NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Biofuels-Current Status and Research Focus

Renewable Energy for Tribal Community Development National Workshop

Kristi Moriarty

June 29, 2011

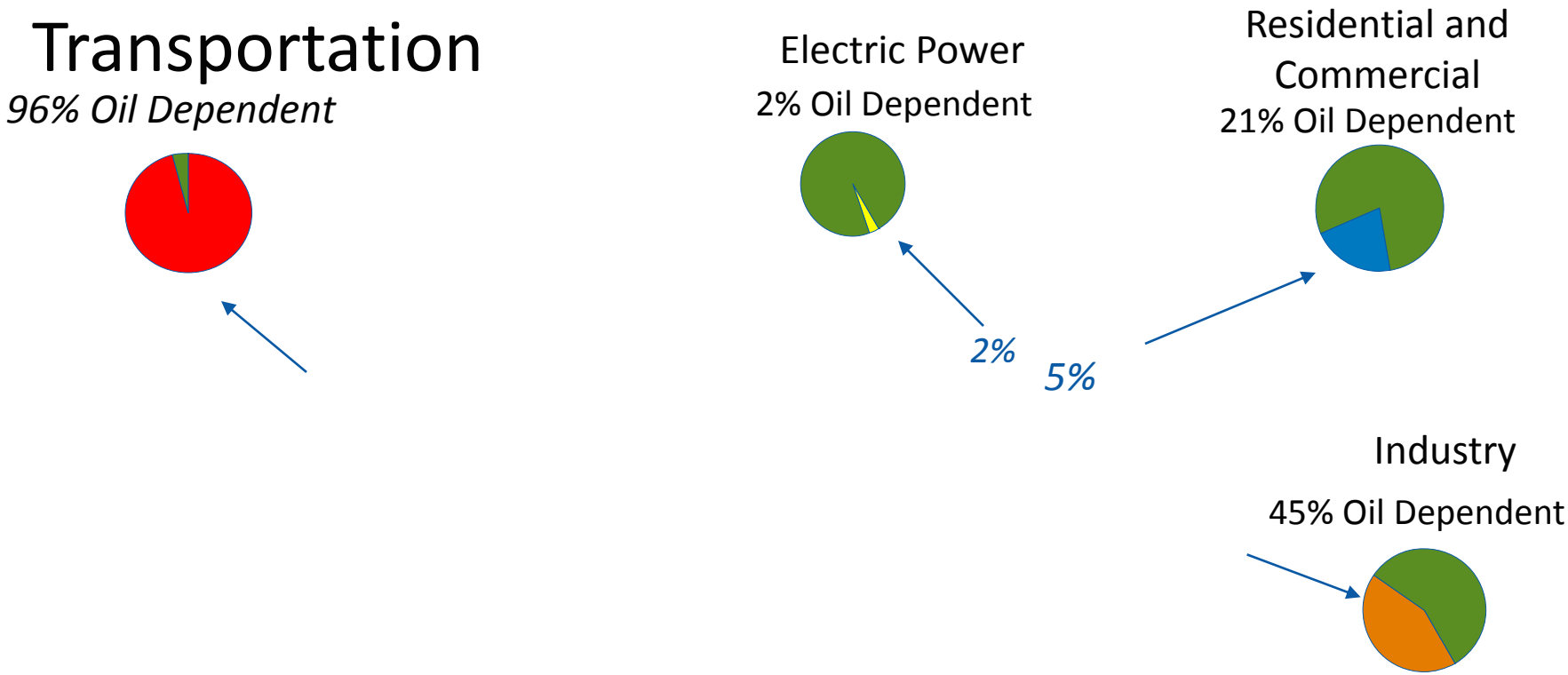
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Agenda

- Motivation
- RFS and the Blend Wall
- Ethanol
- Biodiesel
- Emerging Fuels
- Information Resources

U.S. Oil Dependence Is Driven By Transportation

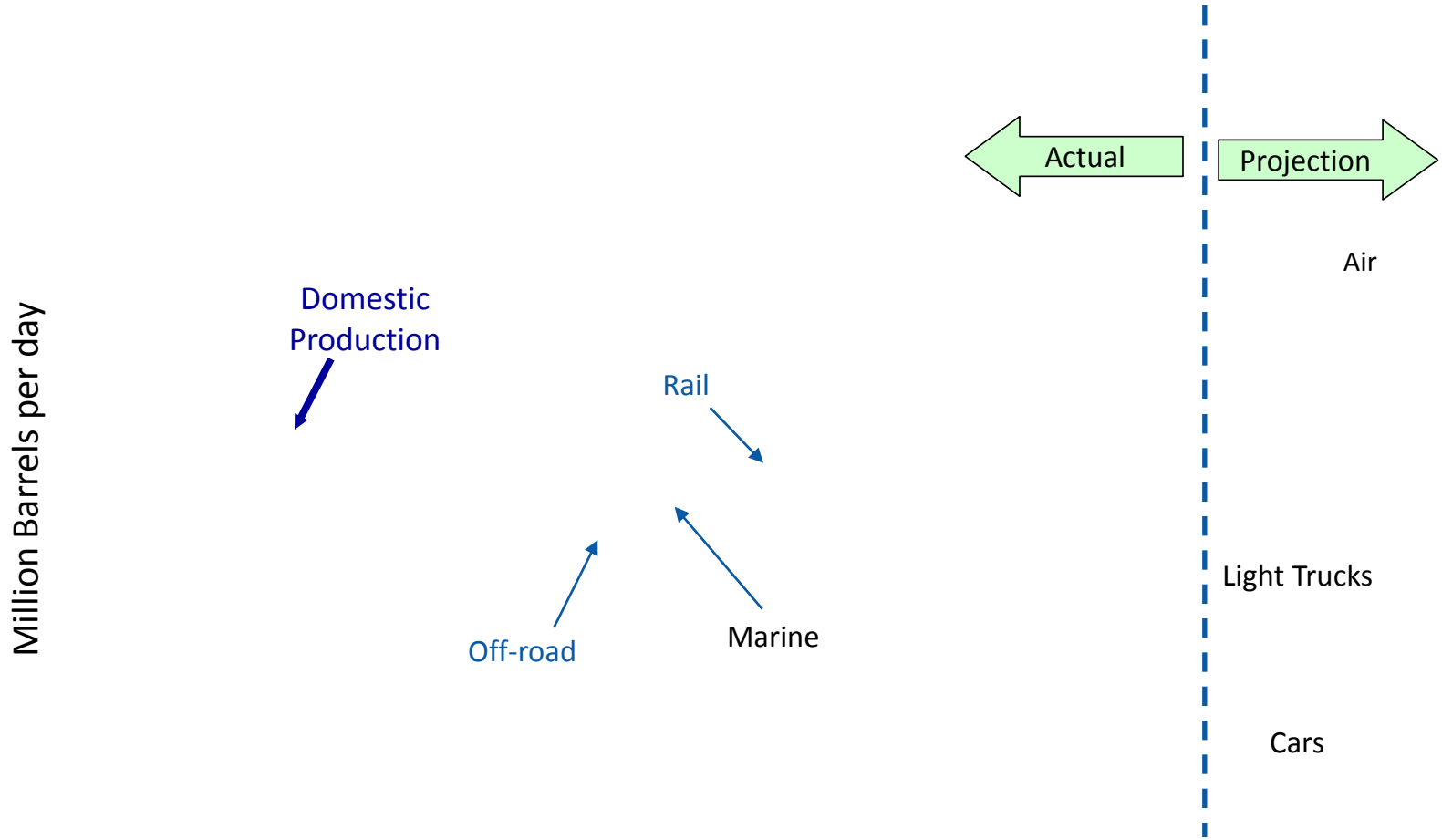
U.S. Oil Consumption by End-Use Sector
18.8 Million Barrels per Day (2009)



