

# Working Toward the Renewable Fuel Standard

Biomass 2009

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# Biomass Program Goals: Making Cellulosic and Advanced Biofuels a Reality



**Short Term:** Foster breakthrough technologies needed to make cellulosic ethanol cost-competitive by 2012 (cost target: \$1.33/gal).

**Mid Term:** Help create an environment conducive to maximizing the sustainable production of biofuels by 2017, including cost-effective technology, sufficient infrastructure, appropriate policies, and supportive consumers (cost target: \$1.20/gal).

**Long Term:** Increase the supply of cellulosic and advanced biofuels to 21 billion gallons by 2022 (per Renewable Fuel Standard in the Energy Independence and Security Act of 2007)



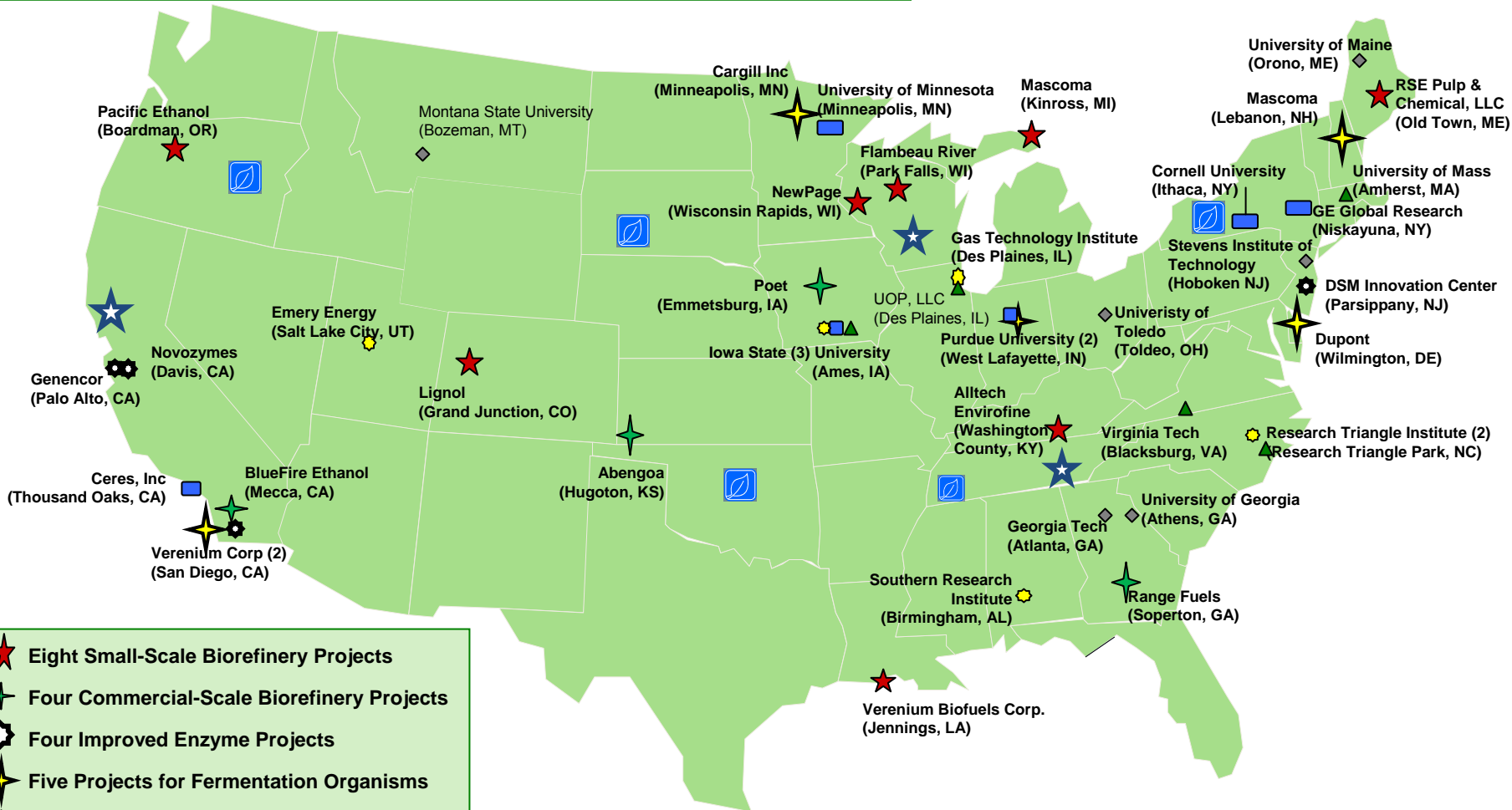
# A Billion Dollar Investment in Biofuels



Since early 2007, DOE has announced investments of *more than* \$1 billion for the RD&D of new biofuels technology, with a focus on non-food, cellulosic feedstocks.

