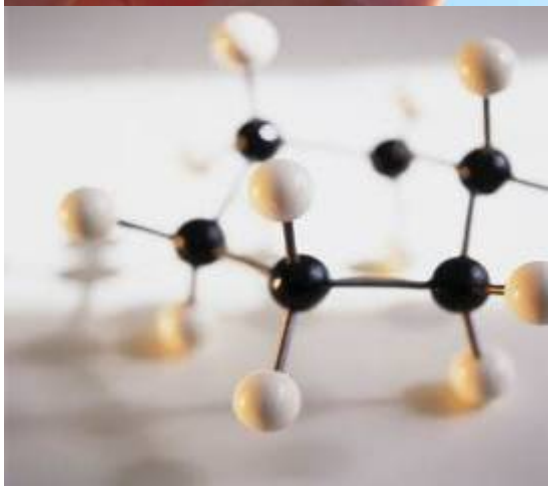





U.S. Biofuels Development Research and Summary of Cooperative R&D with China

July 23, 2010

Carl Wolf
BCS, Incorporated

Biomass

2010 Biomass Program Priorities

"Developing the next generation of biofuels is key to our effort to end our dependence on foreign oil and address the climate crisis -- while creating millions of new jobs that can't be outsourced. With American investment and ingenuity -- and resources grown right here at home -- we can lead the way toward a new green energy economy."

Secretary of Energy Steven Chu

Advancing Presidential Objectives

Science & Discovery
- Connecting basic and applied bioscience.
- Conducting breakthrough R&D:
  - Advances in enzymes and catalysis.
  - Engineering of new microorganisms.
  - Novel sustainability indicators.

Clean, Secure Energy
- Developing & demonstrating cellulosic and advanced biofuels to meet RFS.

Economic Prosperity
- Creating 50 to 75 jobs per new biorefinery.
- Creating major new energy crop markets.
- Reinvigorating rural economies.

Climate Change
- Reducing GHG emissions with advanced biofuels (relative to gasoline).

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Biomass Program Objectives and Goals

Make biofuels cost competitive with petroleum based on a modeled cost for mature technology at the refinery gate.
Forecast to be $2.62/gal gasoline equivalent by 2012

Help create an environment conducive to maximizing production and use of biofuels, 21 billion gallons of advanced biofuels per year by 2022 (EISA).

Research & Development

Feedstock Systems

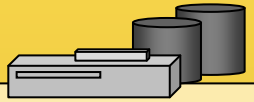
- Sustainable regional biomass resources: 130 million dry tons/yr by 2012.
- Improved logistics systems: $50/dry ton herbaceous by 2012.

Conversion Technologies

Biochemical
- Cost of converting feedstocks to ethanol: $1.40/gal gasoline equivalent (GGE) by 2012.

Thermochemical
- Cost of converting woody feedstocks to ethanol: $1.31/GGE by 2012.
- Cost of converting woody feedstock to hydrocarbon fuels by pyrolysis : $1.47/GGE by 2017.

Demonstration & Deployment



Integrated Biorefineries

- Validate integrated process technologies
  - 4 commercial scale
  - 8 demonstration scale
  - Up to 20 pilot or demonstration scale

Infrastructure

- Testing of E15 & E20 and develop biofuels distribution infrastructure

Sustainability & Analysis

Increase understanding of and impacts on:

- GHG emissions
- Water quality
- Land use
- Socioeconomics
- Predictive Modeling
- International

China – U.S. Biofuels Cooperation

"By jointly developing new technologies and learning from China's experiences, we can create new export opportunities for American companies and ensure that we remain on the cutting edge of innovation. This partnership will also be a foundation for broader partnerships with China on cutting carbon pollution."

-Secretary of Energy Steven Chu

- The United States and Chinese governments are fully engaged in collaboration on clean energy technology research, development, and deployment, and working to facilitate the deployment of commercial technologies that will spur economic growth, lower greenhouse gas emissions, and promote sustainable development.

- Cooperation makes sense from a technical, economic, environmental, energy security, and policy/diplomacy perspective.

