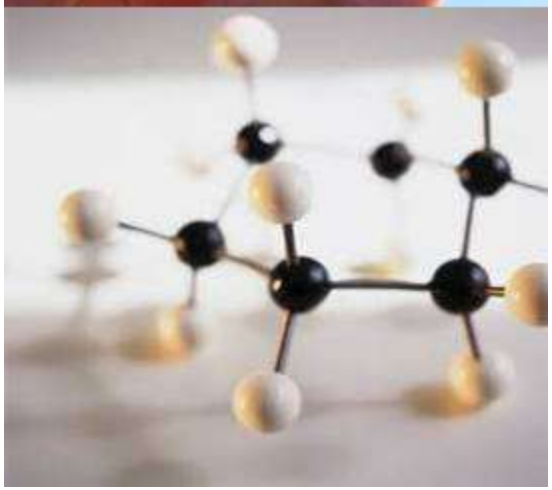
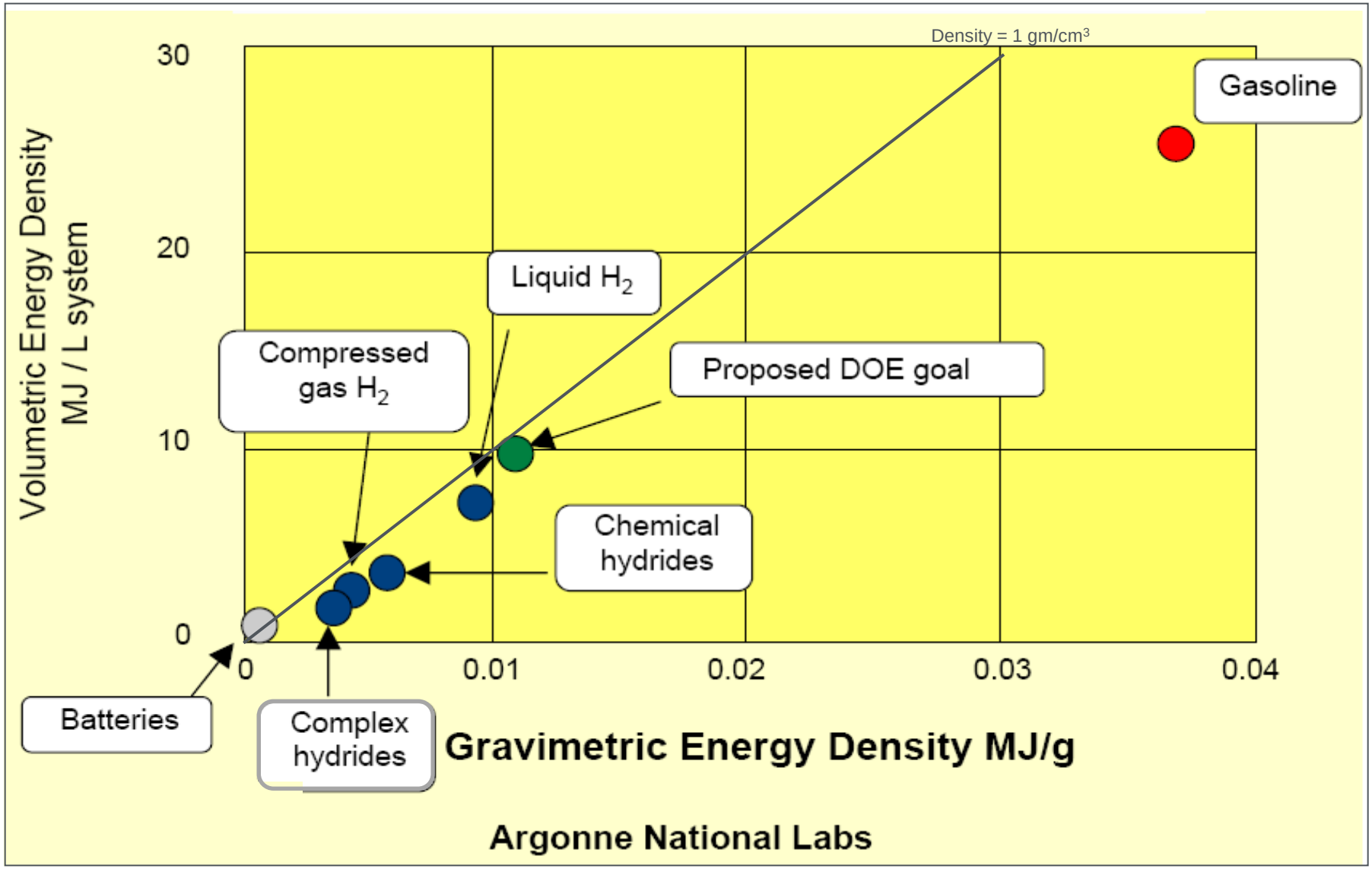


