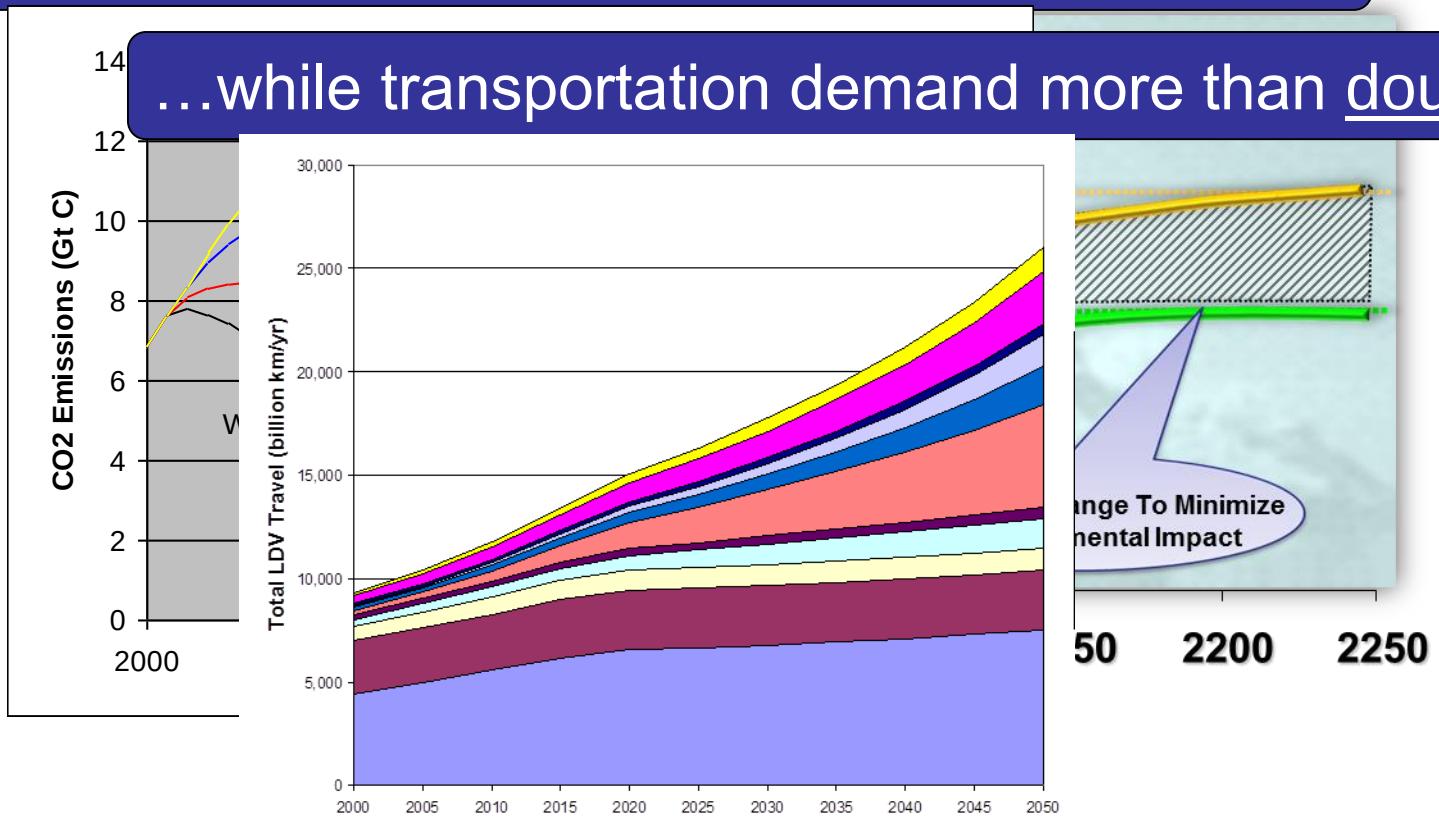




CO_2 Stabilization at 450 ppm Requires that:

