DOE Office of Biological and Environmental Research Update

Briefing for Biomass R&D Technical Advisory Committee

June 2, 2009

John C. Houghton, PhD
Biological & Environmental Research
Office of Science

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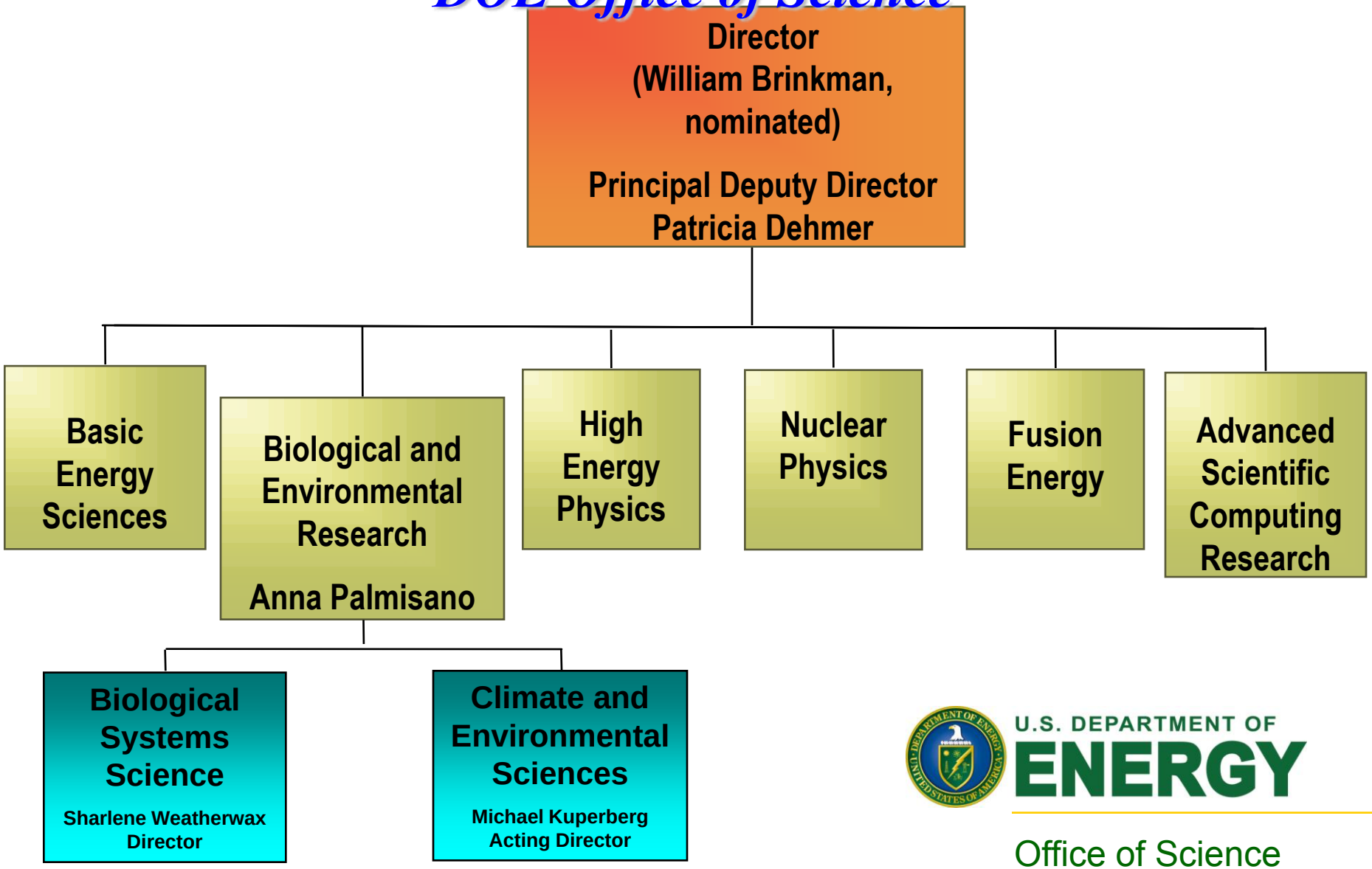

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FY 2010 Budget Request to Congress

(dollars in thousands)