- Cellulosic Ethanol Biorefinery Demonstrations at commercial and 10%-scale
- World-class Biomass Research Centers (Office of Science)
- University Research projects (including Advanced Biofuels)
- New and Improved Enzymes and Micro-organism R&D
- Thermochemical Processes R&D (Pyrolysis, Gasification)
- Annual USDA/DOE Joint Solicitation
- Field Trials under the Regional Biomass Energy Feedstock Partnership
- Biofuels Sustainability Studies and GIS-Based System
- Joint EPA/DOE Ethanol Blend Studies

# Major DOE Biofuels Project Locations



- Eight Small-Scale Biorefinery Projects
- Four Commercial-Scale Biorefinery Projects
- Four Improved Enzyme Projects
- Five Projects for Fermentation Organisms
- Five Thermochemical Syngas Projects
- DOE Joint Solicitation Biomass Projects
- Five Thermochemical Bio-Oil Projects
- Six University Conversion Projects

**Office of Science Bioenergy Centers**  
 DOE Great Lakes, Madison, WI  
 DOE Joint Bioenergy Institute, Berkeley, CA  
 DOE Bioenergy Science Center, Oak Ridge, TN

**Regional Partnerships**  
 South Dakota State Univ., Brookings, SD  
 Cornell University, Ithaca, NY  
 Univ. of Tennessee, Knoxville, TN  
 Oklahoma State Univ., Stillwater, OK  
 Oregon State Univ., Corvallis, OR

# Upcoming & Pending Solicitations



## In Progress

- Annual USDA/DOE Joint Solicitation for Biomass Research and Development Initiative
  - Up to \$25M for awards of \$1M to \$5M for up to 4 years
- Clean Cities Solicitation for Biofuels Outreach and Education
  - Up to \$1.8M for training so that vehicles and fueling equipment are installed, maintained, and operated in a safe and proper manner
- Integrated Pilot-Scale or Demonstration-Scale Biorefinery for Advanced Biofuels
  - Up to \$200M over 6 years for 5-12 projects



## Future Opportunities

- R&D Lab Call
- Recovery Act Funds (\$800 million) -- TBD



# Developing A Ready End-Use Market for Ethanol



- More than 9 billion gallons of ethanol were used in the U.S. in 2008
  - More than 99% used in the form of E10
  - E10 market will be saturated at about 14 – 15 billion gallons
- DOE strategy for expanding ethanol use
  - Determine feasibility of using intermediate ethanol blends (e.g., E15, E20) in conventional vehicles (non-flex fuel vehicles)
  - Expand E85 by targeting specific regions/cities to establish high concentration of FFVs and infrastructure
- EPA has authority to issue a “substantially similar” waiver to allow alternative fuels to be used in place of gasoline
  - Evaluate effects on durability, driveability, materials, and emissions



# DOE's Intermediate Blends Effort



- Sponsored by DOE's Biomass and Vehicle Technologies Programs
- DOE initiated analysis in Spring 2007
  - Small, non-road engines given priority in Summer 2007 at EPA request
  - Vehicle evaluations began late CY 2007
- Leveraging work of other stakeholders (CRC, EPA and others)
- Working in close coordination with EPA to ensure test data can effectively address analytical questions
- DOE has invested approximately \$15M (additional \$6M from partners co-funding) through FY2008 on testing of intermediate ethanol blends.



# DOE's Intermediate Ethanol Blends Test Program



- The DOE test program is evaluating --
  - Vehicle exhaust and evaporative emissions
  - Catalyst durability and aging
  - Cold-start operation and drivability
  - Fuel-system and catalyst materials compatibility
- DOE is also evaluating impacts of higher ethanol blends on small engines and infrastructure components
  - Tested leaf blowers, line trimmers, pressure washers, and small generators
  - Plan to expand test plan for marine engines, all-terrain vehicles, motorcycles, and dispensers.