Global emissions decrease 40% by 2050 …

…while transportation demand more than doubles …



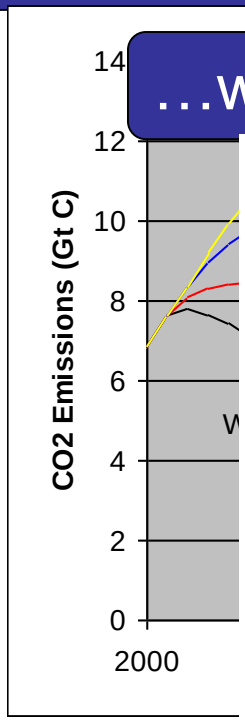
CO_2 Stabilization at 450 ppm Requires that:

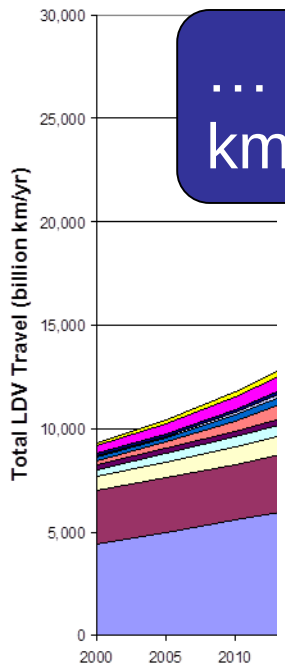
Global emissions decrease 40% by 2050 …

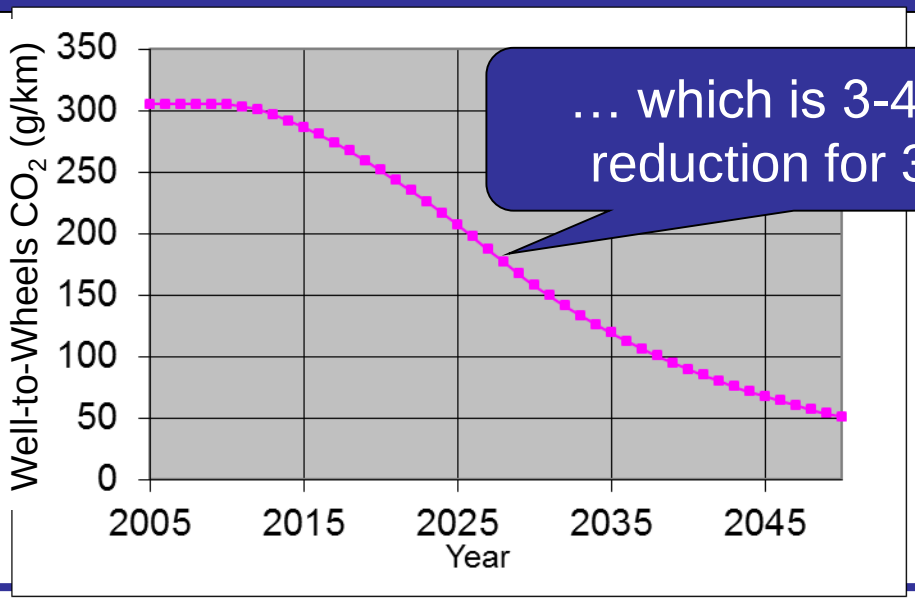
…while transportation demand more than doubles …

… which means 80% reduction in per km CO_2 vehicle emissions …

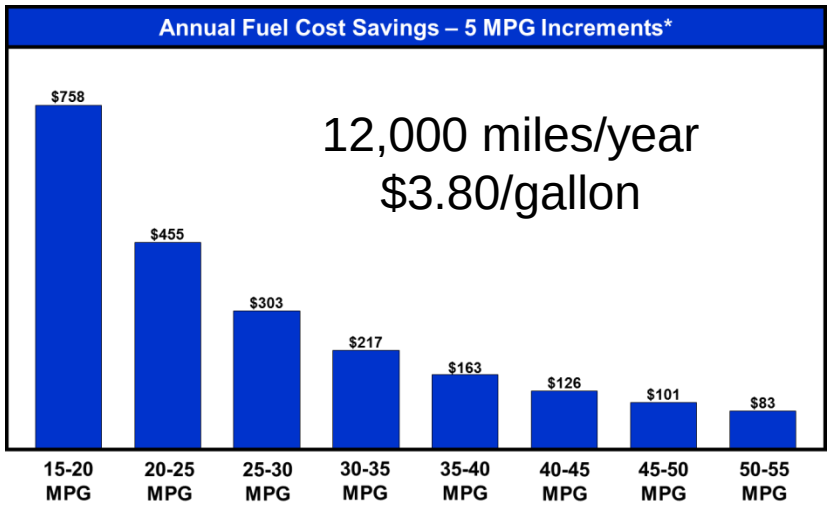
… which is 3-4% annual reduction for 35 years!