Source: *DOE/EIA Annual Energy Outlook 2011*, April 2011

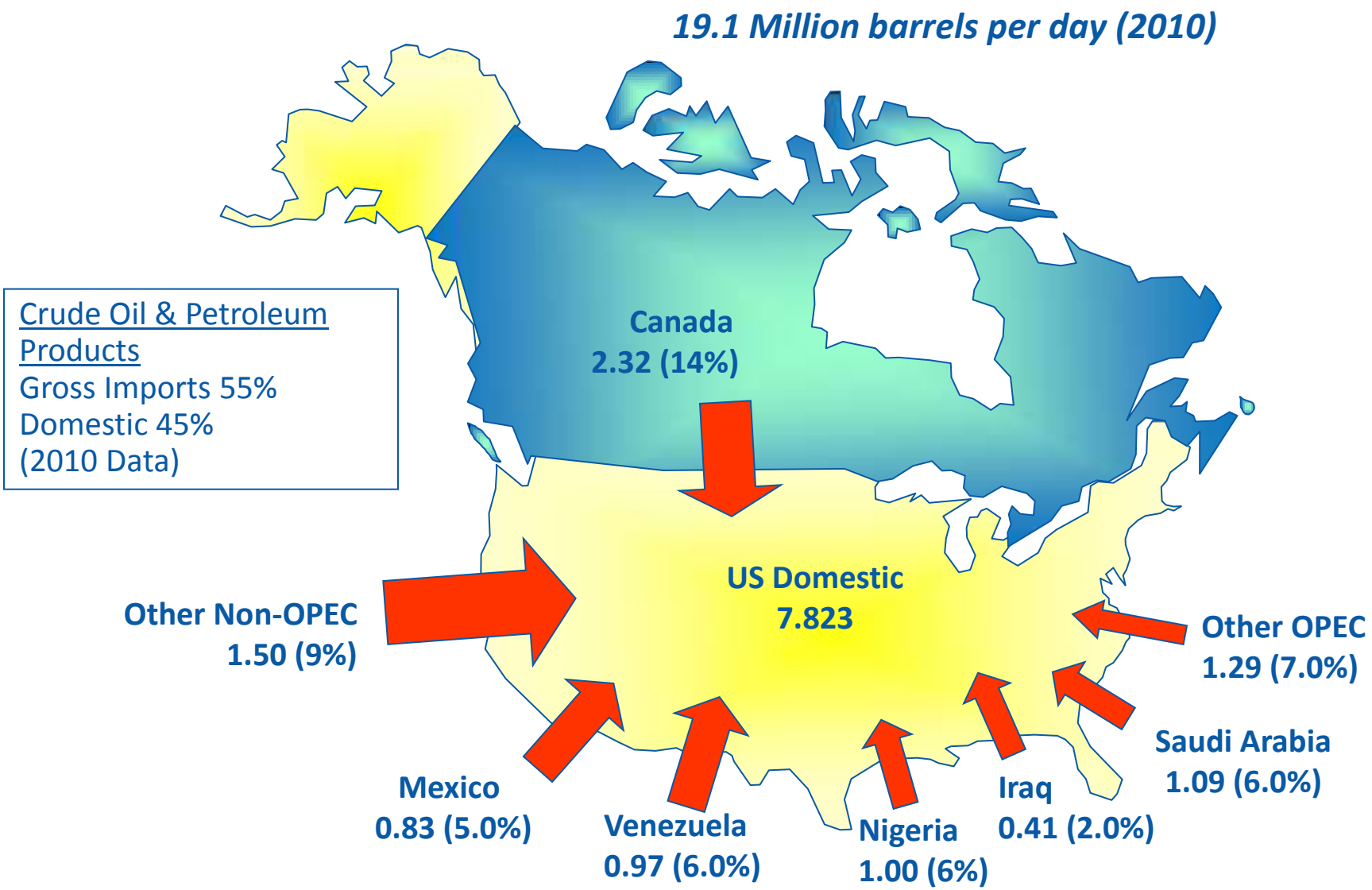
U.S. Oil Dependence is Driven By Transportation

U.S. Transportation Oil Use



Sources: Actual: *Transportation Energy Data Book, Edition 28*, ORNL, 2009.
Projections: 2009 to 2030: *EIA Annual Energy Outlook 2009*, March 2009.

Our Oil Situation



Source: Crude Oil and Petroleum Products, EIA 2010.

Domestic Oil Finds Will Not Provide Enough

"ExxonMobil announced on Wednesday that it struck oil in the Gulf of Mexico, a discovery that could yield 700 million barrels."

"This is one of the largest discoveries in the Gulf of Mexico in the last decade," said Steve Greenlee, president of ExxonMobil Exploration Company, in a press release.

-- CNN June 8, 2011

- Approximately one month supply
- It will take years to extract

http://www.thedailyshow.com/watch/wed-june-16-2010/an-energy-independent-future

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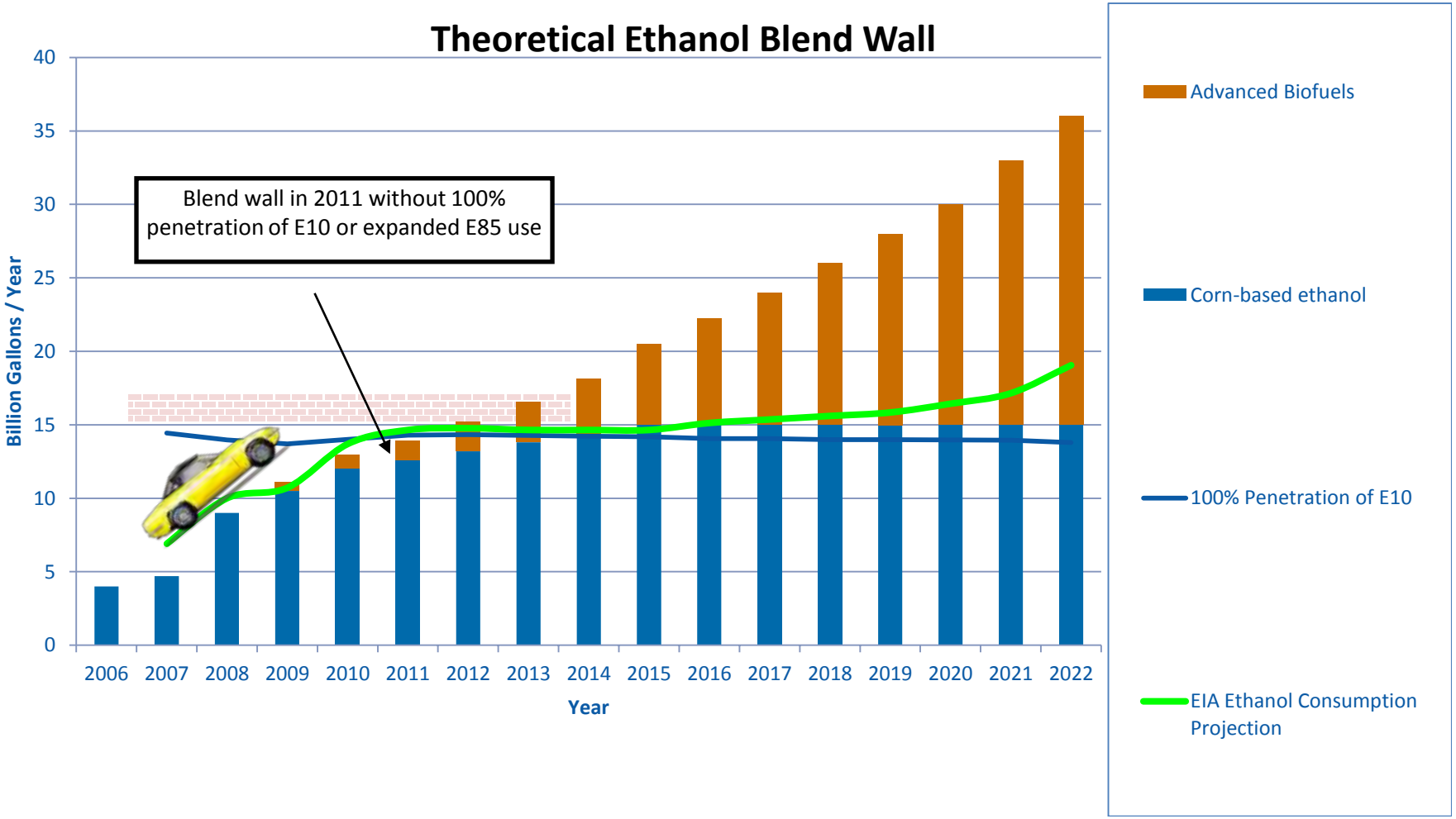
Renewable Fuel Standard and E10 Blend Wall