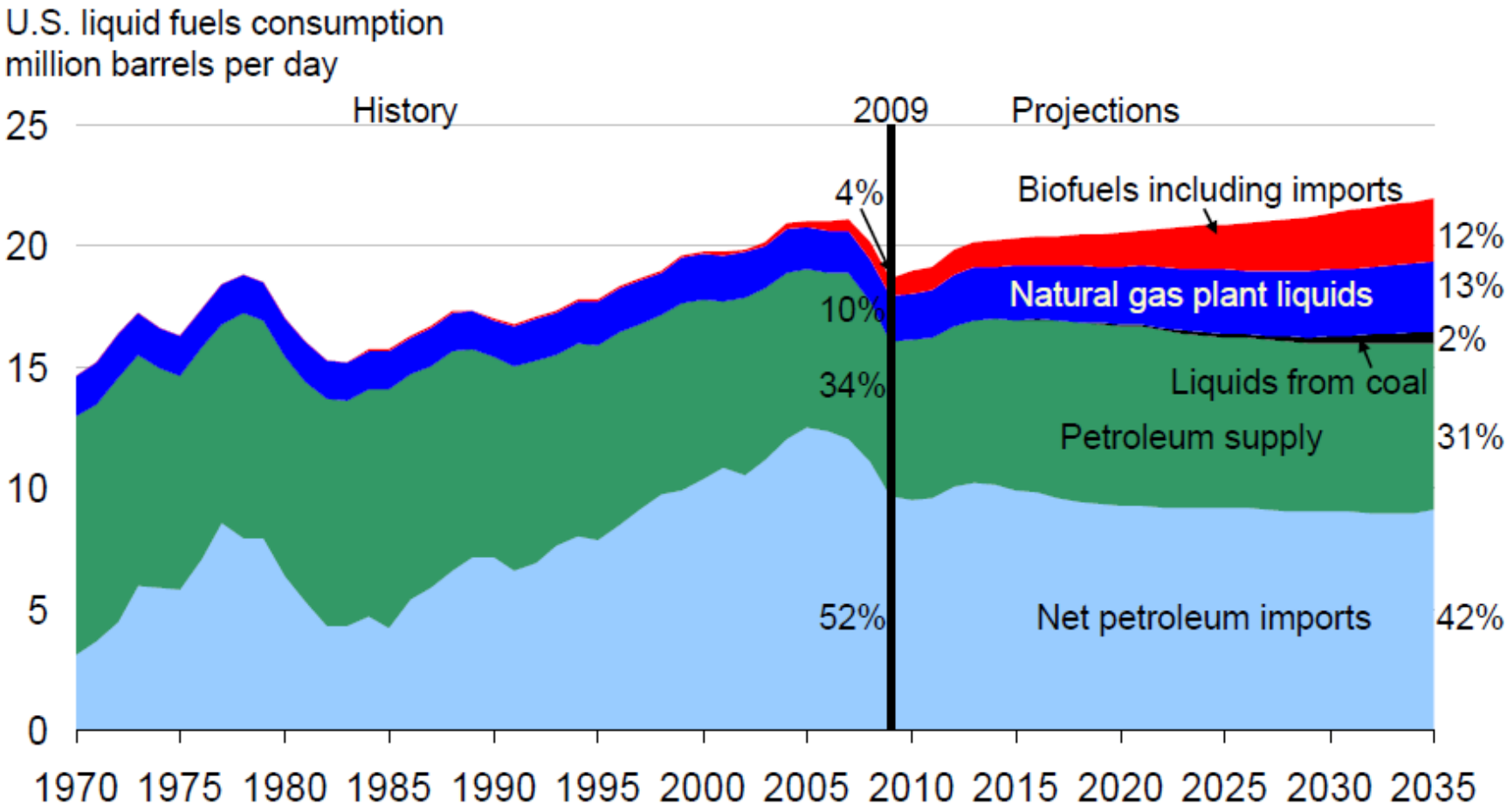
Zia Haq – U.S. Department of Energy Biomass Program

