NREL/BK-570-30425

Presentations

for the

DOE National Bioenergy Center

Strategic Partnerships Workshop

April 11 - 12, 2001
Colorado

DOE National Bioenergy Center
Strategic Partnerships Workshop

April 11 – 12, 2001
Sheraton Denver West
Lakewood, Colorado

PRESENTATIONS

NREL
National Renewable Energy Laboratory

Overview of the DOE National Bioenergy Center

Stanley R. Bull
National Renewable Energy Laboratory

Strategic Partnerships Workshop
April 11, 2001

Operated for the U.S. Department of Energy by Midwest Research Institute • Battelle • Bechtel

NREL

A Strategy

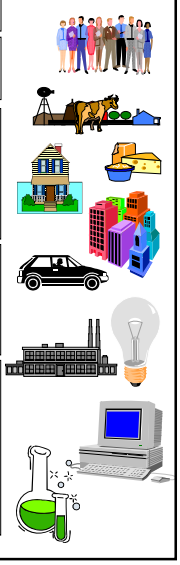
Two principal thrusts form a strategy for realizing the opportunity

- Multiproduct focus from residues and traditional biomass
- Designed biomass

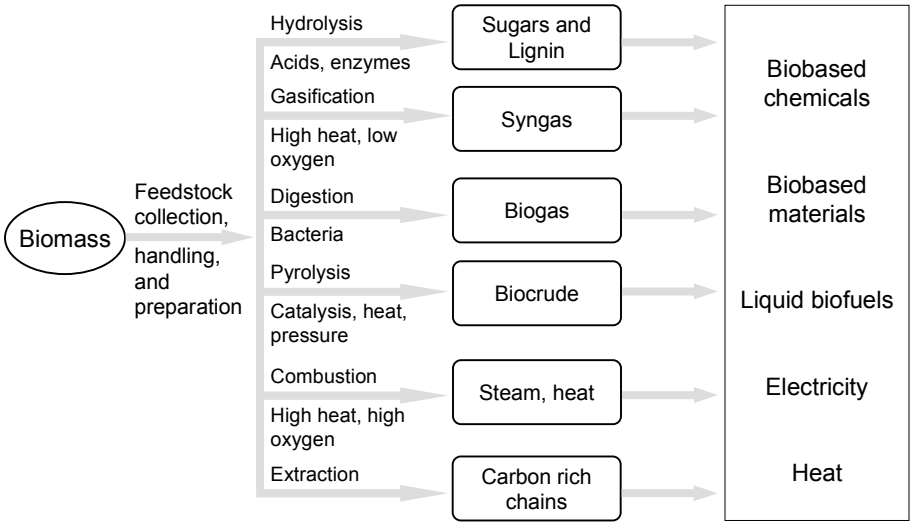
Both thrusts consider the whole life cycle approach to realizing the strategy

Multiple Factors in Biomass Use

Land	Feedstocks	Technologies	Output
Current cropland	**Grains & Feed** Seed Stalks/leaves	**Planting, Harvesting, Management**	**Food/Feed**
Forest land	**Trees** Hardwoods Softwoods Short rotation Trimmings	**Materials Handling**	**Fiber/Pulp** **Solid Wood Products**
Rangeland and Pastures	**Grasses** Switchgrass Sugar cane Bagasse Stalks	**Chemical/Thermal/ Mechanical** Gasification Combustion Pulping Grinding, cutting, sawing Spinning	**Chemicals/ Materials** Polymers Fertilizer Pesticides Textiles
Fallow land CRP	**Fiber Crops** Cotton Sisal	**Energy Conversion Systems** Advanced Turbines Fuel Cells	**Power** Electricity Heat Combined Heat/ Power
Marginal land	**Row Crops**	**Biological** Fermentation Enzymes Composting Digestion	**Fuels** Ethanol Methanol Biodiesel Biogas Hydrogen Synthesis gas Hydrocarbons
	Post-consumer Waste	**Manufacturing**	
	Construction Demolition Wood		
	Animal Residues		