	FY 2008 Current Approp.	FY 2009 Base Approp.	FY 2009 Recovery Act	FY 2010 Request	FY 2010 vs. FY 2009 Base Approp.	
Office of Science						
Basic Energy Sciences	1,252,756	1,571,972	+555,406	1,685,500	+113,528	+7.2%
Advanced Scientific Computing Research	341,774	368,820	+157,110	409,000	+40,180	+10.9%
Biological and Environmental Research	531,063	601,540	+165,653	604,182	+2,642	+0.4%
High Energy Physics	702,845	795,726	+232,390	819,000	+23,274	+2.9%
Nuclear Physics	423,671	512,080	+154,800	552,000	+39,920	+7.8%
Fusion Energy Sciences	294,933	402,550	+91,023	421,000	+18,450	+4.6%
Science Laboratories Infrastructure	66,861	145,380	+198,114	133,600	-11,780	-8.1%
Science Program Direction	177,779	186,695	+1,600	213,722	+27,027	+14.5%
Workforce Development for Teachers and Scientists	8,044	13,583	+12,500	20,678	+7,095	+52.2%
Safeguards and Security	75,946	80,603	——	83,000	+2,397	+3.0%
SBIR/STTR (SC funding)	92,997	——	+19,004	——	——	——
Subtotal, Office of Science	**3,968,669**	**4,678,949**	**+1,587,600**	**4,941,682**	**+262,733**	**+5.6%**
Congressionally-directed projects	120,161	93,687	——	——	-93,687	-100.0%
SBIR/STTR (Other DOE funding)	47,241	——	——	——	——	——
Coralville, Iowa project rescission	-44,569	——	——	——	——	——
Unallocated Recovery Act funding	——	——	+12,400	——	——	——
Less security charge for reimbursable work	-5,605	——	——	——	——	——
Use of prior year balances	-3,014	-15,000	——	——	+15,000	+100.0%
Other adjustments*	-53,188	-15,000	+12,400	——	+15,000	+100.0%
Total, Office of Science	**4,082,883**	**4,757,636**	**+1,600,000**	**4,941,682**	**+184,046**	**+3.9%**
Advanced Research Projects Agency-Energy (ARPA-E)	——	15,000	——	——	-15,000	-100.0%
Total, Science Appropriation	4,082,883	4,772,636	+1,600,000	4,941,682	+169,046	+3.5%

* Other adjustments includes a rescission of a prior year Congressionally-directed project (-$44,569,000 in FY 2008), an offset for Safeguards and Security costs charged to reimbursable customers (-$5,605,000 in FY 2008), use of prior year balances (-$3,014,000 in FY 2008 and -$15,000,000 in FY 2009), and $12,400,000 of currently unallocated Recovery Act funding.

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Office of Biological & Environmental Research

Biological Systems Science Division

- Genomics: GTL
- Bioenergy Research Centers
- Joint Genome Institute
- Low Dose Radiation
- Radiochemistry, Imaging & Instrumentation
- Structural Biology

Climate & Environmental Sciences Division

- Climate Change Research
- ARM Climate Research Facility
- Environmental Remediation Science Program
- Environmental Molecular Sciences Lab

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BSSD—FY2010 Budget request (in millions)

	FY 2008	*FY 2009*	*FY 2010*
Genomic Science	164	169	165
Radiological Sciences	46	50	46
Ethical, Legal, and Societal Issues	5	5	5
Medical Applications	8	8	8
Biological Systems Facilities and Infrastructure	80	80	84
SBIR/STTR		8	8
Total, Biological Systems Science	**303**	**322**	**318**