Biofuels Activities at DOE

Liquid Hydrocarbons Pack a Lot of Energy



U.S. Liquid Fuels Consumption

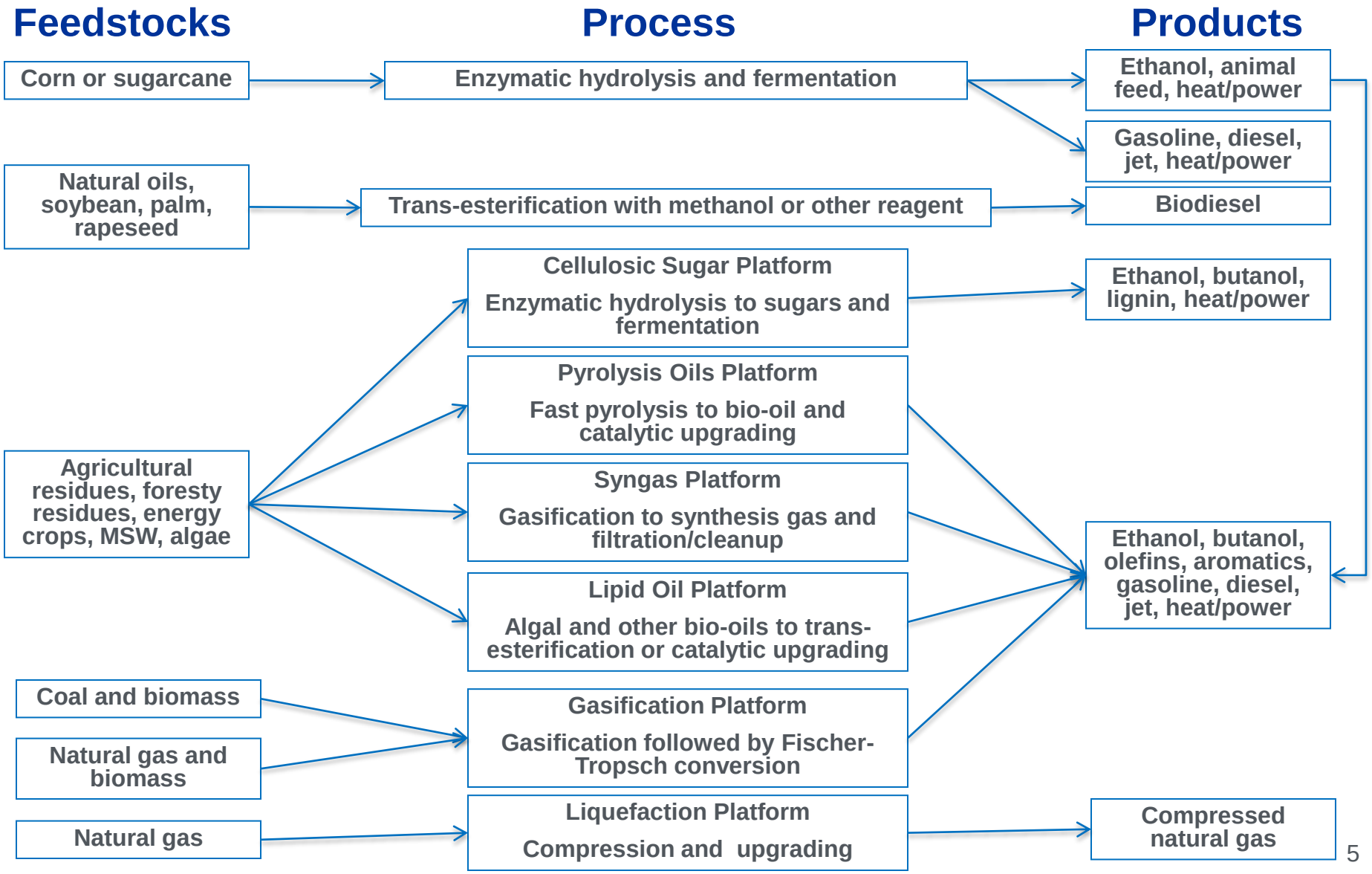


U.S. Biofuels Status

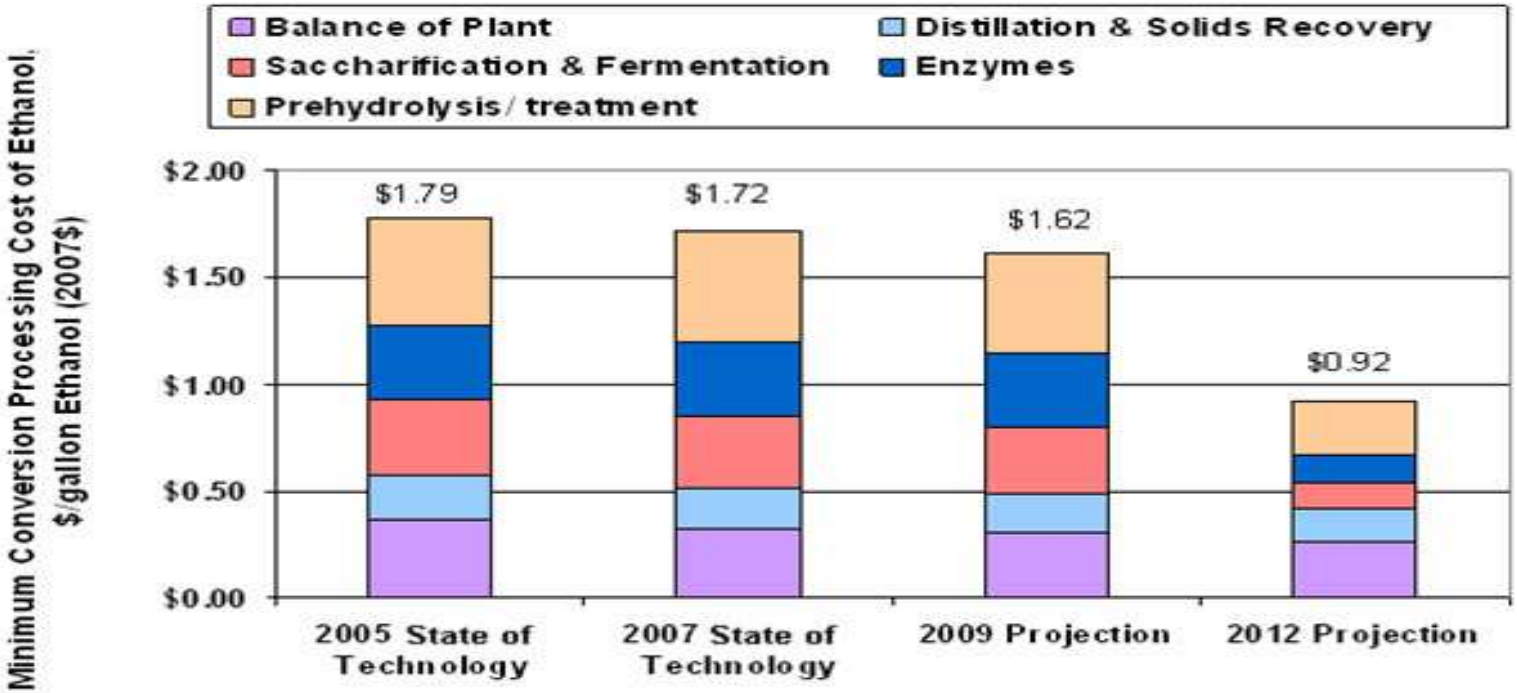
- U.S. biofuels production in 2010
  - 13 billion gallons of starch-based ethanol (approximately 10% by volume of gasoline demand)
  - 310 million gallons of soybean based biodiesel (compared to 58 billion gallons of diesel demand)
- Corn was the feedstock for about 95% of U.S. ethanol production (other feedstocks like sugarcane and soybean are negligable by comparison)
- U.S. is accelerating advanced biofuels through:
  - DOE grants to 29 integrated biorefineries
  - DOE loan guarantee program – Diamond Green Diesel
  - DOE annual R&D budget of $340 million requested in 2012
  - USDA loan guarantee program 3 awards – Coskata, Ineos, Enerkem
  - Programs at DOE-ARPA-E and Office of Science