Bioenergy Pathways



Elements of the Integrated Systems Role

- Research
- Development
- Demonstration
- Technical Assistance
- Strategic and Multiyear Planning
- Resource and Environmental Evaluation
- Process and Life Cycle Analysis
- Models, Data, and Information

The National Bioenergy Center

Background on DOE/EE National Centers

- National Wind Technology Center - 1994 (NREL and SNL)
- National Center for Photovoltaics - 1996 (NREL and SNL with other labs)
- National Bioenergy Center - 2000 (NREL and ORNL with other partners)

NREL and ORNL have a history of successful informal partnerships

- Biofuels Program
- Biomass Power Program
- Biotechnology Symposium
- Alternative Feedstocks
- 11-Lab Study
- Phytocarbon research

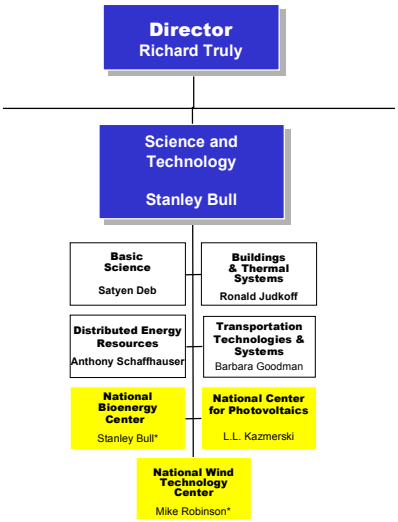
National Bioenergy Center mission supports the development of a viable bioenergy industry

The National Bioenergy Center fosters capability building in renewable biobased fuels, chemicals, industrial products, and power to catalyze the creation of new industries and will support technical improvements in efficient and economical use of biomass in agriculture- and forest-based industries.

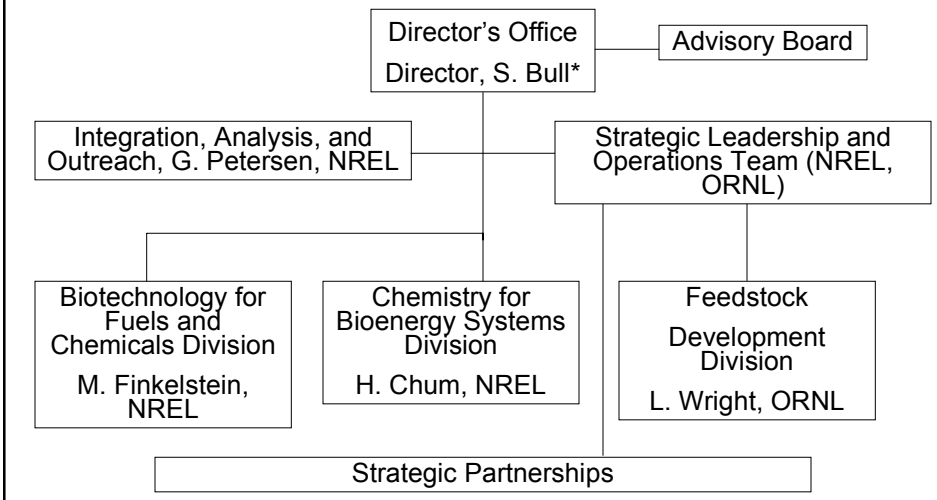
The benefits of a National Bioenergy Center

1. Support existing sector programs
2. Support the Biomass R&D Initiative
3. Strategic and multi-year integrated planning to assure optimum use of Laboratory, university and industry resources.
4. Provide process and life cycle analyses
5. Center for models, data, and information
6. Provide technical assistance to industry and others
7. Leverage DOE's biomass resources with life and plant science capabilities of DOE and other agencies.