Technology Only Goes So Far and Customers May Not Be Willing to Pay For It



HEV Example:

- CV: 30 mpg
- HEV: 45 mpg
- Δ cost: $3000
- Fuel: $2.50/gal.
- → 9 year payback

Vicious Circle:

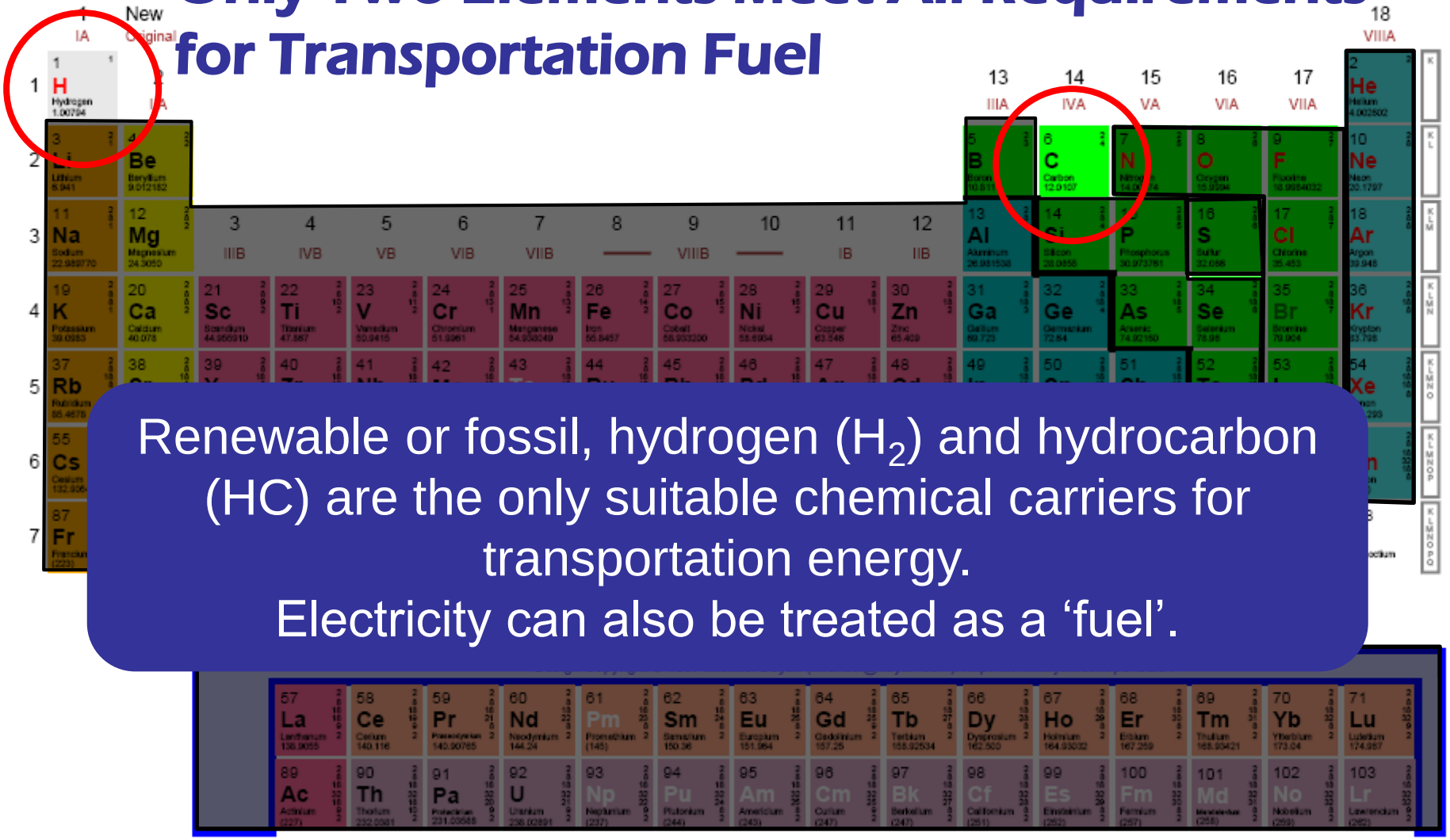
- FE technology gets more expensive while customer savings decline.
- Declining consumption (and fracking) keep oil prices low!