Exploring Multiple Routes to Fuels

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



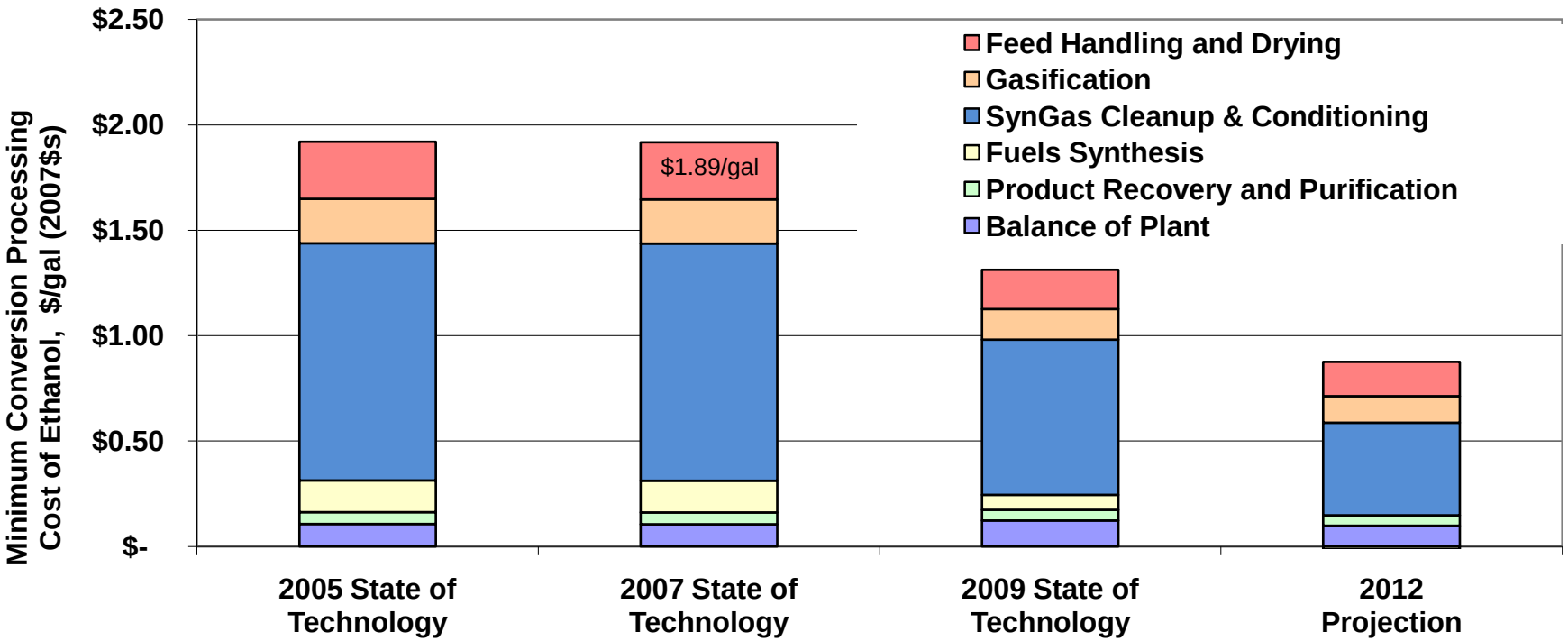
Cellulosic Sugar Cost Targets



- For biochemical conversion of lignocellulosic feedstocks to ethanol
- Excludes feedstock costs, which can add about $1/gallon
- Modeled costs for nth plant mature technology, at scale of 2,000 tons/day
- Source: Biomass Program Multi-Year Program Plan