Data Source: EIA Annual Energy Outlook, Dec. 2009

Renewable Fuel Standard and E10 Blend Wall

RFS Category 2010	2007 EISA	EPA Requirement	Consumption
Conventional (starch ethanol)	12 billion gallons	12 billion gallons	13.2 billion gallons
Cellulosic	100 million gallons	6.5 million gallons	0 gallons
Biomass-based Diesel	650 million gallons	1.15 billion gallons*	538 million gallons
Other Advanced Fuels	299 million gallons	300 million gallons	unknown
Total Renewable Fuel Requirement	12.95 billion gallons	12.95 billion gallons	13.8 billion gallons
*biodiesel requirements for 2009 & 2010 were combined for 2010 EPA EISA requirements			

RFS Category 2011	2007 EISA	EPA Requirement	Projected Consumption
Conventional (starch ethanol)	12.6 billion gallons	12.6 million gallons	13.3 billion gallons
Cellulosic	250 million gallons	6.6 million gallons	unknown
Biomass-based Diesel	800 million gallons	800 million gallons	674 million gallons
Other Advanced Fuels	300 million gallons	300 million gallons	unknown
Total Renewable Fuel Requirement	13.95 billion gallons	13.95 billion gallons	13.97 billion gallons

Data Source: EPA and DOE EIA

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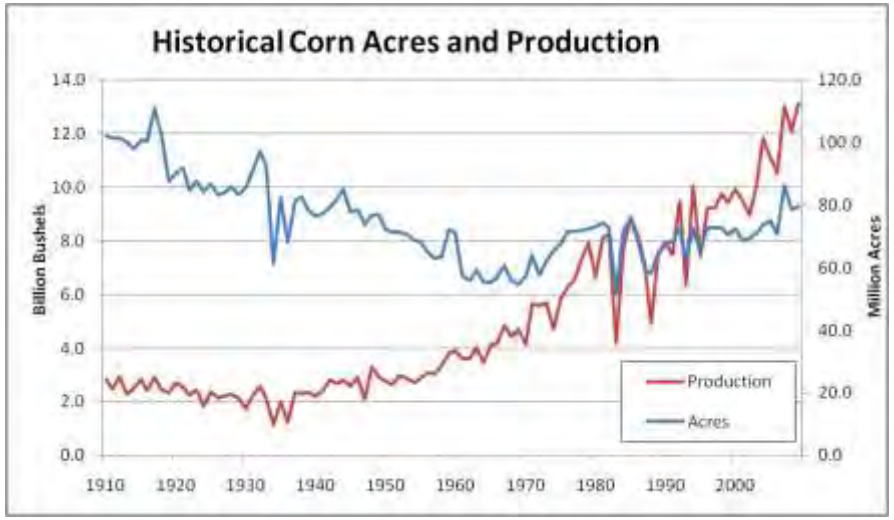
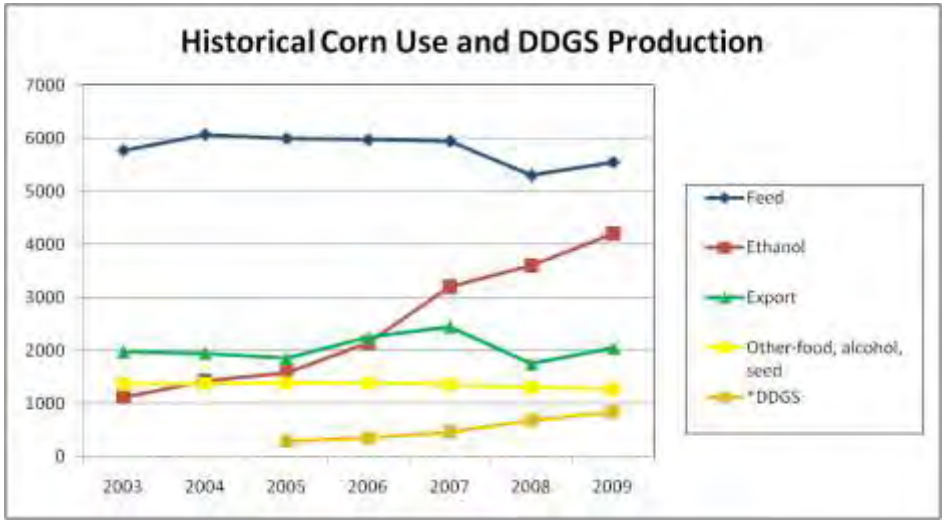
Ethanol Statistics

- 2.8 gallons of ethanol per bushel of corn (56 pounds/bushel)
- U.S. ethanol is ~98% corn; a few plants use barley, milo, and wheat
- 208 plants with capacity of 14.6 billion gallons/year; 80% of capacity built since 2005
- Energy to produce gallon of ethanol: ~30,000 BTU and 0.75 kWh (less than 15 plants use coal for thermal energy)
- Water usage (gallons of water to produce gallon of fuel): ethanol-3; gasoline-2.5
- Energy content: ethanol-76,000 BTU/gallon; gasoline-110,000 BTU/gallon
- Energy balance: 1.3

Ethanol-Corn Use & Fuel vs. Food



(Source: USDA)