China – U.S. Biofuels Cooperation MOU

- Memorandum Of Understanding (MOU) for Biofuels Cooperation signed December 2007 between U.S. DOE and USDA with China's National Development and Reform Commission (NDRC).
- Collaboration on scientific, technical, and policy aspects of biofuels development, production, and use.
- Technical aspects of cooperation include feedstocks, sustainability, conversion technologies, bio-based products, and rural development strategies. Beginning to discuss cooperation on algal biofuels.
- Under the guidance of National Energy Administration (NEA) areas of mutually beneficial research and development identified and refined in May 2009.
- International Seminar for Bioenergy & Biofuels December 2009 hosted by NDRC and NEA and supported by Honeywell.
- Sino-U.S. Advanced Biofuels Forum May 2010 hosted by NEA and supported by U.S. DOE and USDA.
- Technical Working Group Meetings and Site Visits by U.S. DOE and USDA with Chinese project partners scheduled for September 2010.

Summary

-Currently there is a two tiered bioenergy technology exchange between China and U.S.:

- Applied Research & Development between USDA and DOE National Laboratories and Chinese universities, institutes and companies.

- Applied Research & Development & Demonstration between U.S. industrial entities and Chinese industrial entities.

-With the active R&D collaboration, applied tangible results that benefit both nations are being attained.

-Additional opportunities for collaborations in the field of bioenergy are being sought out and developed.

-The harmonization of biofuels policies and standards, including sustainability analysis, will help establish global markets for US and Chinese industry stakeholders, and facilitate increased economic growth.