	2005 State of Technology	2007 State of Technology	2009 Projection	2012 Projection
Processing Total	**$1.79**	**$1.72**	**$1.62**	**$0.92**
Prehydrolysis/ treatment	$0.50	$0.51	$0.47	$0.26
Enzymes	$0.35	$0.35	$0.35	$0.12
Saccharification & Fermentation	$0.35	$0.34	$0.31	$0.12
Distillation & Solids Recovery	$0.21	$0.19	$0.18	$0.16
Balance of Plant	$0.37	$0.32	$0.31	$0.26

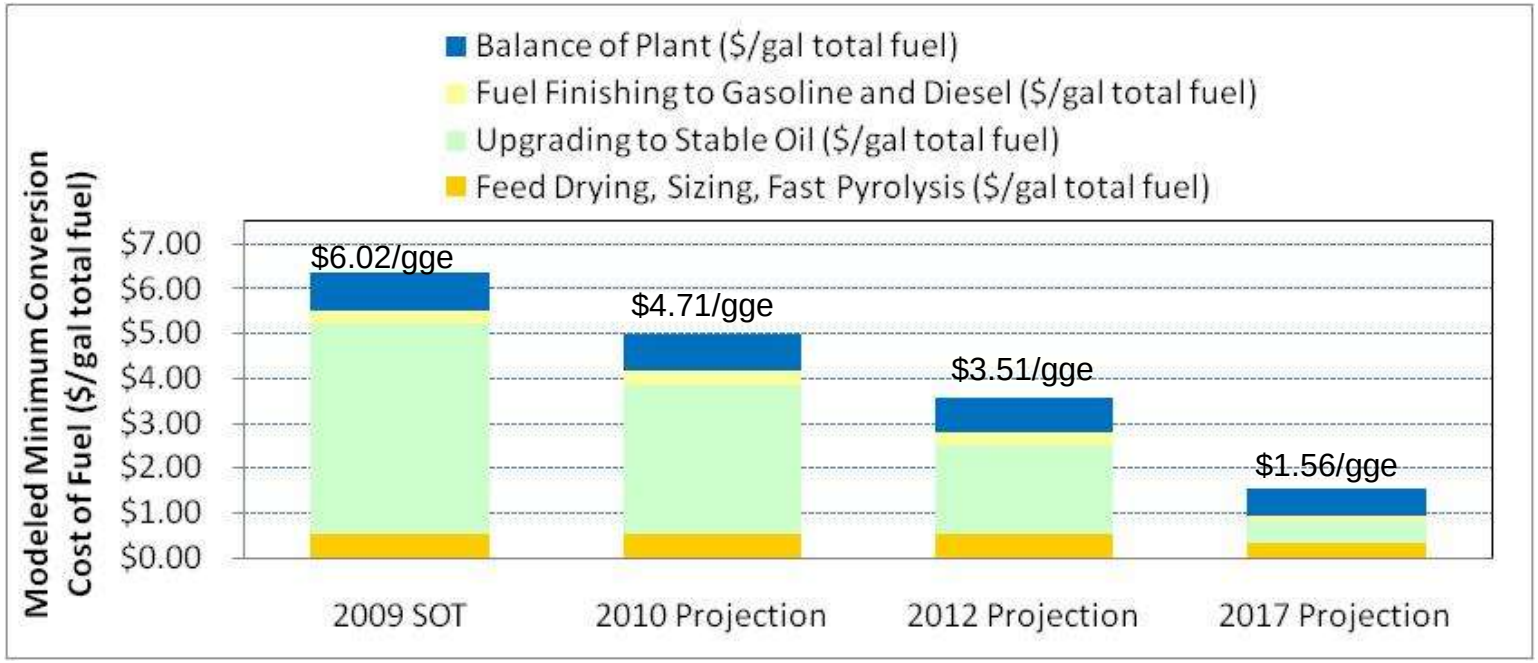
Syngas Cost Targets



- For thermochemical conversion (gasification) of lignocellulosic feedstocks to ethanol
- Excludes feedstock costs, which can add about $1/gallon
- Modeled costs for nth plant mature technology, at scale of 2,000 tons/day
- Source: Biomass Program Multi-Year Program Plan

	2005 SOT	2007 SOT	2010 Projection	2012 Target
Processing Total	$ 1.89	$ 1.89	$ 1.10	$ 0.93
Balance of Plant	$ 0.11	$ 0.11	$ 0.10	$ 0.12
Product Recovery and Purification	$ 0.06	$ 0.06	$ 0.05	$ 0.05
Fuels Synthesis	$ 0.15	$ 0.15	$ 0.03	$ (0.01)
SynGas Cleanup & Conditioning	$ 1.13	$ 1.13	$ 0.63	$ 0.46
Gasification	$ 0.21	$ 0.21	$ 0.13	$ 0.15
Feed Handling and Drying	$ 0.27	$ 0.27	$ 0.17	$ 0.16