National Renewable Energy Laboratory

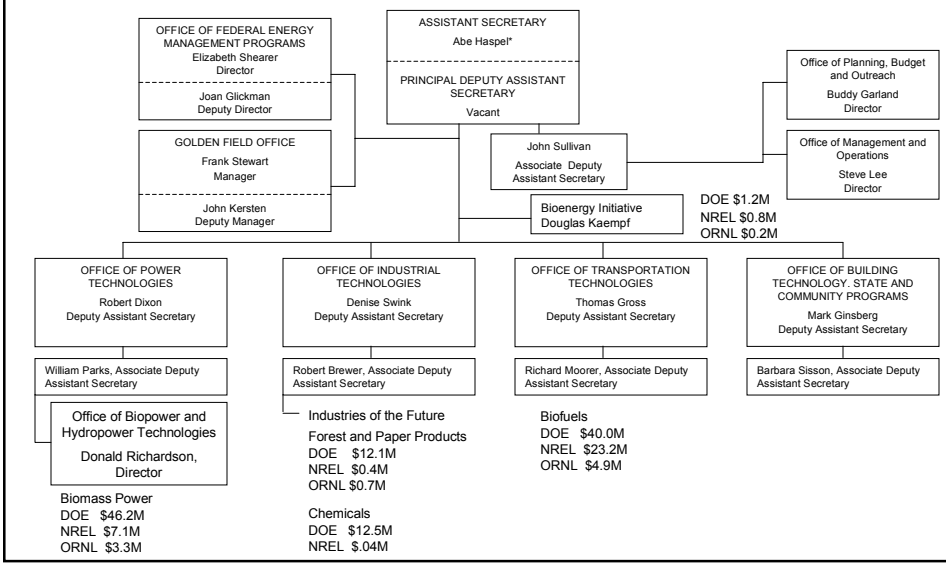


National Bioenergy Center



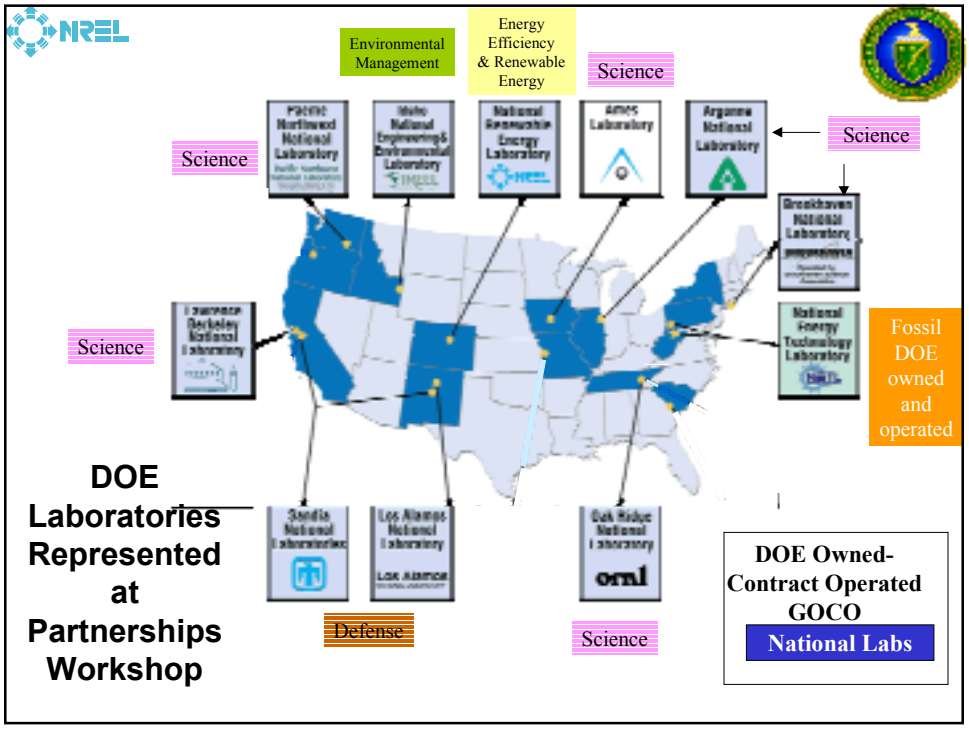
*Acting

Office of Energy Efficiency and Renewable Energy
Bioenergy and Biobased Products ($M, FY 2001)