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Genomic Science

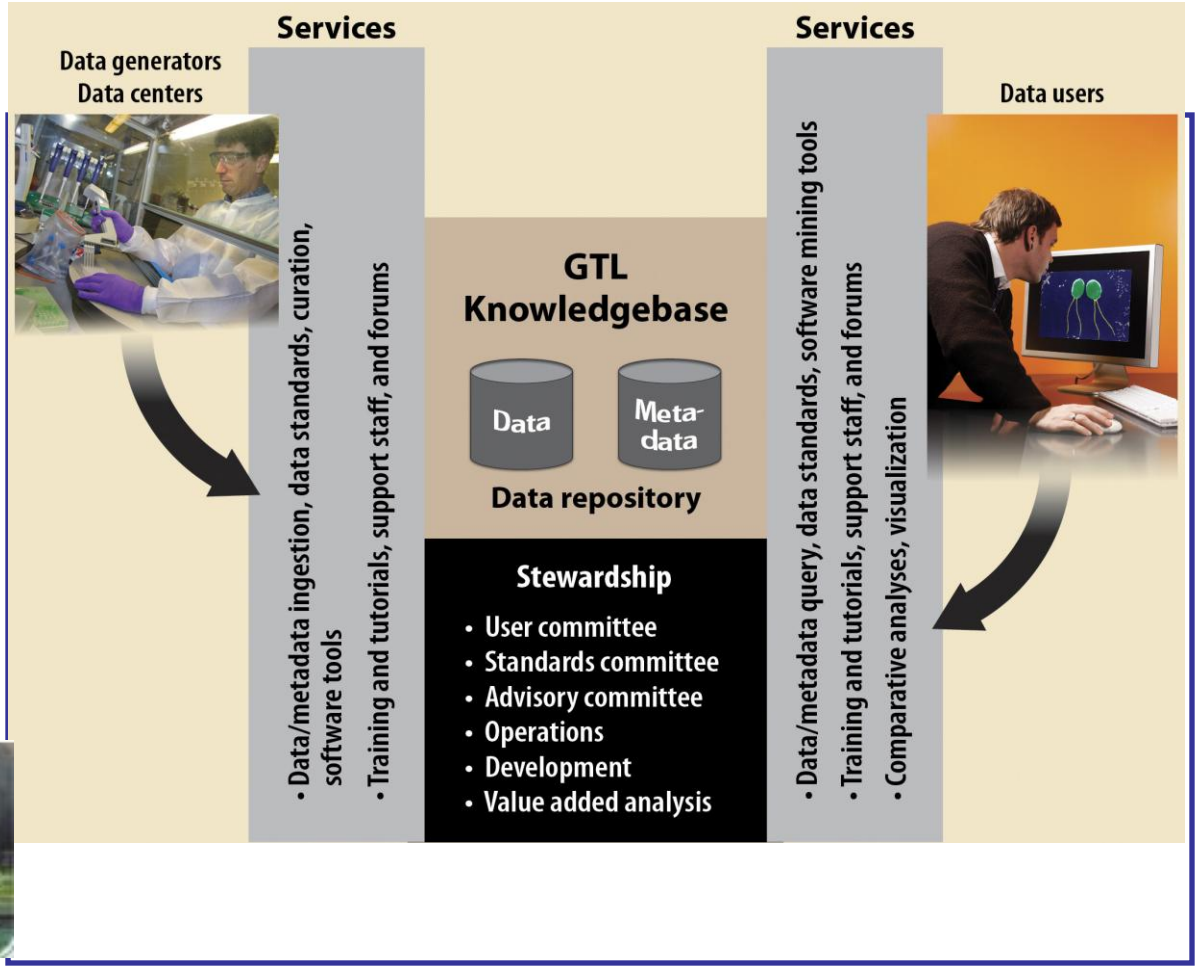
(dollars in millions)

Genomic Science	***2008***	***2009***	***2010***
Foundational Genomics Research (E.g. "Bring environmental organisms to model organism status")	33	38	33
Genomics Analysis and Validation (E.g. "Proteogenomics" for environmental samples)	11	10	10
Metabolic Synthesis and Conversion (E.g. Plant Genomics, Biohydrogen)	41	42	39
Computational Biology (E.g. cellulase simulation, metabolic modeling, KBase)	4	4	8
Bioenergy Research Centers	75	75	75
Total	**164**	**170**	**166**
Joint Genome Institute	65	65	69