Pyrolysis Cost Targets



- **For thermochemical conversion (pyrolysis) of lignocellulosic feedstocks to diesel**
- **Excludes feedstock costs, which can add about $1/gallon**
- **Modeled costs for nth plant mature technology, at scale of 2,000 tons/day**
- **Source: Biomass Program Multi-Year Program Plan**

	2009 SOT	2010 Projection	2012 Projection	2017 Projection
Conversion Contribution ($/gal gasoline)	**$6.30**	**$4.92**	**$3.51**	**$1.56**
Conversion Contribution ($/gal diesel)	**$6.37**	**$4.99**	**$3.57**	**$1.56**
Conversion Contribution ($/gge total fuel)	**$6.02**	**$4.71**	**$3.38**	**$1.48**
Feed Drying, Sizing, Fast Pyrolysis ($/gal total fuel)	$0.54	$0.53	$0.52	$0.34
Upgrading to Stable Oil ($/gal total fuel)	$4.69	$3.34	$2.01	$0.46
Fuel Finishing to Gasoline and Diesel ($/gal total fuel)	$0.30	$0.29	$0.29	$0.12
Balance of Plant ($/gal total fuel)	$0.82	$0.81	$0.74	$0.64

Biomass Program's Integrated Biorefinery Project Portfolio

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

For more information visit:
http://www.eere.energy.gov/biomass/integrated_biorefineries.html

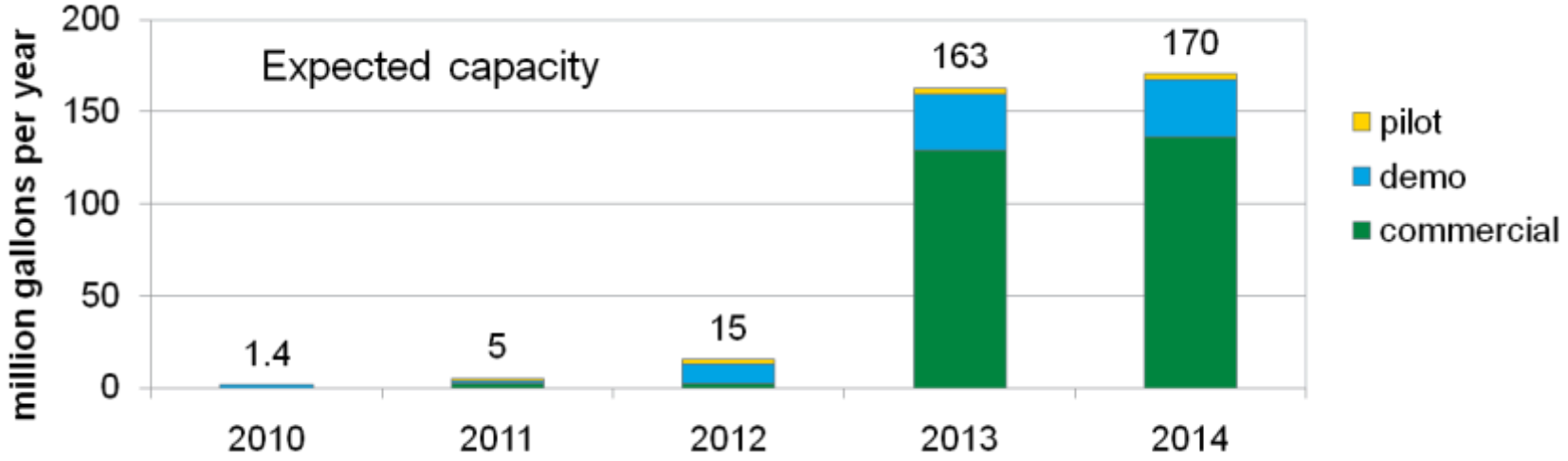
Integrated Biorefinery Status

- **Investments broadened to include more hydrocarbon fuels, diverse biomass feedstocks, and geographical diversity:**

  Over $1B in DOE investments in 29 IBR projects

  - » 11 hydrocarbon fuels - $326M
  - » 16 cellulosic ethanol - $703M
  - » 1 butanol - $30M
  - » 1 succinic acid - $50M