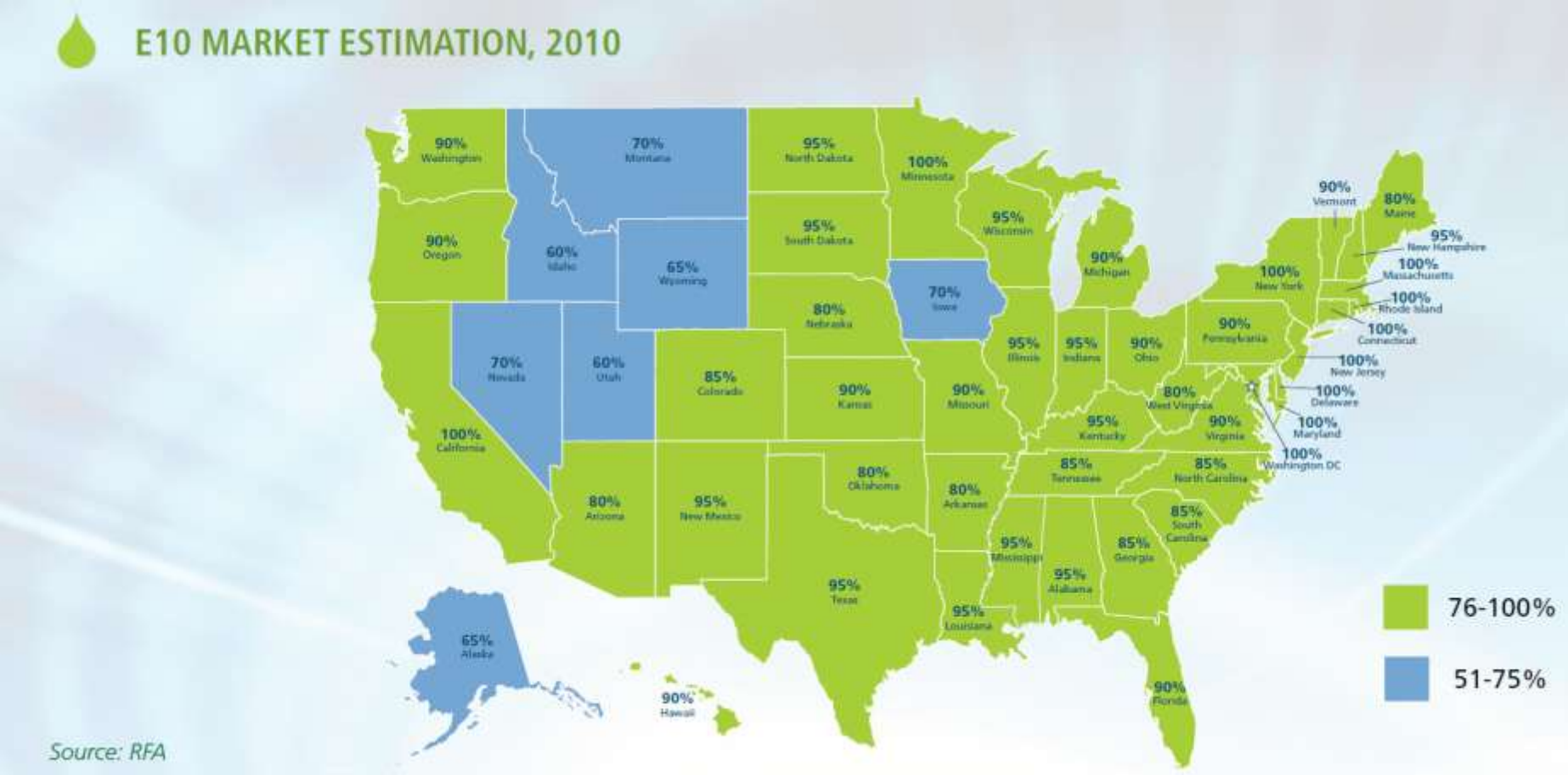


(Source – National Corn Growers Association and USDA)

Factors Impacting Food Price:

- Higher costs of fossil fuels used to transport food to retail outlets
- Increased demand as emerging economies grow and populations adopt better diets and eat more meat
- Adverse weather in parts of the world and droughts leading to poor harvests
- Devaluation of the dollar, which may reduce importing costs and increase export buying
- Hedge funds and index funds buying of grain and oilseed futures
- Less than 10% of U.S. corn used for direct human consumption (USDA)
- 4.9¢ of corn in a box of corn flakes (USDA 2007)

Ethanol Market Saturation



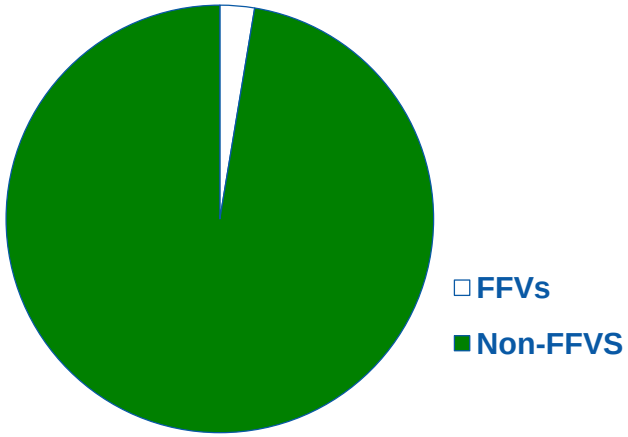
E15 Waiver Decision

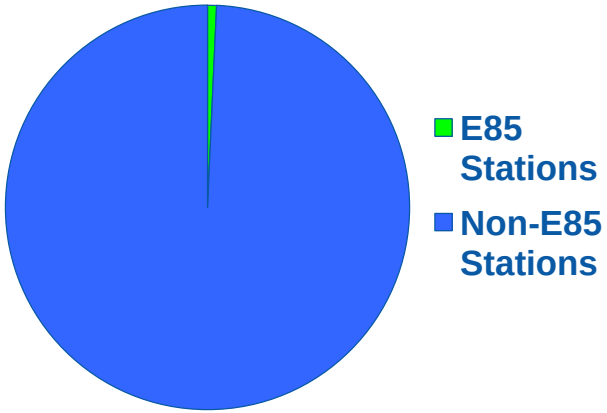
- Growth Energy requested a waiver to allow the use of 15% ethanol in gasoline (March 2009)
- EPA approved E15 for 2001 model year and newer vehicles (Jan 2010)
- E10 waiver granted 12/1/78 without decision – not possible today
- Not a legal fuel – many federal steps & state laws/regs need to be updated to sell fuel nationwide

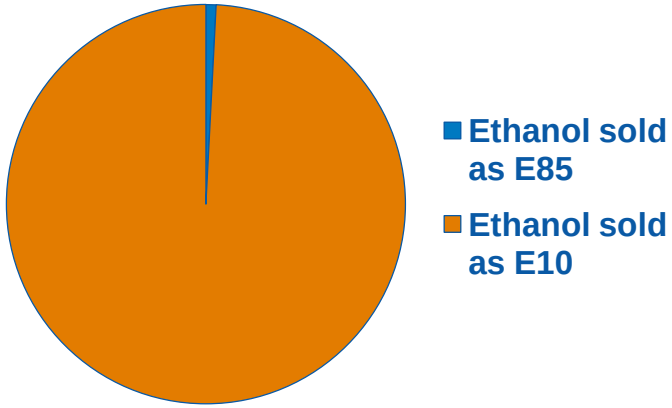
growth energy™
America's Ethanol Producers