# Completed Testing



## Vehicles

- Emissions and Catalyst Temperature Pilot Study (16 vehicles)
  - Tests of 13 vehicles completed last year – Report #1 published October 7, 2008
  - Final 3 vehicles completed December 2008 – to be reported in February 2009 in a Revised Report #1
- Tailpipe Emissions (with EPA) (22 vehicles, 31 different fuels)
  - Phase 1 (75°F) and Phase 2 (50°F) completed; 3 total phases
- Cold Start and Driveability (with CRC) (6 vehicles)
  - Sub 50°F testing completed - CRC Report No. 652 issued Oct 2008
- Evaporative Emissions (with CRC and EPA) (8 vehicles)
  - Project E-77-2 testing complete, CRC report expected 2nd Quarter 2009

## Small Non-Road Engines (lawn equipment, generators)

- Emissions and Exhaust Temperature Pilot Study (6 engines)
  - Testing completed May 2008 – Report #1 published October 7, 2008
- Full Useful Life Emissions and Durability (17 / 22 engines aged to full life)
  - Testing completed May 2008 – Report #1 published October 7, 2008

# DOE Results to Date: Vehicles



## ■ Emissions / temperature

- Regulated tailpipe emissions with E15 and E20 were similar to levels with E0.
  - NMHC and CO decreased slightly (CO flat from E10-E20).
  - Ethanol and acetaldehyde emissions increased as expected.
- Under most conditions, catalyst temperatures were largely unchanged with E15 and E20 compared to E0.
- Under full throttle conditions, about half of the cars exhibited increased catalyst temperatures with E15 and E20 compared to E0.

## ■ Driveability

- Driveability issues were not identified with either E15 or E20.
- No malfunction indicator lights or filter plugging.
- Informal observations only.

## ■ Fuel Economy

- Fuel economy on volumetric basis decreased for E10, E15, E20.
- Closely tracked fuel energy content.

# DOE Results to Date: Small Engines



- Emissions / Temperature
  - With increasing ethanol content:
    - Regulated emissions – combined HC+NO<sub>x</sub> – decreased in most cases.
    - Engine and exhaust temperatures increased.
- Durability
  - Commercial engines, as well as more sophisticated residential engines, exhibited no particular sensitivity to ethanol from a durability perspective.
  - The effect of E15 and E20 on the durability of smaller, less expensive residential engines (e.g., leaf blowers) was not clear.
- Safety:
  - Potential issue: Increased ethanol caused spontaneous clutch engagement on tested commercial line trimmers (Note: Problem was fixable with carburetor adjustment.).



## Vehicles

- **Tailpipe Emissions** (with EPA)

- Phase 1 and 2 completed
- Phase 3 underway with results expected in February 2010

### **Full Useful Life Emissions Study** (with CRC)

- Testing underway; Results expected 2010

### **Evaporative Emissions** (with CRC and EPA)

- Project E-77-2b in initial stages; CRC Report expected in 2010

### **Fuel System Materials Compatibility** (with CRC)

- Testing underway; Results expected by October 2009

### **Cold Start and Driveability** (with CRC)

- Testing at high ambient temperature
- Tentative start and completion: Summer 2009

## Other Engines/Infrastructure Components

**Motorcycles, marine, snowmobiles, chain saws, dispensers**

**Back-Up Slides**



# Biomass Support from the American Recovery and Reinvestment Act, 2009



- **Renewable R&D and Demonstration Projects:** \$2.5 billion to support DOE RD&D activities, including biomass technologies (\$800 million)
- **Renewable Energy Loan Guarantee Program:** \$6 billion to support loan guarantees for renewable energy projects. Up to \$500 million of this amount is allocated to innovative biofuels technologies that are capable of deployment on a commercial scale. Must begin construction by September 30, 2011.
- **Tax credits:**
  - Extends the Production Tax Credit for biomass and other renewable energy facilities through 2013
  - Extends the Investment Tax Credit, allowing owners of biomass and other renewable technology projects that are eligible for the PTC to use the full 30% ITC previously available only to solar facilities
  - Allows renewable energy project developers to apply for a Treasury Dept. grant equal to 30% of the cost of an eligible project if construction starts in 2009 or 2010 (in lieu of ITC)



## Expediting Commercialization

### Commercial-Scale Biorefineries (up to \$272 M)

- Four cost-shared, integrated biorefinery demonstrations to produce 98 million gallons of cellulosic ethanol in 5 years with variety of conversion technologies and cellulosic feedstocks



### 10%-Scale Biorefinery Validation (up to \$240 M)

- Cost-shared, integrated biorefinery demonstrations using cellulosic feedstocks to produce renewable fuels at one-tenth of commercial scale
- Eight projects now in progress

# Commercial-Scale Biorefinery Demonstrations



DOE investments in cellulosic biofuels will accelerate commercialization and help create a biofuels market based on non-food feedstocks.