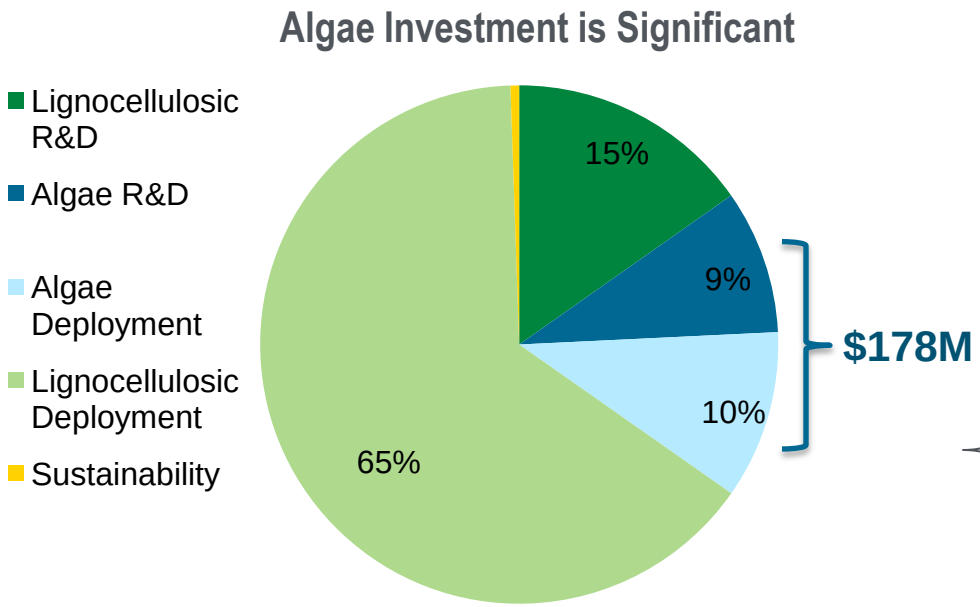
- **These projects represent up to 170 million gallons in planned capacity of biofuels and products by 2014, with an industry cost share of about $2.5Bm, including loan guarantees**



DOE Conditional Commitment for a Loan Guarantee for Advanced Biofuels Plant

- Diamond Green Diesel, LLC joint venture between Valero Energy Corp., and Darling International Inc. facility in Norco, Louisiana, - $241 million
- Feedstocks: animal fats, used cooking oil, and other waste grease streams. Product: 137 million gallons/year of renewable diesel.
- 700 jobs during construction and 60 jobs during operation
- First application of UOP hydrotreating/isomerization process known as Ecofining™ and a pre-treatment process from Desmet Ballestra Group.
- Reduce greenhouse gases by more than 80% compared to fossil based diesel

Algae Portfolio



*2010 appropriations and ARRA funds

- Feedstock production and crop protection
- Energy efficient harvesting and drying
- Extraction, conversion, and product purification
- Siting and sustainability of resources
- Co-products
- Techno-economic modeling

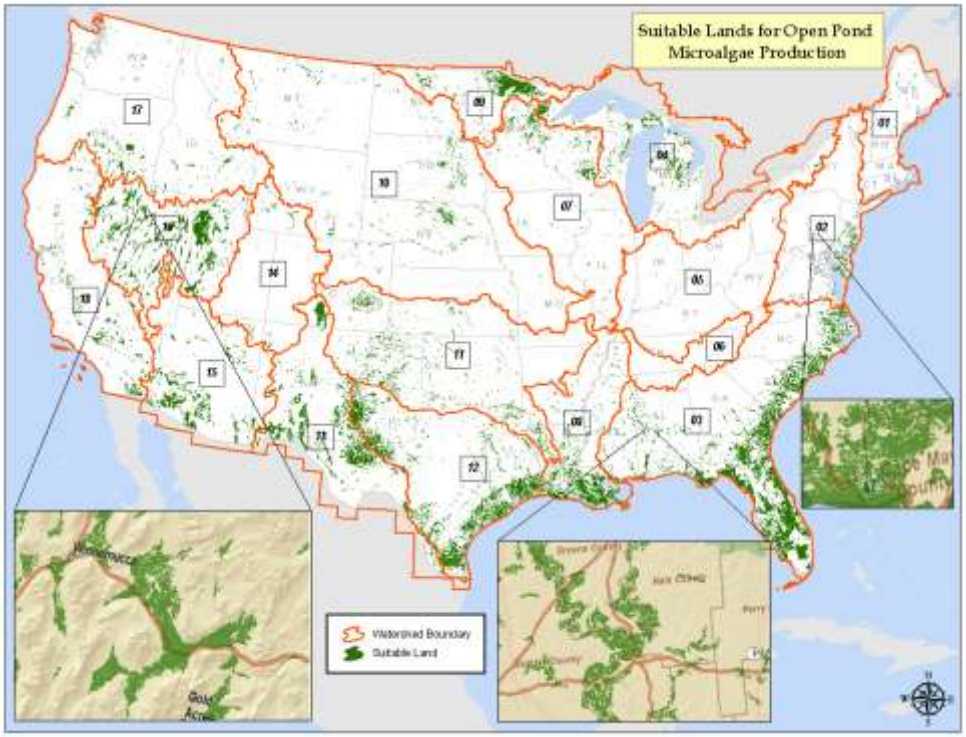
Pilot-scale raceway ponds, courtesy of Cellana LLC

Pilot-scale photobioreactor systems, courtesy of ASU

Microalgae Potential

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

"A National Resource Availability Assessment for Microalgae Biofuel Production"



Courtesy of Pacific Northwest National Laboratory; Wigmosta, MS et al., manuscript in preparation. **Funded by EERE-OBP in FY 2010**

Critical Resources and Constraints

- Climate, land, water, CO_2 and nutrients

Conclusions

- Water intensity ~ corn or soy-based biofuels
- ~50M hectares available nationally
- Gulf Coast and Southwest among ideal locations