- For more information…

Office of Energy Efficiency and Renewable Energy

http://www.eere.energy.gov/

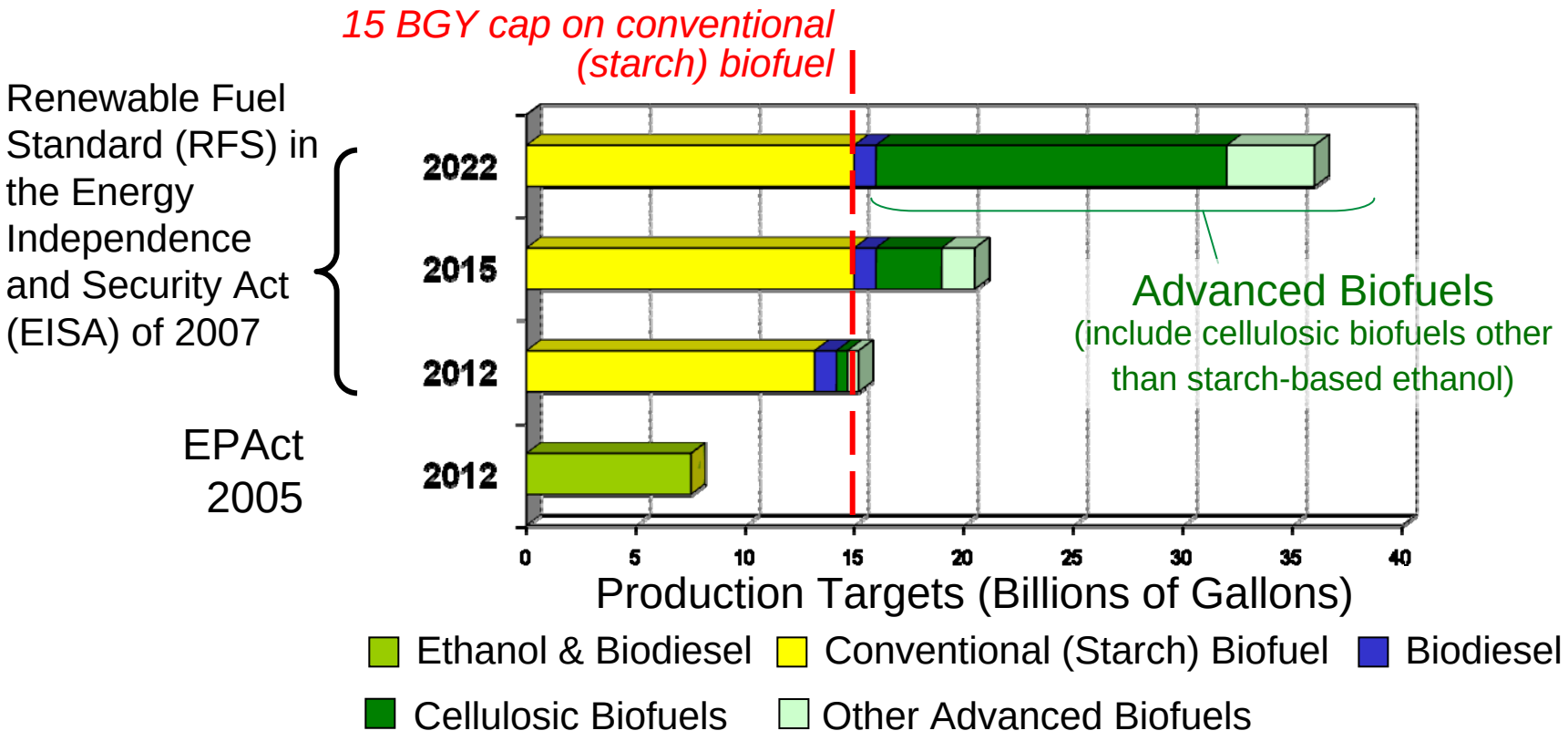
Biomass Program

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

THANK YOU

Back Ups

EISA Mandated Production Targets



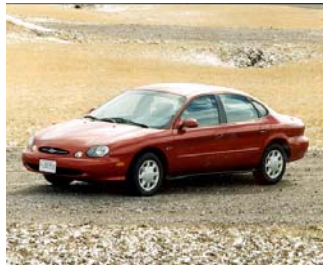
EISA defines *Advanced Biofuel* as "renewable fuel, other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions…that are *at least 50 percent less* than baseline lifecycle greenhouse gas emissions."

Cellulosic ethanol technology is important to reaching the 2022 EISA target, however, other advanced biofuels will be needed to aid in this endeavor.

U.S. DOE Biomass Program

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



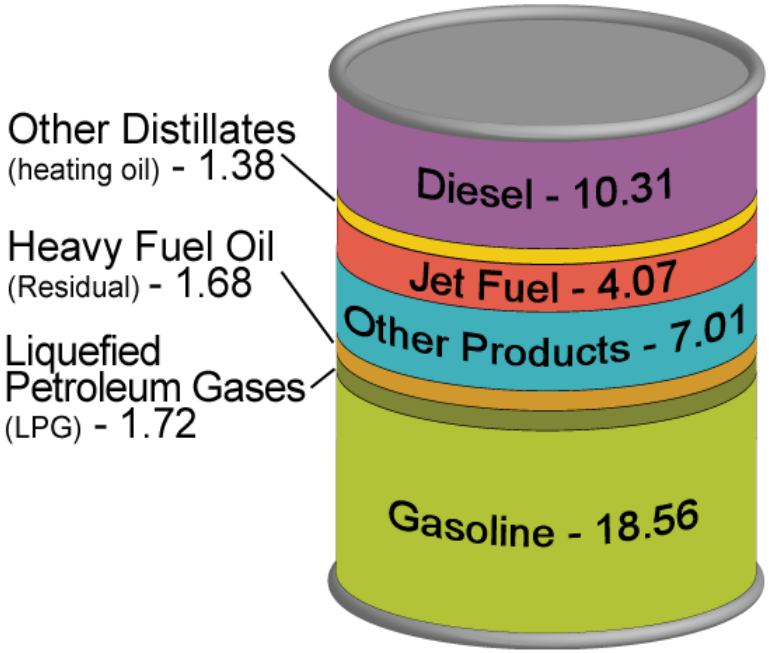
Mission Statement

Develop and transform our renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts, and biopower. Conduct targeted research, development, and demonstrations, leading to deployment in integrated biorefineries, supported through public and private partnerships.

Cellulosic Biofuels: Cellulosic ethanol in the near term with a transition to liquid biofuels that are current fuel infrastructure compatible i.e. (renewable) gasoline, diesel and jet fuel.