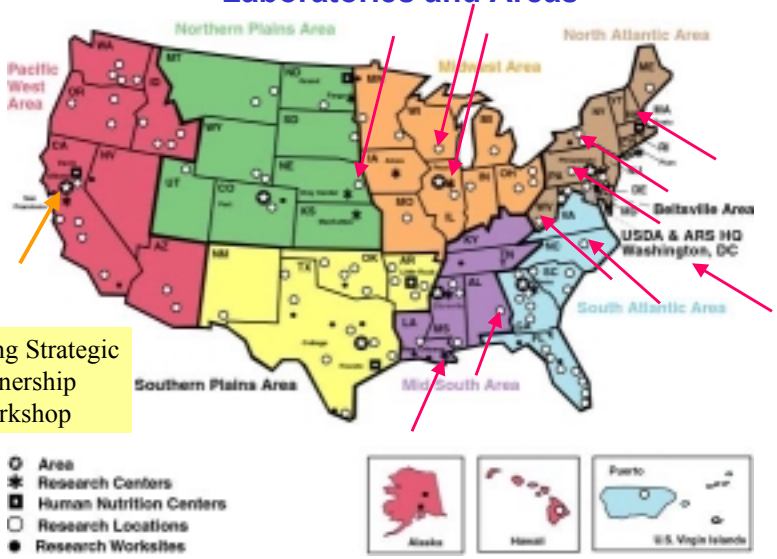


NREL Bioenergy Research and Development Tour Topics

- Plant/Crop Genomics Characterization
- Biomass Characterization
- Biorefinery Concepts
- Molecular Beam Mass Spectrometry
- Thermochemical Users Facility
- Strain Development/Genetic Engineering
- Enzyme Technology and Genomics/Robotics
- Process Development Unit



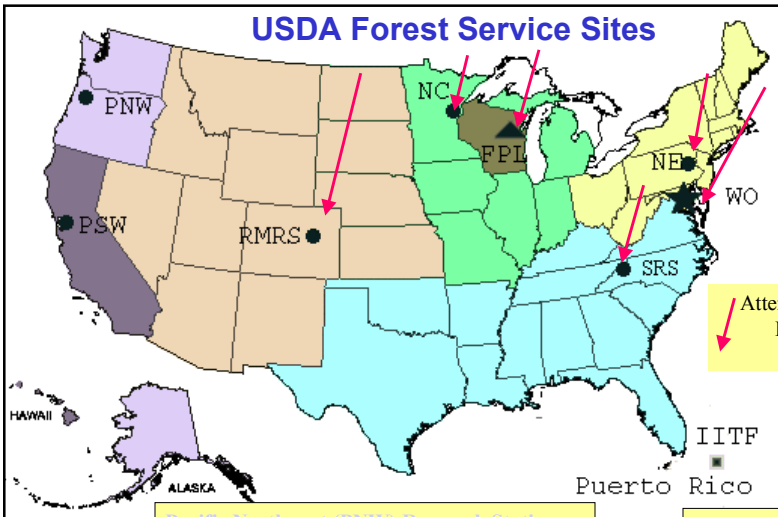
USDA Agricultural Research Services Laboratories and Areas



Attending Strategic Partnership Workshop

http://www.nps.ars.usda.gov/map.htm

USDA Forest Service Sites



Attending Strategic Partnership Meeting

Pacific Northwest (PNW) Research Station,
Pacific Southwest (PSW) Research Station
Rocky Mountain Research (RMRS) Station,
North Central (NC) Research Station
Forest Products Laboratory (FPL),
Northeastern (NE) Research Station,
Southern Research Station, (SRS)

International Institute of Tropical Forestry (IITF)
Washington Office (WO) Headquarters

http://www.fs.fed.us/research/corporate


USDA's 1938 Four Mandated
ARS Regional Research Centers
ERRC, NCAUR (NRRC),
SRRC, WRRC
John P. Cherry
Eastern Regional Research Center
Agricultural Research Service
U.S. Department of Agriculture
600 East Mermaid Lane
Wyndmoor, Pennsylvania 19038


Utilization Laboratories
In 1938 the Agricultural Adjustment Act provided:
"The Secretary is hereby authorized and directed to establish, equip, and maintain four regional research laboratories, one in each major farm producing area, and at such laboratories to conduct researches into and to develop new scientific, chemical and technical uses and new and extended markets and outlets for farm commodities and products and byproducts thereof…."