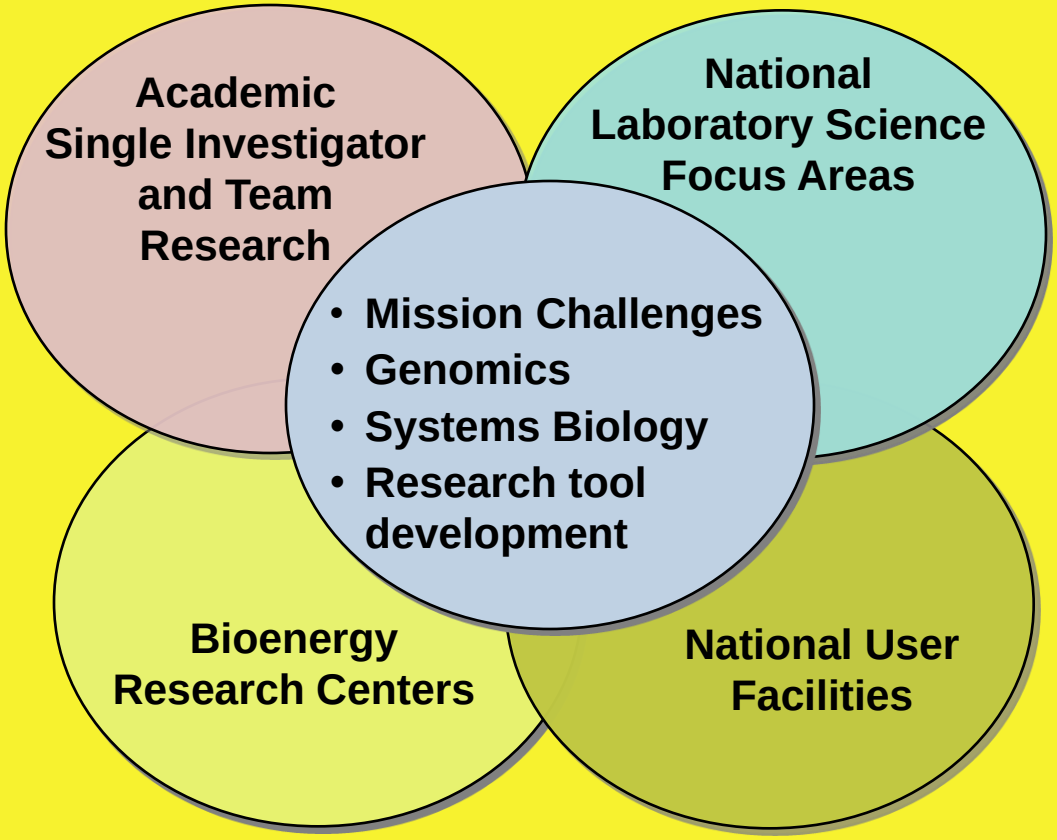
BSSD Priority Areas for FY2010

+$3.8M
Systems biology knowledgebase:
an integrated experimental framework
for accessing comparing, analyzing, modeling, and testing systems biology data.

+$4.0M
Joint Genome Institute:
Metagenomics, plant-microbe rhizosphere



The BSSD Research Enterprise



Other Federal agencies, industry, international research community

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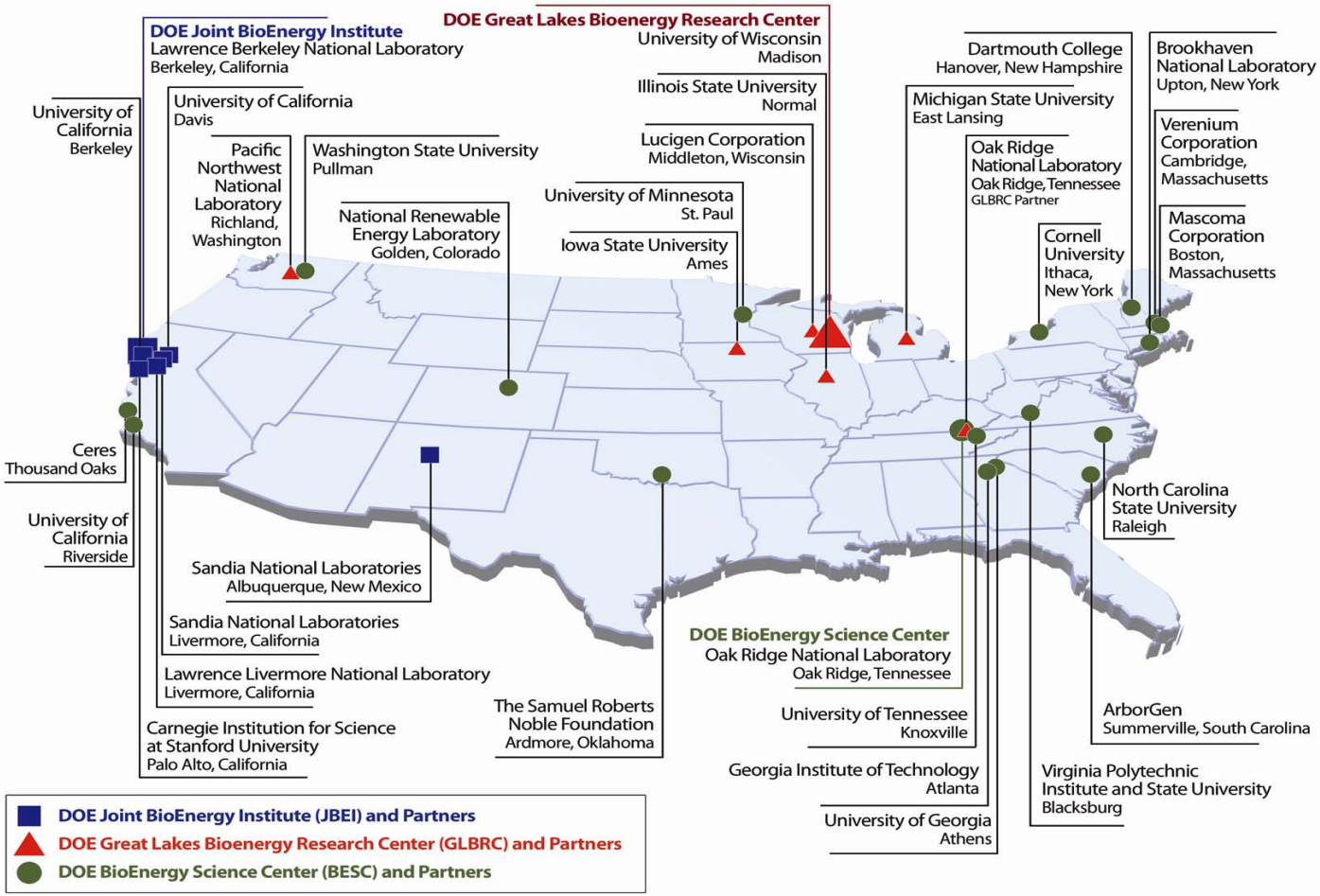
DOE Bioenergy Research Centers