Rationale for Advanced Biofuels

Products Made from a Barrel of Crude Oil (Gallons)



U.S. Diesel Outlook
(EIA AEO 2009 Reference Case for 2030)

- 71 billion gal/yr
- 0.5 billion gal/yr biodiesel production (2007)

U.S. Jet Fuel Outlook
(EIA AEO 2009 Reference Case for 2030)

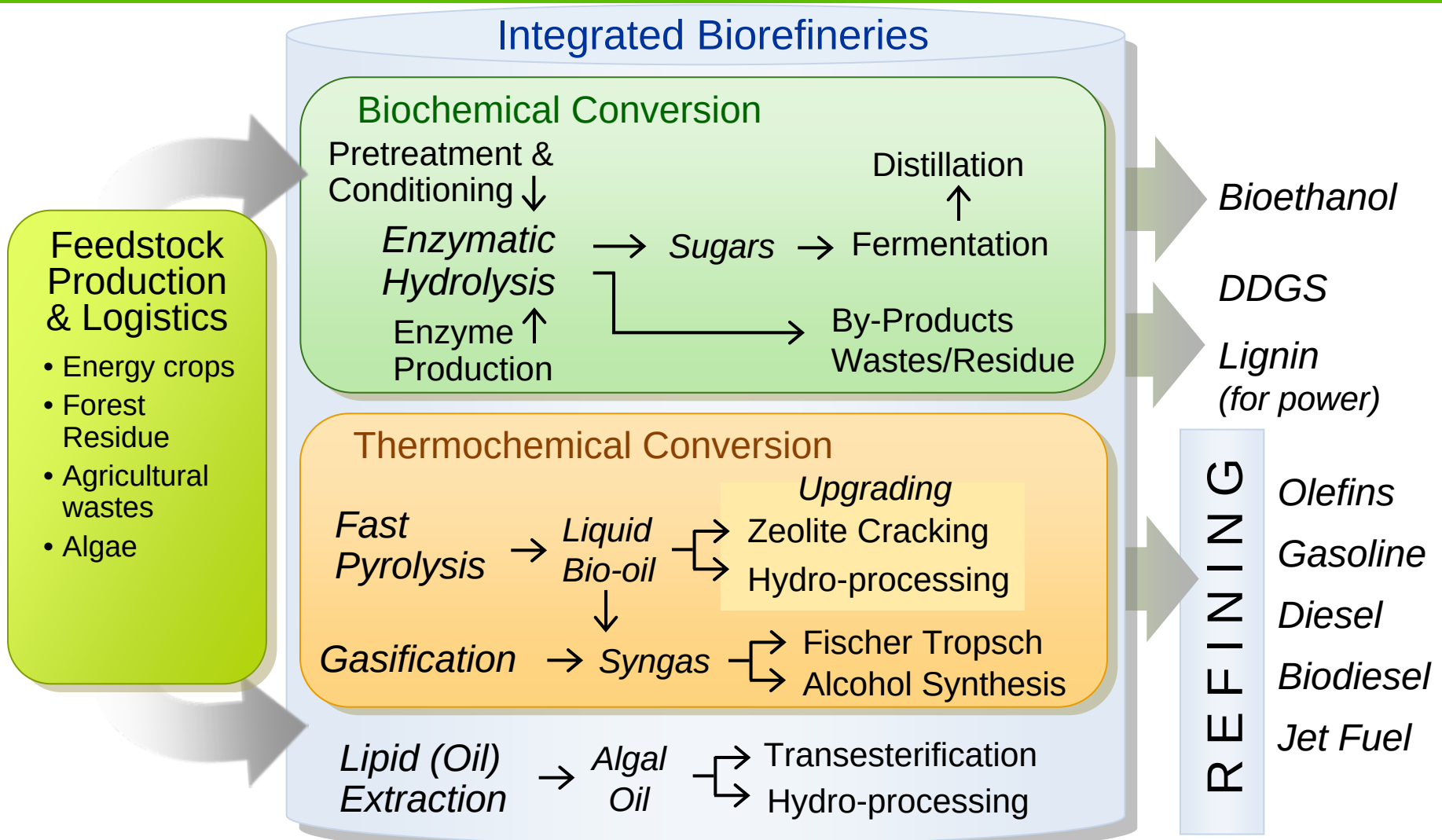
- 30 billion gal/yr

- Cellulosic ethanol displaces light duty gasoline fraction only
- Heavy duty/diesel and jet fuel substitutes are needed to displace other components of the barrel

Source: Energy Information Administration, “Petroleum Explained” and AEO2009, Updated (post-ARRA), Reference Case.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Exploring Routes to Convert Biomass



Research on biochemical and thermochemical conversion pathways is improving the efficiency and economics of biofuels production.