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

US E85 Infrastructure very limited





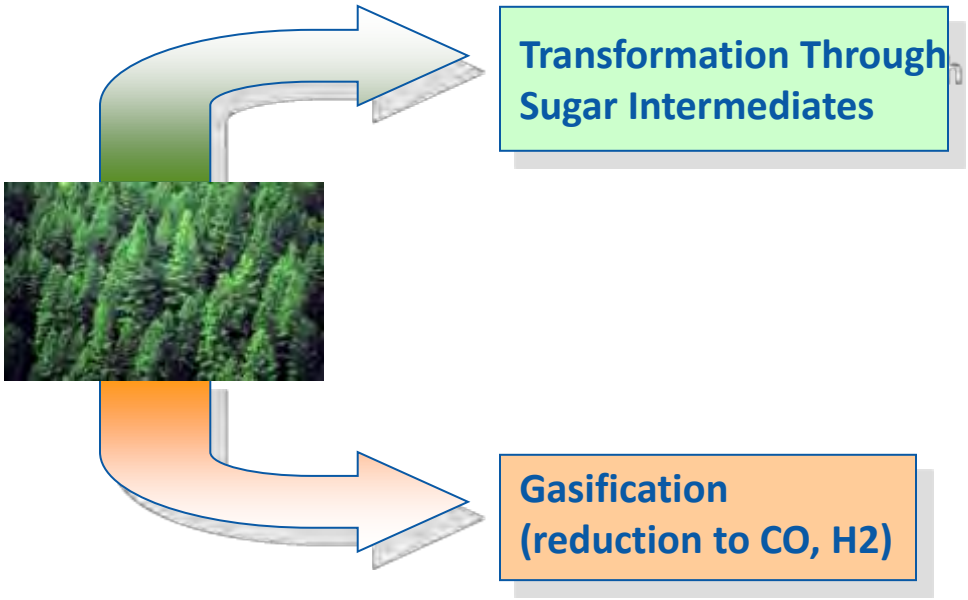


- 3% of vehicles are FFVs
- 1% of stations sell E85
- 1% of ethanol sold as E85

DOE Funded Biorefineries

http://www1.eere.energy.gov/biomass/integrated_biorefineries.html

Pathways

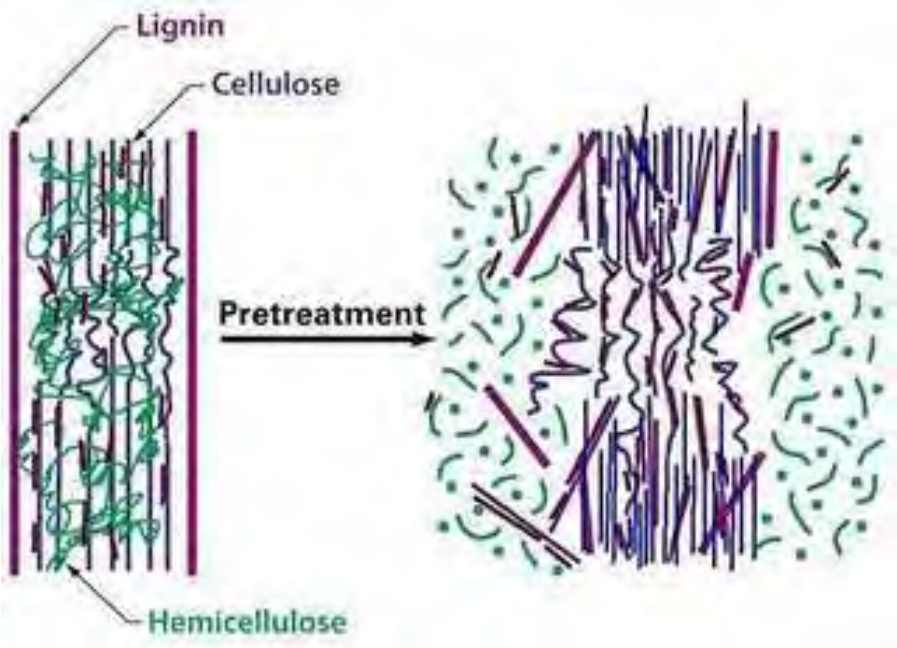


"Biochemical conversion"

"Thermochemical conversion"

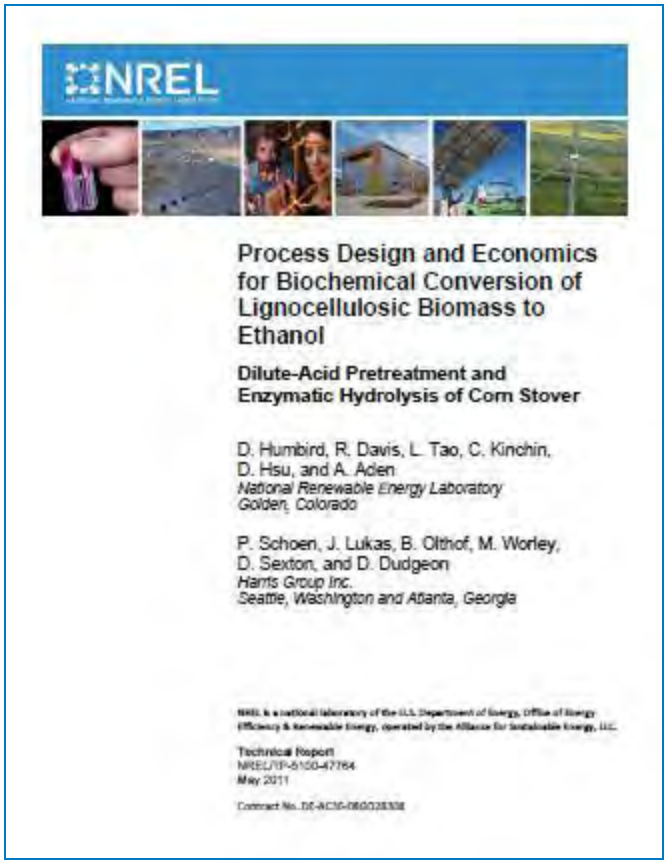
- Biochemical challenges include enzymatic conversion of five carbon sugars
- Thermochemical challenges include syngas cleanup to remove contaminants that poison catalysts
- Capital and operation costs are higher than conventional biofuels plants
- Difficult for projects to obtain funding/financing

Biomass Feedstocks to Biofuels-Why is it Challenging?



- Cellulose-comprised of glucose
- Hemicellulose-comprised of several types of sugar
- Lignin-provides strength in biomass; provides energy for biochemical pathway

Cellulosic Ethanol Pathways Research Reports



NREL

Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol

Dilute-Acid Pretreatment and Enzymatic Hydrolysis of Corn Stover

D. Humbird, R. Davis, L. Tao, C. Kinchin, D. Hsu, and A. Aden
National Renewable Energy Laboratory
Golden, Colorado

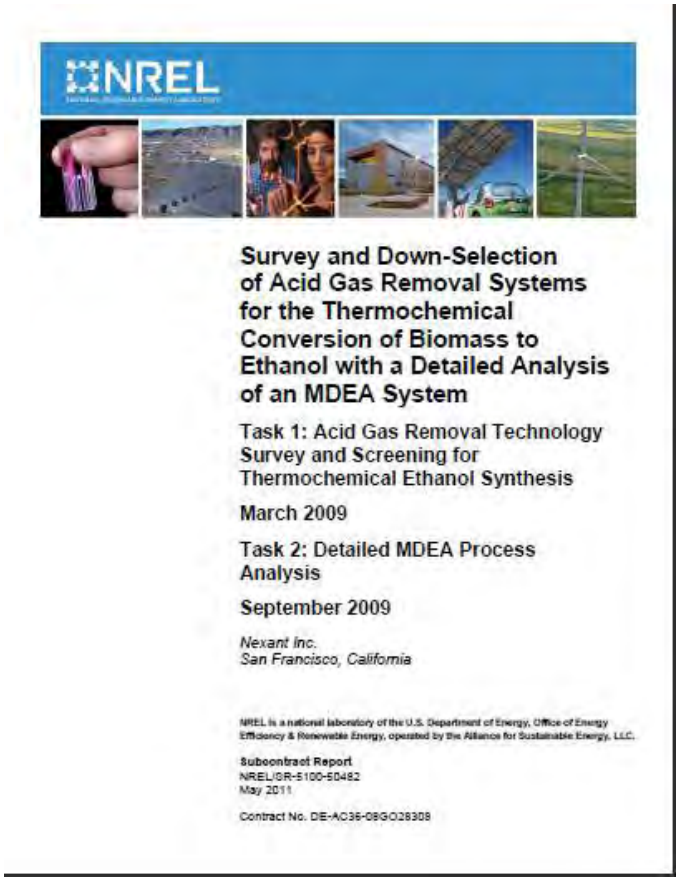
P. Schoen, J. Lukas, B. Olthof, M. Worley, D. Sexton, and D. Dudgeon
Harris Group Inc.
Seattle, Washington and Atlanta, Georgia

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

Technical Report
NREL/TP-5100-47764
May 2011

Contract No. DE-AC36-08GO28308

http://www.nrel.gov/docs/fy11osti/47764.pdf



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Survey and Down-Selection of Acid Gas Removal Systems for the Thermochemical Conversion of Biomass to Ethanol with a Detailed Analysis of an MDEA System

Task 1: Acid Gas Removal Technology Survey and Screening for Thermochemical Ethanol Synthesis