Bottom Line

>10B gallons of algal biofuels technically feasible from 5M hectares alone

Information Resources

- Office of Biomass Program- www.eere.energy.gov/biomass/
- 2011 Biomass Program Review – http://www.obpreview2011.govtools.us/
- Alternative Fuels Data Center- www.eere.energy.gov/afdc/fuels/ethanol.html
- Bioenergy Feedstock Information Network - bioenergy.ornl.gov/
- Biomass R&D Board – www.biomassboard.gov
- Grant Solicitations - www.grants.gov and www.fedconnect.net
- Office of Science – www.science.doe.gov/
- Loan Guarantee Program Office – www.lgprogram.energy.gov

Additional Slides

Sustainable Biofuels, Biopower, and Bioproducts

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The Biomass Program is working to advance biomass technologies in support of DOE's mission to strengthen America's energy security, environmental quality, and economic vitality through:

Feedstocks

Developing lower cost feedstock logistics systems

Conversion technologies

Improving conversion efficiencies and costs

Integrated biorefineries

Systematically validating and deploying technology at first-of-a-kind facilities

Infrastructure

Evaluating vehicle emissions, performance, and deployment options

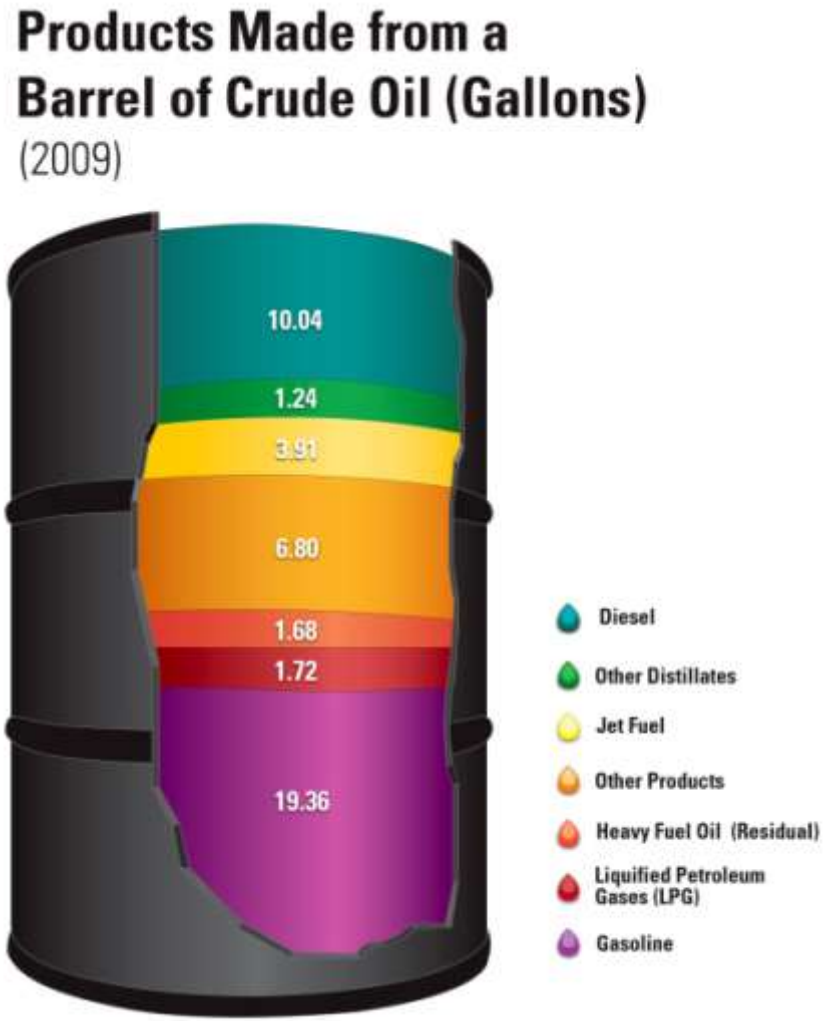
Biopower

Providing a clean, domestic, dispatchable renewable source of power

Advanced biofuels

Expanding portfolio beyond cellulosic ethanol to hydrocarbon fuels

Energy Security: Liquid Fossil Fuel Displacement



Source: Energy Information Administration, "Oil: Crude Oil and Petroleum Products Explained" and AEO2009, Updated February 2010, Reference Case.

- **Below E10, refiners can adapt**
- **Somewhere above E10, problems arise:**
  - **Refiners shift gasoline to lower-value products**
  - **Reduced crude runs reduce diesel / jet supply**
  - **Refinery balance can be disrupted (aromatics, H2, light / heavy, heat / process integration, etc.)**
- **Foreseeable capacity ~100% ethanol:**
  - **Conv. RF will be ethanol (mostly corn)**
  - **Adv. NCRF will be ethanol (mostly cane)**
  - **Adv. CRF will initially be ethanol (cellulosic)**
  - **Limited biodiesel & renewable diesel from veg oils and waste fats & oil**
- **No single hydrocarbon is a panacea:**
  - **Paraffin vs. aromatic**
  - **Single component (volatility)**
  - **Acceptability as "contaminant" in other fuels**
  - **Combustion behavior**
  - **Refinery adaptability**