Feedstock Analysis

Project Objectives

- Task 1: Feedstock supply state of technology information exchange
  - Assemble feedstock analysis working group with DOE, USDA, Chinese participants.
- Task 2: Cellulosic feedstock supply and feedstock cost analyses
  - China based case stud(ies) of feedstock supply system.
- Task 3: Economics of sustainable Jatropha production
  - Evaluate Jatropha production potential and costs.

Project Partners

- U.S.: Idaho National Laboratory (INL) and Oak Ridge National Laboratory (ORNL), USDA agencies and experts.
- China: Potential corporate partners (SinoPec, PetroChina, COFCO, ZTE, CNOOC) and others – universities and research institutes (TBD).

Feedstock Analysis

Accomplishments

- Assembled a feedstock working group (DOE - USDA) for technical exchange with Chinese partners.
- Compiled information on state of the art feedstock supply analysis.
  - Current US feedstock supply options and costs.
  - Analysis of bioenergy resource availability.
  - Review of sorghum production and harvest knowledge.

Next steps

- Supply documents to Chinese partners.
- Expand working group to engage Chinese partners.
- Establish video- or tele-conferences for information exchange.
- Begin China-based case study and develop mechanism for sharing technical information on modeling methods and supply chain options.
- Complete analysis of Jatropha production potential and costs.

Outcomes

- Regular information exchange forums for all research partners.
- China-based logistics model and integrated data to guide research decisions and identify technical barriers.
- Detailed collaborative research plans to refine case study and address technical barriers.

Biochemical Conversion Joint Research

Objectives

- Conduct joint research for cellulosic conversion to ethanol using corn stover and other biomass feedstocks in China.
- Characterize advanced solid state fermentation process for sweet sorghum conversion to ethanol in support of commercialization.

Cellulosic Conversion of Chinese Feedstocks to Ethanol

Partners: NREL (US), Tsinghua University/PetroChina and others (TBD)

Research Activities:

- Characterization of pentose utilization of US strains of Zymomonas mobilis on hydolysates of Chinese feedstocks, starting with corn stover and sweet sorghum bagasse – strain transfer complete, research initiated at Tsinghau University.

Future Activities:

- Complete characterization of pentose utilization strains.
- Evaluate the hydrolysate toxicity of microorganisms (US and China) on hydolysates of Chinese feedstocks (FY2010).
- Improve the conversion efficiency of glucose and xylose and other minor sugars to ethanol, research planned for FY2011.
- Identification and characterization of cellulase enzymes from Tsinghua University cellulosic hydrolysis consortium, research planned for FY11.

Members of Congress visit NREL's cellulosic ethanol pilot plant

At NREL In the Biochemical Process Development Unit pilot plant, researchers study biochemical processes for converting lignocellulosic biomass to ethanol

Biochemical Conversion Joint Research

Advanced Solid State Fermentation (ASSF) of Sweet Sorghum

Partners: NREL (US), Tsinghua University and PetroChina.

Research Activities:

- Characterization of yeast fermentation strain Saccharomyces cerevisiae (TSH-Sc-1) from China for the Advanced Solid State Fermentation (ASSF) process – strain transfer complete.
- Tsinghau University post-doctoral research associate working at NREL.
- ASSF process assessment and modeling of rotating reactor drum bioreactor – publication of one reviewed journal paper, 2 presentations at AIChE 2009.
- Techno-economic analysis of ASSF process and comparison with wet fermentation process – ASSF preliminary analysis complete, validation and sensitivity analyses in progress.

Future Activities:

- Complete techno-economic analyses of sweet sorghum fermentation processes (wet and dry).
- Complete assessment of TSH-Sc-1 fermentation strain.

Impacts:

- Understanding the ASSF technology from biological and process perspectives for sweet sorghum to ethanol conversion.
- Identify the advantages and potential limitations of the process.
- Improve the process for commercial scale of interest in China and US (National Sorghum Growers Association).

Testing sweet sorghum varieties in Inner Mongolia

Tsinghua University small and pilot scale reactors for ASSF sweet sorghum ethanol

Thermochemical Conversion Joint Research

Objectives

- Development of analysis to facilitate decision making on selection of thermochemical pathways.

Partners: PNNL and China National Offshore Oil Corporation (CNOOC).