March 2009

Task 2: Detailed MDEA Process Analysis

September 2009

Nexant Inc.
San Francisco, California

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

Subcontract Report
NREL/SR-5100-50482
May 2011

Contract No. DE-AC36-08GO28308

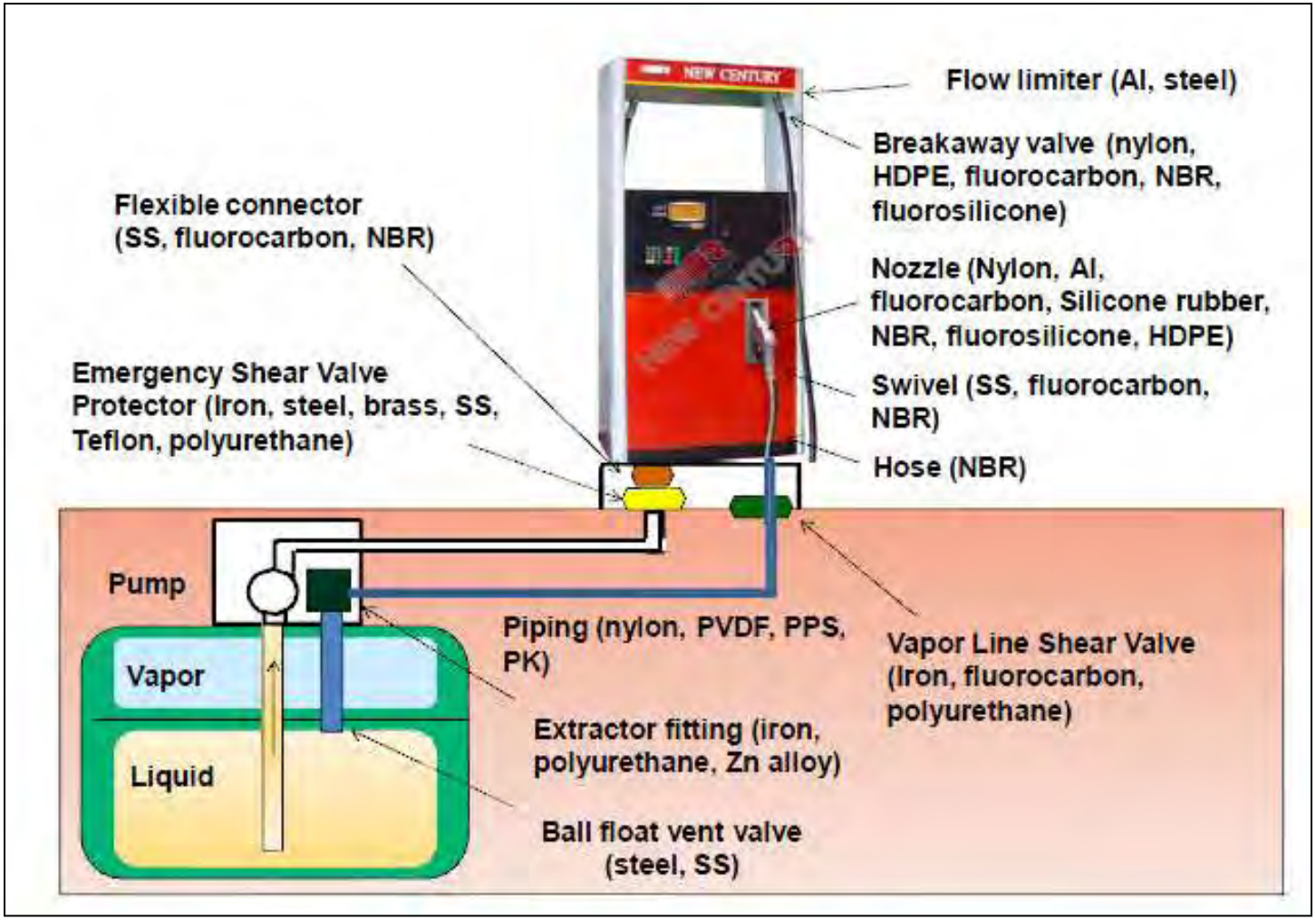
http://www.nrel.gov/docs/fy11osti/50482.pdf

Challenges Across Entire Biofuel Supply Chain

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

- Producing dedicated energy crops
- Collecting and storing feedstocks
- Producing biofuels from biomass
- Compatibility and regulations of existing fueling infrastructure
- Compatibility with existing fleet

Using New Fuels in Existing Infrastructure



Are these materials compatible with all fuels in market?

Agenda

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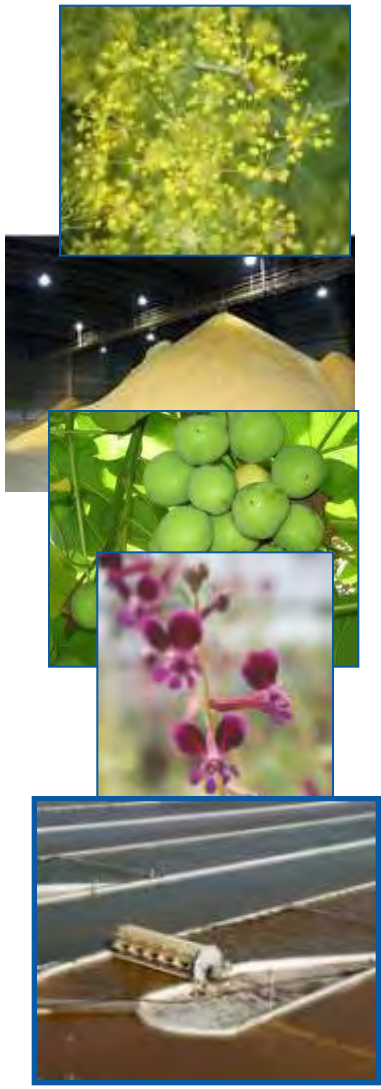
Market Status of Biodiesel

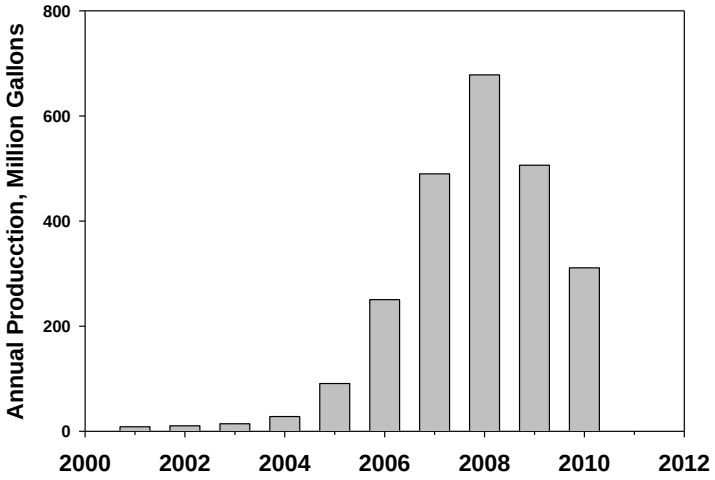
Roughly 2 billion gallon per year resource

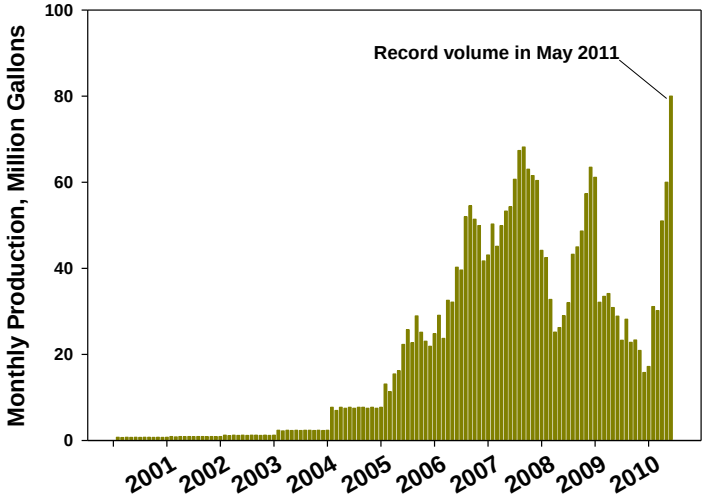
- Market demand is leading to increased grease collection
- Potential for new oil-seed crops or increased oil content in conventional crops
- Corn oil recovery from ethanol production
- Longer-term, algae may provide a large feedstock resource