Performers	Feedstock Type	Conversion Technology	Status of Project
<b>Abengoa</b>	Agricultural Residue	Biochemical	Phase 1-Cooperative Agreement signed Sept. 2007
<b>Bluefire</b>	MSW	Biochemical	Phase 1-Cooperative Agreement signed Sept. 2007.
<b>Poet</b>	Corn cobs Corn Fiber	Biochemical	Phase 2-Technology Investment Agreement – Signed Oct. 2008
<b>Range Fuels</b>	Woody Waste	Gasification + Mixed Alcohol synthesis	Phase 2-Technology Investment Agreement – Signed Nov. 2007 Ground Breaking Nov. 2007

# Small-Scale (10% of Commercial Scale) Biorefinery Demonstrations



Performers	Feedstock Type	Conversion Technology
Alltech Envirofine, LLC	Wood Residue	Biochemical
Flambeau River	Wood Residue	Thermochemical
Lignol Innovations	Wood Residue	Biochem-organosolv
NewPage Corporation	Wood Waste	Thermochemical
Mascoma	Switchgrass & hardwoods	Biochemical
Pacific Ethanol	Agricultural & Forest Residue	Biochemical
RSE Pulp & Chemical	Wood chips (mixed hardwood)	Biochemical
Verenium Biofuels	Bagasse, Agricultural & Wood Residue	Biochemical



# Solicitation Selections Announced Since September 2008



## University R&D for up to \$4.4M (\$5.7M w/ cost share)

- **Montana State University** - Evaluate algae cultures and identify populations that naturally have higher rates of oil production
- **University of Georgia** - Develop processes for harvesting algae and processing into biofuels and bioproducts
- **University of Maine** - Model conversion and fermentation pathways for pre-pulping extracts and seaweed sludge
- **Georgia Tech Research Corporation** - Evaluate and model the reaction kinetics in two experimental gasifiers using forest residue
- **University of Toledo** – Simultaneously convert cellulose to sugar and ferment 5 and 6 carbon sugars to ethanol with native yeasts
- **Steven's Institute of Technology** - Evaluate and demonstrate a novel microchannel reactor to reform pyrolysis oil to synthesis gas



## Pyrolysis Oil R&D for up to \$7M (\$8.75M w/ cost share)

- **Virginia Polytechnic Institute & State University** – Perform catalytic hydrodeoxygenation (HDO) and upgrading together with pyrolysis in a single fluidized bed reactor
- **Iowa State University** - Improve biomass pretreatment, bio-oil filtering fractionating recovery, and catalytic post-treatment
- **RTI International** - Develop highly active and stable catalysts for the stabilization of bio-oil
- **University of Massachusetts** - Produce a stable bio-oil that has low char content and a neutral pH using a combination of membrane and catalytic technologies
- **UOP LLC** - Develop and demonstrate at pilot scale an efficient, economical system for pyrolysis oil stabilization



# Loan Guarantees



## FY2007

- 143 pre-applications received
- Funds authorized February 2007
- 16 full applications requested
  - 6 for biomass
    - 2 submitted full applications
  - Others in fossil, industrial, solar, hydrogen, alternative fuel vehicles, electricity delivery, and reliability



## FY2008

- Announced solicitation for \$30.5B on June 30, 2008
  - \$10B for renewable energy and electricity transmission
    - Applications due February 26, 2009

## ARRA

- Permits guarantees for leading-edge, pilot- or demonstration-scale biofuel projects for technologies that will substantially reduce GHGs and commence construction prior to 9/30/11

# Successive Generations of Biofuels



## Corn Ethanol

- Commercially available (no DOE research)
- Reduced GHG emissions
- Capacity constrained



## Cellulosic Ethanol

- Focus of current DOE research
- Potential to lower GHG emissions 86%
- Uses biomass from waste and non-agricultural land



## Advanced Cellulosic Biofuels

- Focus of planned DOE research
- Could minimize environmental footprint
- Energy content, fuel economy, and chemistry may be more similar to petroleum-based fuels

# Biomass Program Mission



Develop and transform our renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts, and biopower.

Focus on targeted research, development, and demonstration

- Support through public and private partnerships
- Deploy in integrated biorefineries