- The **DOE Bioenergy Research Centers** continue pursuit of breakthroughs needed to make cellulosic biofuels cost-effective, with new developments on pretreatment, plant oils, and microbial deconstruction and conversion of biomass **(with 95 peer-reviewed publications, 23 patent filings, and 5 patent disclosures to date)**
- Full operations in FY 2009--$25M each BRC
- Planning underway for second year on-site progress reviews

DOE Bioenergy Research Centers: Multi-Institutional Partnerships

DOE Bioenergy Research Centers



The BESC Team

Joint Institute for Biological Sciences (JIBS)

Alternative Fuels User Facility

Complex Carbohydrate Research Center (CCRC)

- Oak Ridge National Laboratory
- University of Georgia
- University of Tennessee
- National Renewable Energy Laboratory
- Georgia Institute of Technology
- Samuel Roberts Noble Foundation
- Dartmouth College
- ArborGen, LLC
- Verenium Corporation
- Mascoma Corporation
- Individuals from University of California-Riverside, Cornell University, Washington State University, University of Minnesota, North Carolina State University, Brookhaven National Laboratory, Virginia Polytechnic Institute

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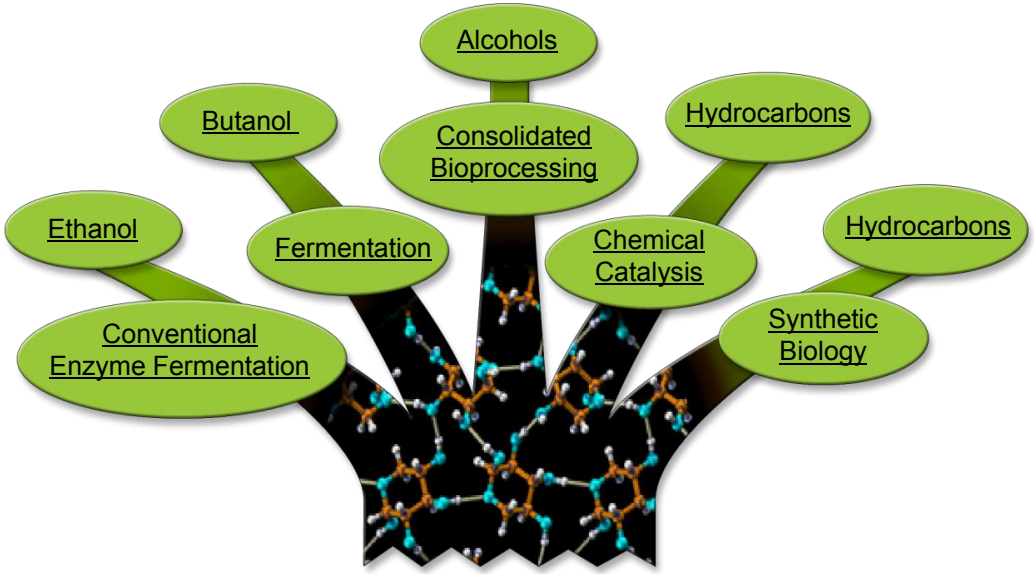
Access to the Sugars in Lignocellulosic Biomass is the Current Critical Barrier



Recalcitrance

- Solving this will cut processing costs significantly and be used in most conversion processes
- This requires an integrated multidisciplinary approach
- Timeframe
  - Modified plants to field trials: Year 5
  - New or improved microbes to development: Years 4−5
  - Analysis and screening technologies: Year 3 on

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High Throughput Feedstock Characterization Pipeline

Objectives

•Rapid identification of feedstock features that determine the ease of their conversion to fermentable sugars by microbes

•Detection of these chemical, structural, and genetic features will provide targets for further analysis and new paths towards the development of improved biomass varieties.

Approach

•In their first year of funding, the BESC has developed a high throughput pipeline to characterize the recalcitrance of feedstock material.

•Other linked systems include a detailed follow-up feedstock characterization pipeline, a multi-sample HTP pretreatment pipeline, and a plant transformation screening pipeline. This information is integrated into a LIMS (Laboratory Information Management System).

Impact and Results

•Analysis of a thousand poplar tree (Populus) samples has led to the new knowledge of links between genes and genetic markers that will help develop feedstocks with less recalcitrance.

•The analysis of the samples also confirmed the power of rapid analytical pyrolysis as a compositional screen with a rate of more than 30 samples/hour.