Research Activities

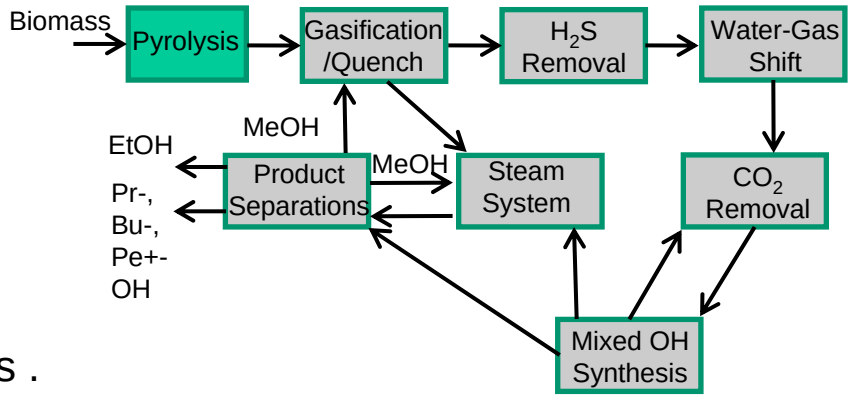
- Techno-economic analysis of thermochemical conversion pathways based on the data provided by CNOOC and a hybrid process of NREL's and PNNL's .
- Identification of catalysts to further improve yields.

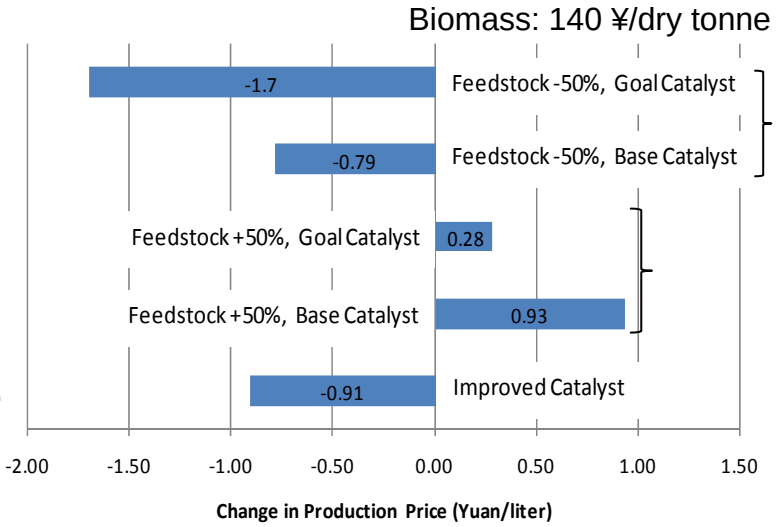
Impacts

- Techno-economic analysis of thermochemical conversion pathways showed that feedstock cost and catalyst performances in syngas conversion have significant impacts on the overall cost of biofuel.

Future Activities

- Optimization of technical routes based on techno-economic analysis to further reduce the cost of biofuel.
- Improve performances of key conversion steps.





Thermochemical Conversion Joint Research

Objectives

- Development of key conversion and separation technologies (advanced pyrolysis, gasification, syngas clean up, and syngas conversion).
- Demonstration and validation at Process Development Unit scale.

Partners: PNNL,China National Offshore Oil Corporation (CNOOC) and Dalian Institute of Chemical Physics (DICP).

Activities

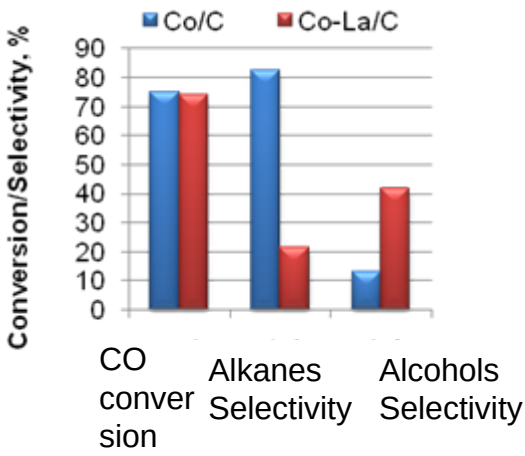
- Advanced catalyst characterization, process work and modeling of Cobalt catalysts for higher alcohol production from syngas.
- Exchange of scientists between DICP and PNNL to advance the research.