Renewable Fuel Standard mandates 1 billion gallon market in 2012

More than 800 million gallons ar







Key Opportunities for Biodiesel

- Diesel vehicle sales are expected to triple in the next 10 years
- Opportunity to capture the “unspecified” 4 billion gallons of advanced biofuel required by RFS
- Niche markets: mining, railroad, heating oil etc.
- Education/outreach: counter the misperceptions about biofuels and biodiesel quality, publicize benefits
- Address need for UL pump and tank listing for B20, or variance to this requirement

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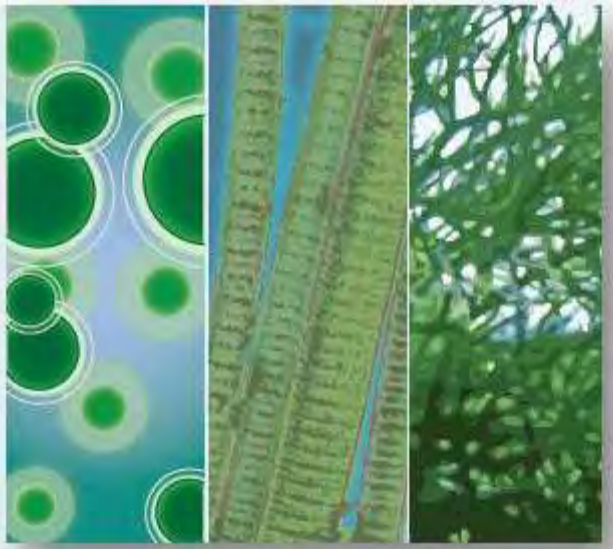
Drop-In Biofuels

- Viewed as replacement for diesel and jet applications
- Production of hydrocarbon fuels substantially similar to gasoline, diesel, or jet fuels from biomass feedstocks
- Anticipate few issues with introducing biomass hydrocarbons into existing infrastructure
- Potential technology pathways:
  - Pyrolysis of biomass to bio-oil with hydroprocessing to upgrade the oils
  - Algae producing hydrocarbons that also can be upgraded via hydrogen
  - Upgrading ethanol and butanol to hydrocarbons using catalysts
  - Catalytic reforming of sugars
  - Hydrocarbons from fermentation
- Research & Development phase

Algae

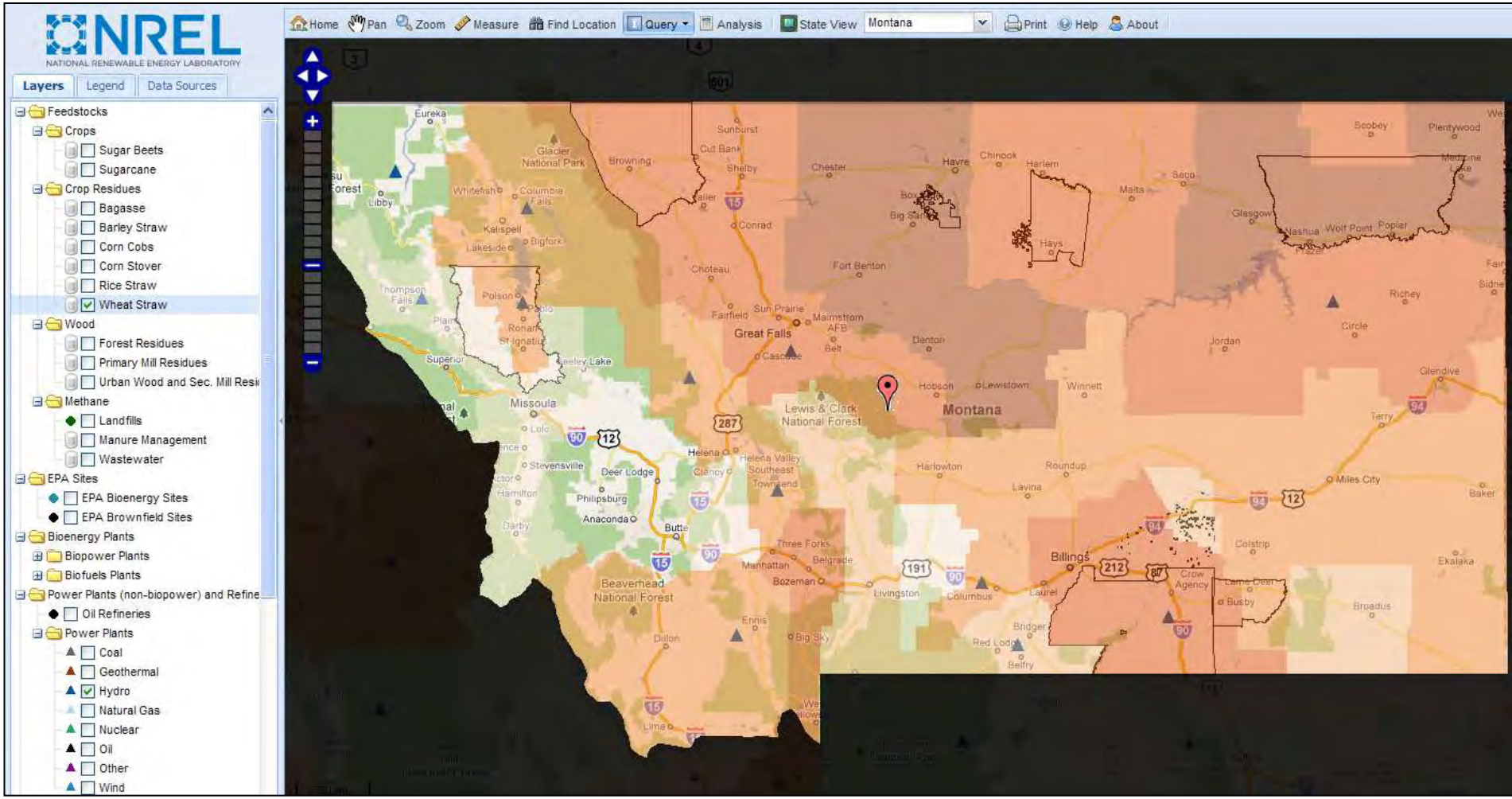
- Research & Development as a feedstock pathway
- Focus on cultivating feedstocks for commercial production and meeting yield potential
- Optimize harvesting and extraction methods
- Develop fuel conversion technologies to produce drop-in fuels
- Determine and extract valuable co-products to increase economic viability



Biobutanol

- Fermentation and pyrolysis technologies are under development
- Technology challenges include yield and feed (if producing it from crops)
- Qualifies as an advanced biofuel
- Higher energy density and lower volatility than ethanol
- Does not attract water
- ASTM standard in process