After 2025 CO_2 reduction must come from the fuel

Ford

FCHEV Research

Only Two Elements Meet All Requirements for Transportation Fuel



Renewable or fossil, hydrogen (H_2) and hydrocarbon (HC) are the only suitable chemical carriers for transportation energy.

Electricity can also be treated as a ‘fuel’.

Propulsion Efficiency is the Same for All 3 'Fuels'

The techno-economically superior renewable fuel will 'choose' the powertrain.

Coal (US avg.): 190 g/km
Coal (best): 146 g/km
NG (IGCC): 79 g/km
US Avg.: 115 g/km

BEV

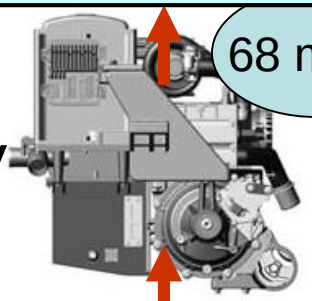
Oil: 126 g/km
NG: 100 g/km
H_2(SRNG): 159 g/km
H_2 (Elect.): 416 g/km

HEV

45 mpg

H_2(SRNG): 106 g/km
H_2(Elect.): 277 g/km

FCV



68 mpg_e

EV: 0.18 kWh/km
CV: 30 mpg, 189 g/km

Conventional
'Base' Vehicle

Ford

FCHEV Research

The Essential Points:

- After 2025, CO_2 reduction must come from the fuel.
- Hydrogen, carbon and electricity are the only viable carriers of transportation energy.
  - Efficiencies are (nearly) equal.
  - Hydrocarbon liquid is the preferred fuel due to energy density.
  - Gaseous fuels (methane, hydrogen) and electricity can work well too if upstream advantages prevail over storage cost and ‘filling’ losses.
- Focus should be on the source(s) of renewable energy, not the form of renewable transportation fuel.
  - Fuel must be standard.
  - The ‘drop-in’ concept does not work at scale (too much to dilute).
  - Conversion & refining are efficient at scale.

The fuel of the future will choose the vehicle of the future.

A fuel cell breakthrough will not create plentiful renewable hydrogen.
A renewable hydrogen breakthrough will force automakers to build FCV!

Ford

FC HEV Research

Panel Discussion

- What actions will accelerate or impede the transition? – *Policy, technology, research, etc.*
- Given finite resources, what alternative fuels or fuel processes investments would be prudent to ensure the transition? (Most investments have been in cellulosic and biofuel alternatives. What about research on other sources to mitigate risk as we move forward?)
- How do external global megatrends impact the investment decisions? (Technology mega trends such as smart grid, internet of things, demand management, stronger integration of electric power and transportation energy sectors, and societal mega trends such as urbanization and changing vehicle ownership patterns and urban transportation choices)

Panel Discussion

- How can innovation be incentivized by policy to help accelerate the transition?
- Is there a competitive advantage to leading this transition?

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The Speakers

Paul Bryan
separ8r@gmail.com

Mike Tamor
mtamor@ford.com

Sharon Burke
burke@newamerica.org

Kathryn Clay
kclay@aga.org

Gary Dirks
garydirks@asu.edu

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