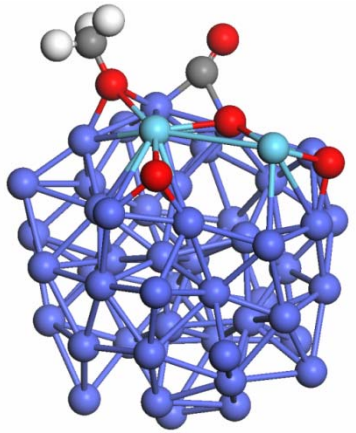
Impacts

- Lanthanum increases the selectivity to alcohols and suppresses the alkane formation.
- Two invited presentations on the projects technical progress.
- A joint publication on the identification of active sites is under preparation.

Future Activities

- Demonstrate improved catalyst space time yields
- A multi-year technical program plan is being finalized.





$CH_3 + CO$

DOE Pacific Northwest National Laboratory

Addressing LCA and Water Issues for Biofuels

- GREET and its documents are available at Argonne's website at *http://www.transportation.anl.gov/software/GREET/*
- There are over 10,000 GREET registered users worldwide.

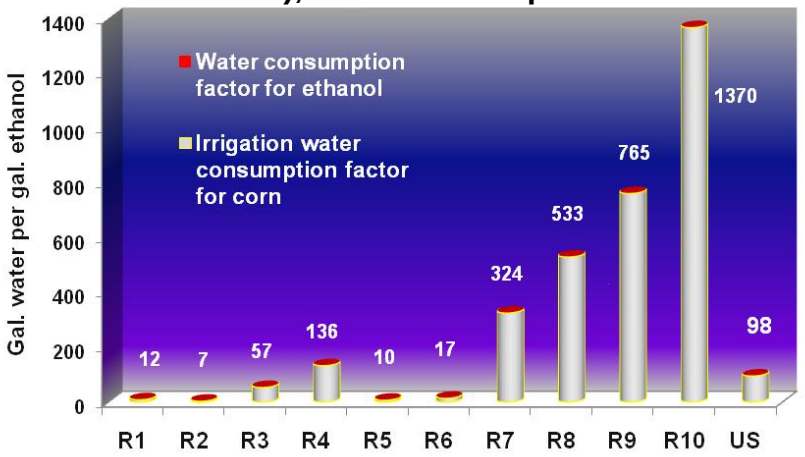
Biofuel Production Pathways Already In GREET

- Sugar Crops for EtOH
  - Sugar cane
- Starch Crops for EtOH
  - Corn
- Cellulosic Biomass for EtOH
  - Corn stover
  - Forest wood residue
  - Energy crops (switchgrass and fast growing trees)
- Oils for Biodiesel/Renewable Diesel
  - Soybeans
- Cellulosic Biomass via Gasification
  - Fitscher-Tropsch diesel
  - Hydrogen
- Butanol Production
  - Corn

Argonne Has Been Addressing both Water Quantity and Quality Issues

- Water is consumed by feedstocks primarily through evapotranspiration
- Irrigation is required when precipitation alone is not sufficient for growth; water stressed areas demand more irrigation.
- Groundwater use for irrigation is a major concern in areas where groundwater is depleting.
- Water management practice affects total water withdrawal
- Water quality implications from biofuel feedstock growth differ among regions.

Water consumption by corn ethanol depends on where corn is grown; in key U.S. corn production regions (R5 and R6), water consumption is small



Clarification on the Projects

1 Cellulosic Ethanol - SinoPec
2 Algal Biodiesel - SinoPec
3 Sweet Potato Crop – COFCO
4 Thermochemical Conversion – CNOOC
5 Sweet Sorghum Industrialization – ZTE
6 Cellulosic Ethanol Pilot Plant – CNPC
7 Hydrogenation for Green-Diesel Production - CNPC

Acknowledgements

Many organizations facilitate China-US collaboration:

NEA

COFCO

CNOOC

SinoPec

ZTE

PetroChina

USDA Foreign Agricultural Service Office, U.S. Embassy in Beijing

U.S. DOE Office in Beijing

Where We Are Going

The Nation's Goal:

36 billion gallons (136 billion liters)/year of biofuels by 2022

DOE's path forward:

- Integrated programs R&D to solve technical barriers
  - Applied research for short- and mid-term impact
  - Fundamental research for longer-term impact
- Cost-shared programs with industry to reduce risk
- Broadening portfolio to maximize volumetric production

Sustainability is highly important in all aspects of our work