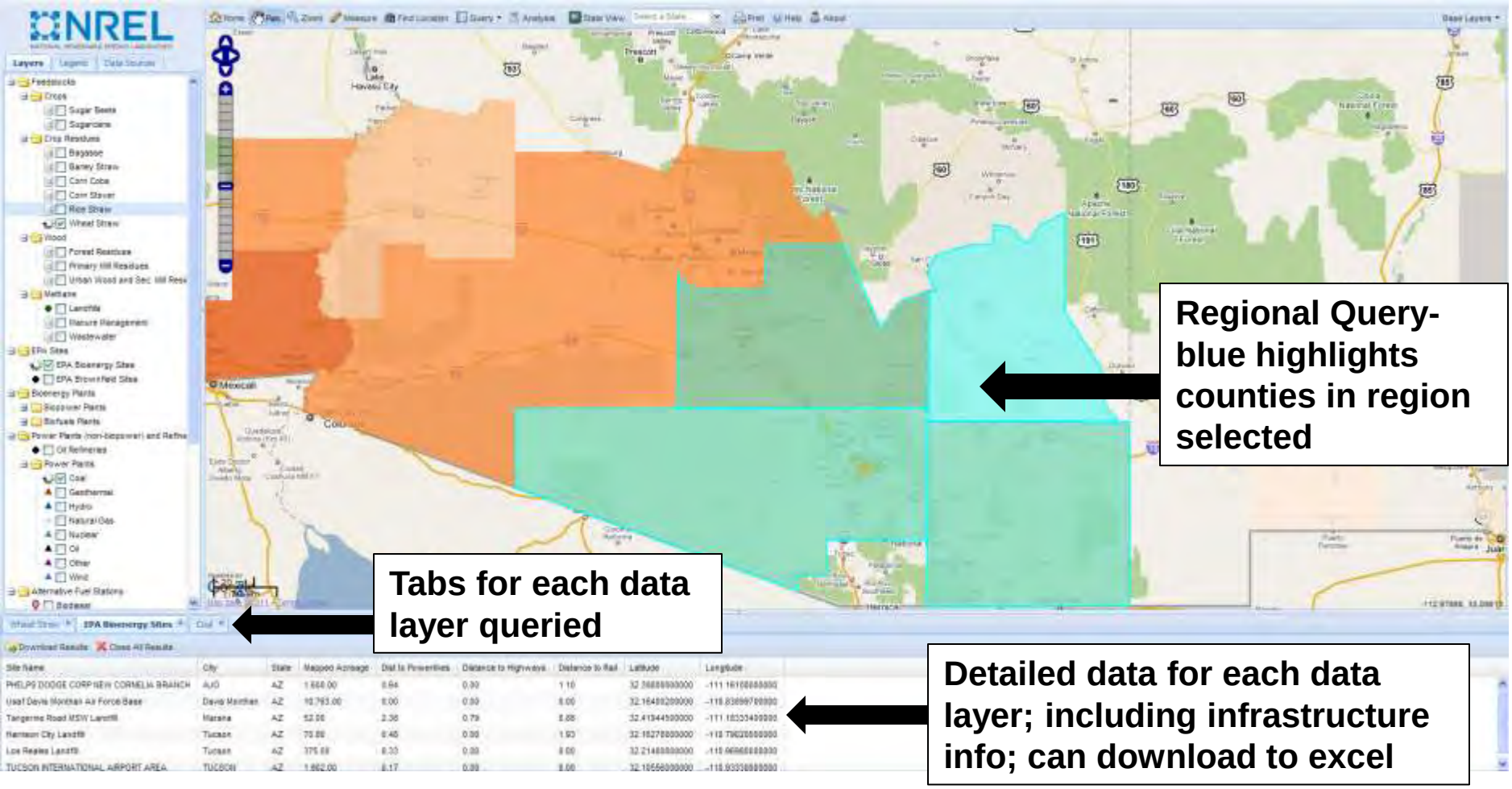
Information Resources - Biofuels Atlas



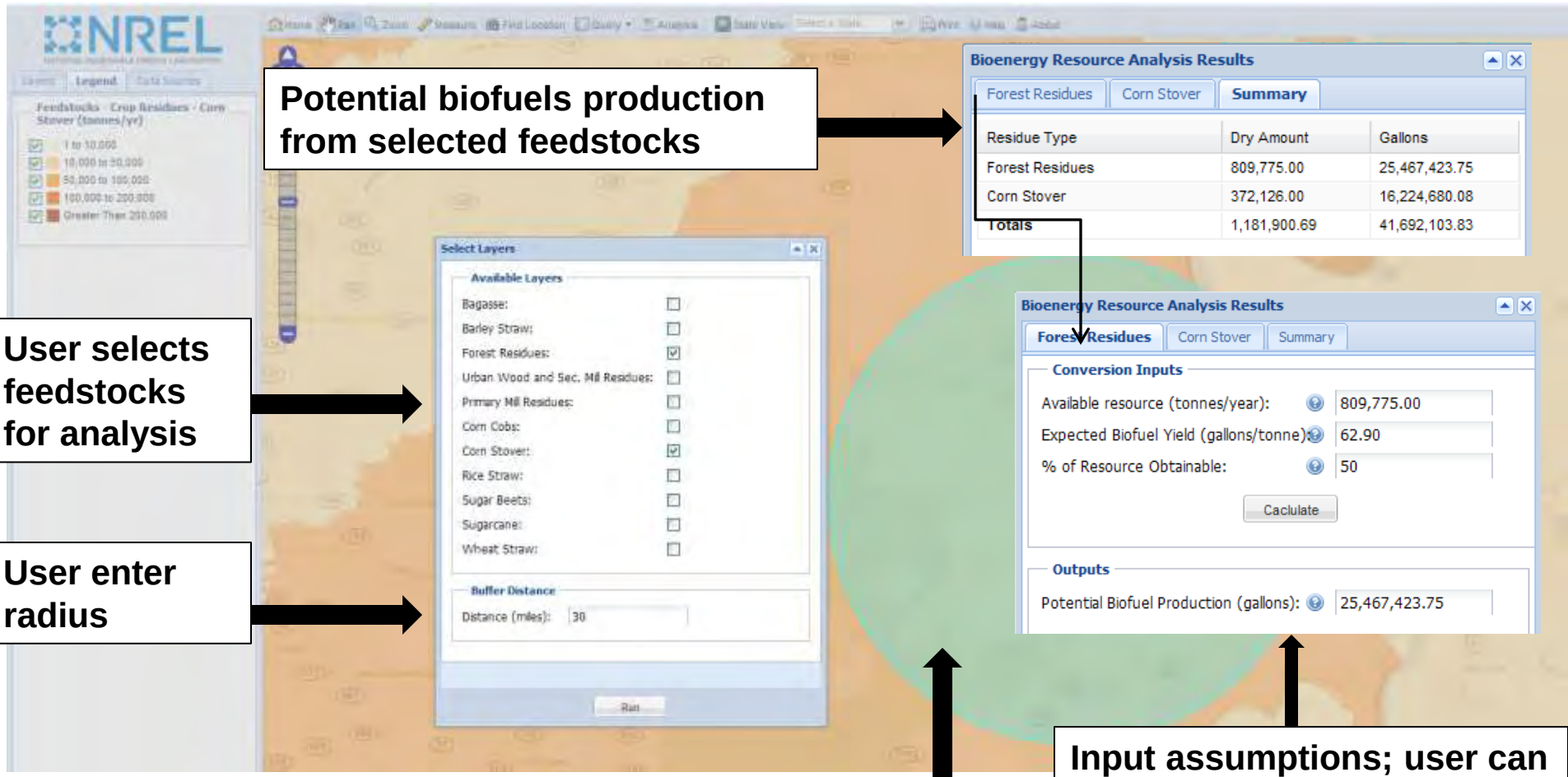
Determine resources & Infrastructure in your area:

http://maps.nrel.gov/biomass

BioFuels Atlas-Query



BioFuels Atlas-Analysis



Potential biofuels production from selected feedstocks

User selects feedstocks for analysis

User enter radius

Input assumptions; user can change and re-calculate

Tool sums each feedstock total for each county in radius

Information Resources

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

BioFuels Atlas - http://maps.nrel.gov/biomass

DOE Office of Vehicle Technologies - http://www1.eere.energy.gov/vehiclesandfuels/

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

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

NREL – http://www.nrel.gov

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

Grant Solicitations - www.grants.gov

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