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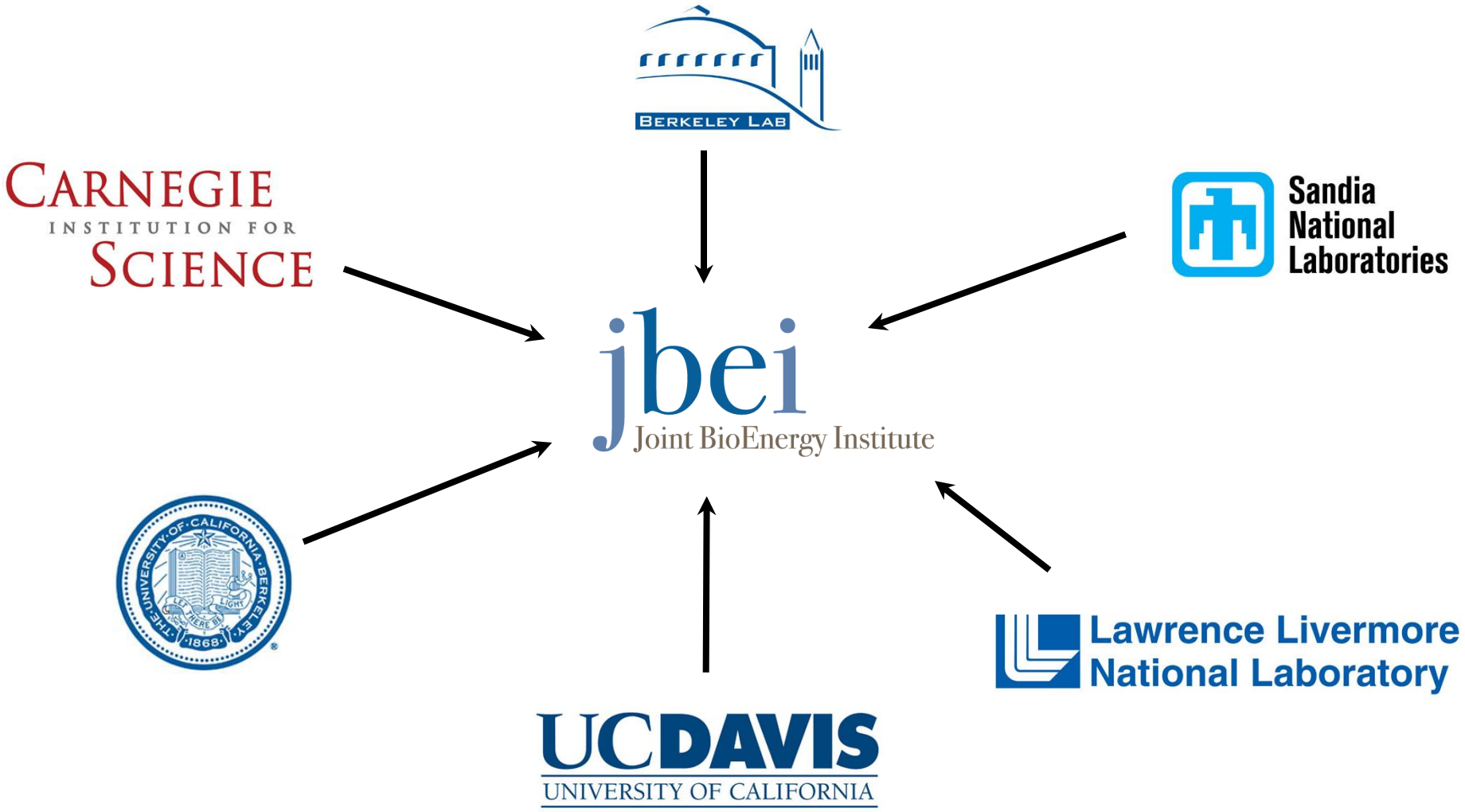
Partners at a single location



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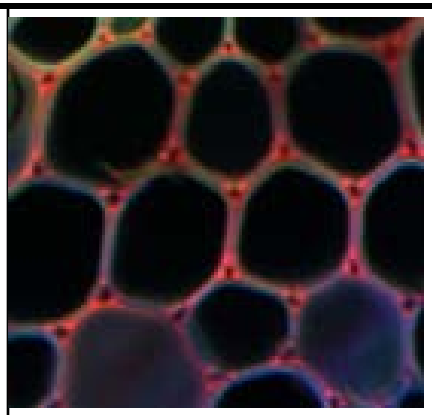
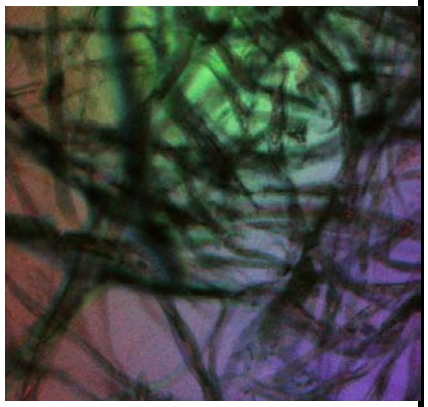
Ionic Liquids as a New Option for Lignocellulosic Conversion

Objectives

•Investigate ionic liquids (room temperature molten salts) to reduce costs of pretreatment.