Regional Research Center's Overall Mission

To develop and commercialize new uses of agricultural commodities for industrial or nonfood and food products for both domestic markets and export; to improve food safety, quality and security; to develop new technologies to control agricultural pests while minimizing adverse environmental impact; and to provide technical support to Federal regulatory and action agencies.

ARS Research Locations

Regional Research Center's Historical Accomplishments

- Fermentation technologies, high yielding penicillium production
- Time-Temperature Tolerance Project helped solve problems - color, texture, flavor, for the fledgling frozen food industry
- Frozen concentrated apple and grape juice - capturing and returning volatile flavors to maintain production quality
- Instant potato flake process
- Supercritical extraction technologies

Regional Research Center's Historical Accomplishments

(continued)

- Durable press cotton textiles
- Flame-retardant cotton finishes
- Glutaraldehyde tanning agents-launderable leather
- Epoxidized ester plasticizers
- Lactose reduction in milk (Lact-aid Dairy Products)
- Fermentation processes for dextran, xanthan gum and levan
- Kenaf paper
- Oatrim

Regional Research Center's Historical Accomplishments

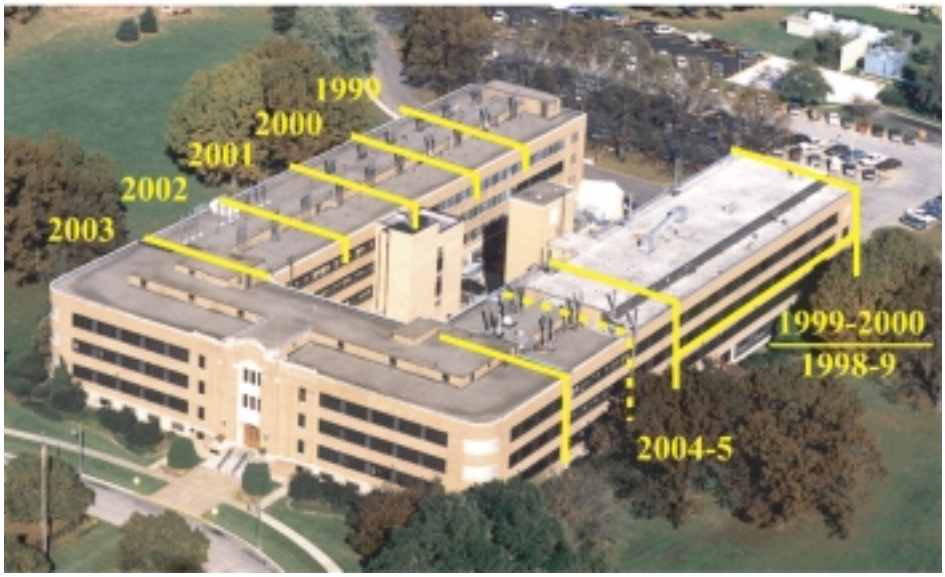
(continued)

- 1970's, identified microbes to ferment biomass and starch to ethanol
- Super slurper
- San Francisco-style sourdough bread
- and 100's more technologies we benefit from as consumers because these basic platform technologies were the basis for new or resurgent multi-million dollar industries, benefiting the farmers, and the American economy

Selected Focus of Two ARS National Programs

- New uses, quality and marketability of plant and animal products
  - Enhance economic viability and market competitiveness
  - Maintain enhanced quality
  - Environmentally friendly
  - Efficient processing concepts
  - Develop value-added food and nonfood products and processes
- Bioenergy and energy alternatives
  - Reduce dependence on foreign oil
  - Alternative energy sources
  - Improve the environment
  - Increase use of agricultural crops as feedstocks