•Rapidly dissolve lignocellulosic material as well as reduce toxic byproducts that increase the cost of downstream processes.





Before/After Ionic liquid pre-treatment of switchgrass

Approach

•Ionic liquids free cellulose and hemicellulose from lignin in a short period of time at mild temperatures; as well as substantially de-crystallize the cellulose.

•Adding an anti-solvent instantly rejects the dissolved cellulosic material, which provides optimism for efficient solvent recovery in addition to other desired attributes, such as low volatility, non-flammability and thermal stability.

Impact and Results

•The resulting cellulose can be enzymatically converted to sugars with high yields in 2-12 hours depending on the type of biomass used and reaction conditions, compared with over 60-90 hours with material pretreated by more conventional routes (for example, acid or base treatment).

Great Lakes Bioenergy Research Center

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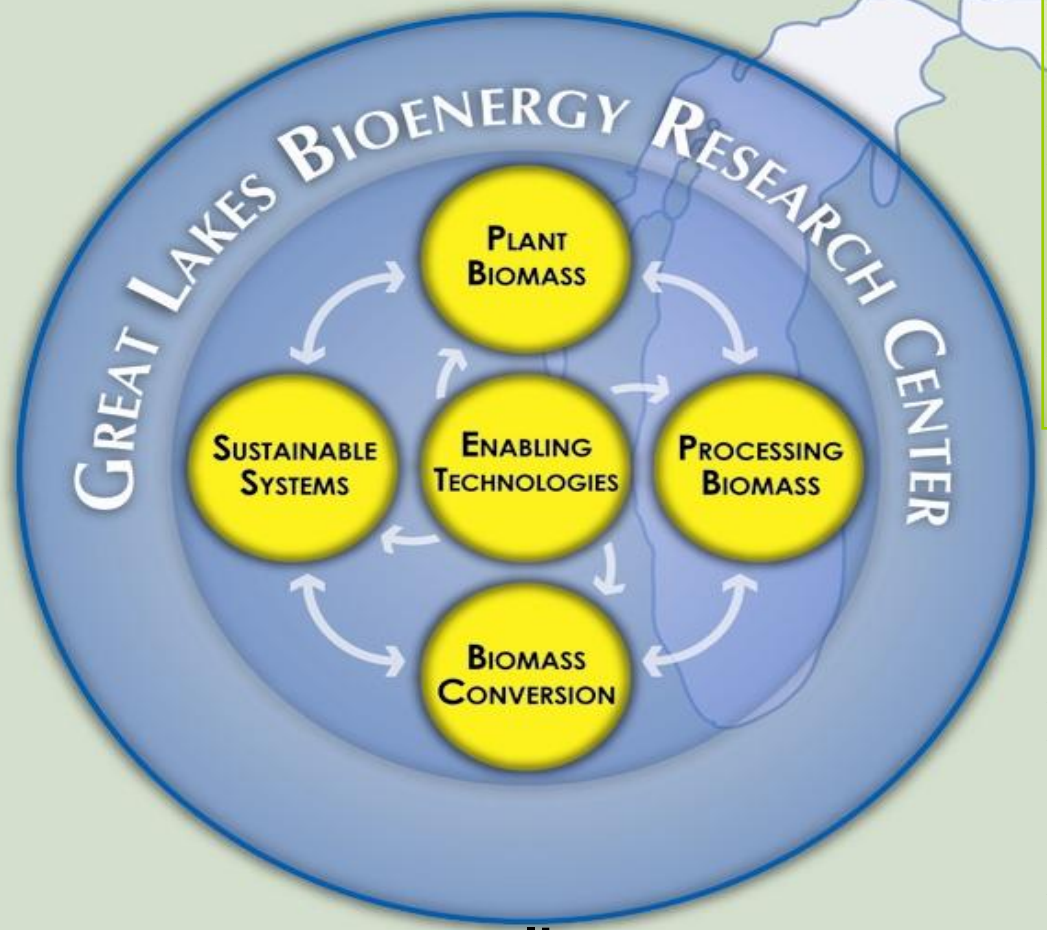

Integrated programs

- Improve plant biomass
- Improve biomass processing
- Improve conversion of biomass to energy products
- Improve sustainability of biofuels pipeline
- Cutting-edge enabling technologies
- Information, informatics & modeling systems
- Education & Outreach

www.glbrc.org

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Leaf-Cutter Ants Analyzed for Novel Deconstruction: Microbes and Enzymes

Objectives

•Mine evolution for sources of novel enzymes and microbes both as candidates for biorefineries and for insight into biochemical options for deconstruction

•Use decomposition of leaves in “fungus gardens and dumps” to complement other gene prospecting samples in insect guts that have undergone fine scale grinding (mastication)

Bert Hölldobler

Approach

•Set up operating Leaf Cutter Ant colonies in GLBRC

•Culture gardens and dumps for cellulytic microbes

•Use 16S and 18S for diversity profiles

•Use enzymatic screens for activity

•Sequence metagenomic samples from gardens and dumps

Impact and Results

•16S profiles show groups dominated by enterics, different from cow or termite guts (composting material selects for fast growers?)

•Dominant fungus doesn’t degrade cellulose (captures sugars from bacteria?)

•Hundreds of good cellulose degraders isolated

•DNA nearly prepared for metagenomic sequencing

Sustainable Bioenergy Practices

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Objective: develop **economically viable & environmentally responsive ecological, agricultural & life cycle practices**

High Input, Low Diversity (annuals) ⟷ **Low Input, High Diversity (perennials)**

Continuous Corn
Corn-Soybean-Canola

Monoculture switchgrass
Switchgrass/ Legumes

Poplars

Early successional Native prairie

Overcome bottlenecks in agricultural, industrial, & behavioral systems to

- **Improve carbon neutrality** and **greenhouse gas mitigation** across the entire biofuel life cycle at multiple scales
- Improve **ecosystem services** in biofuel landscapes (e.g. **water, soil & air quality, biodiversity, pest suppression, land use**)

www.glbrc.org

GLBRC
Great Lakes Bioenergy Research Center

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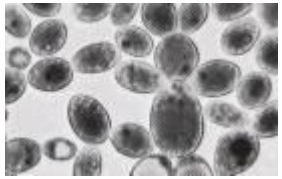
Joint Genome Institute and Bioenergy



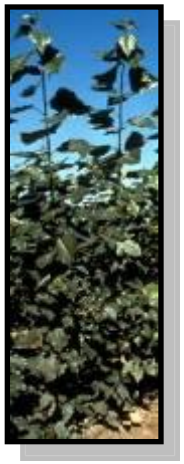
- *Saccharomyces cerevisiae*
- *Zymomonas mobilis*
- *Thermoanaerobacter ethanolicus*
- *Pichia stipitis*

Ethanol producing organisms

Improved Feedstocks

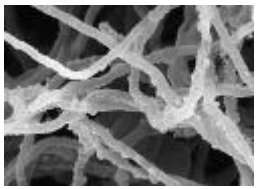
Cellulosic Materials
- Poplar
- Maize/Corn Stover
- Switchgrass
- Brachypodium
- Sorghum

Saccharification → **Sugars** → Fermentation



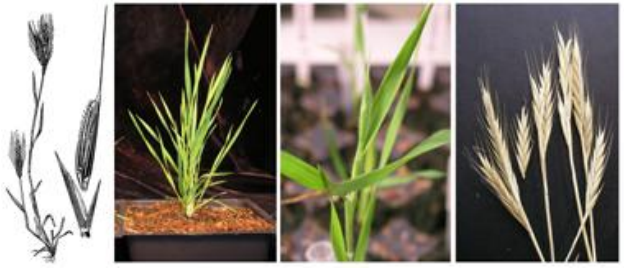
Improved cellulose & lignin degradation

- Termite hindgut microbiota
- White Rot Fungus
- *Clostridium thermocellum*
- *Saccharophagus degradans*
- *Acidothermus cellulolyticus*



DOE Joint Genome Institute
Recent Biomass Highlights

- **Soybean genome**
  - **Major biodiesel crop**
  - **13 million shotgun reads representing >7 fold genome coverage**
  - **Interagency development of genomic resources**
- ***Sorghum bicolor* genome**
  - **2nd grass genome**
  - **730 Mb**
  - **Drought resistant biofuels crop**
  - **January 29, 2009 edition of Nature**
- ***Brachypodium distachyon* genome**
  - **Model organism for wheat, switchgrass**
  - **300 Mb**
  - **8X genome sequence just completed**
  - **Publication in preparation**



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BSSD—Recent Workshops

- Carbon Cycling and Biosequestration (March 2008)
- Systems Biology Knowledgebase for a New Era in Biology (May 2008)
- Sustainability of Biofuels (October 2008)
- New Frontiers of Science in Radiochemistry and Instrumentation for Radionuclide Imaging (November 2008)
- New Frontiers in Characterizing Biological Systems Workshop (May 2009)

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Thank you!

John Houghton

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http://www.science.doe.gov/obp/FY_10_Budget/BER.pdf