Modernization Phases



NATIONAL CENTER FOR AGRICULTURAL UTILIZATION RESEARCH

Biomaterials Research and Development

- New technology platforms
- Market driven applications
- Fundamental to applied research
- Multidisciplinary teams
- Partnership with private sector
- 120 patents since 1980
- 41% licensed to private sector

MICROBIAL TECHNOLOGY

- ARS Microbial Collection
- 80,000 strains available
- Discovery of enzyme systems
- Genetic engineered enhancements
- Enzyme stabilization
- Process engineering

BIO-ENZYME PROCESSING

- Dextran blood extender
- Xanthan gum
  - food ingredient
  - oil well performance enhancer
- Lactic acid
- Xylitol
- Cyclodrextrins
- Alternan
- Astaxanthin pigments

EXRUSION PROCESSING

Transforming Starch, Fiber and Proteins

- Biodegradable plastics
- Foams and films
- Packaging materials
- Adhesives and glues
- Ion-exchange resins
- Micro-encapsulating

SOYBEAN OIL PRODUCTS

- Biodiesel fuels
- Fuel additives
- Industrial Lubricants
- Hydraulic fluids
- Oil drilling lubricants
- Litho news inks
- Sheet-fed & heat-set inks
- Paints and Coatings

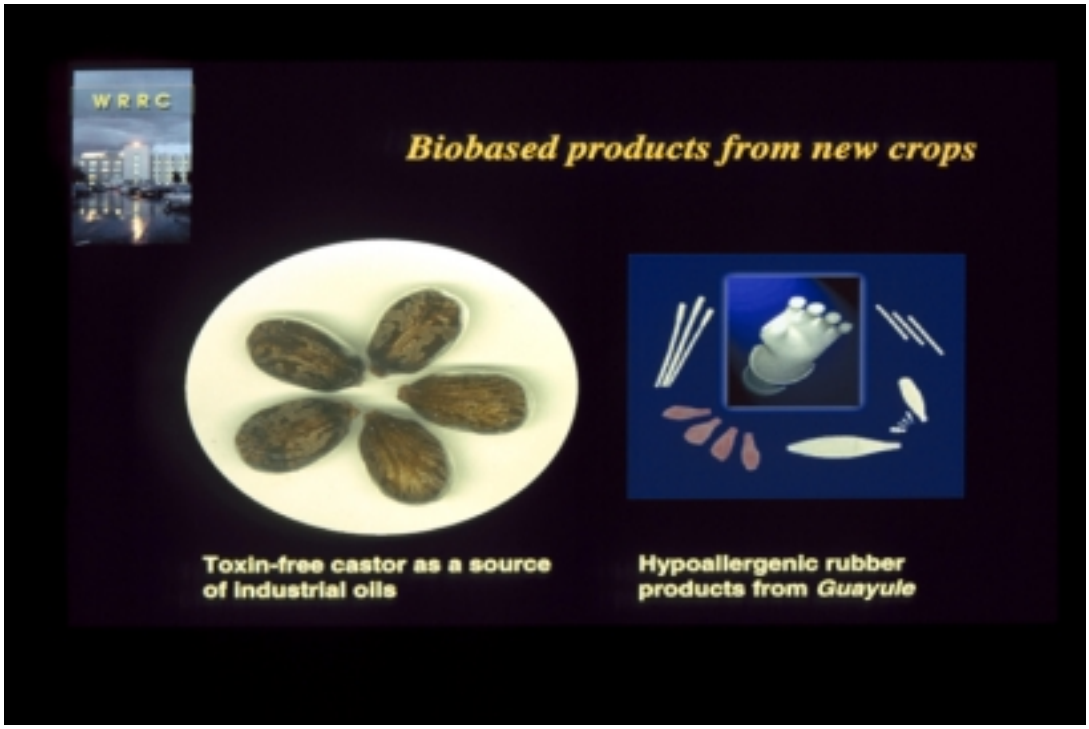
USDA

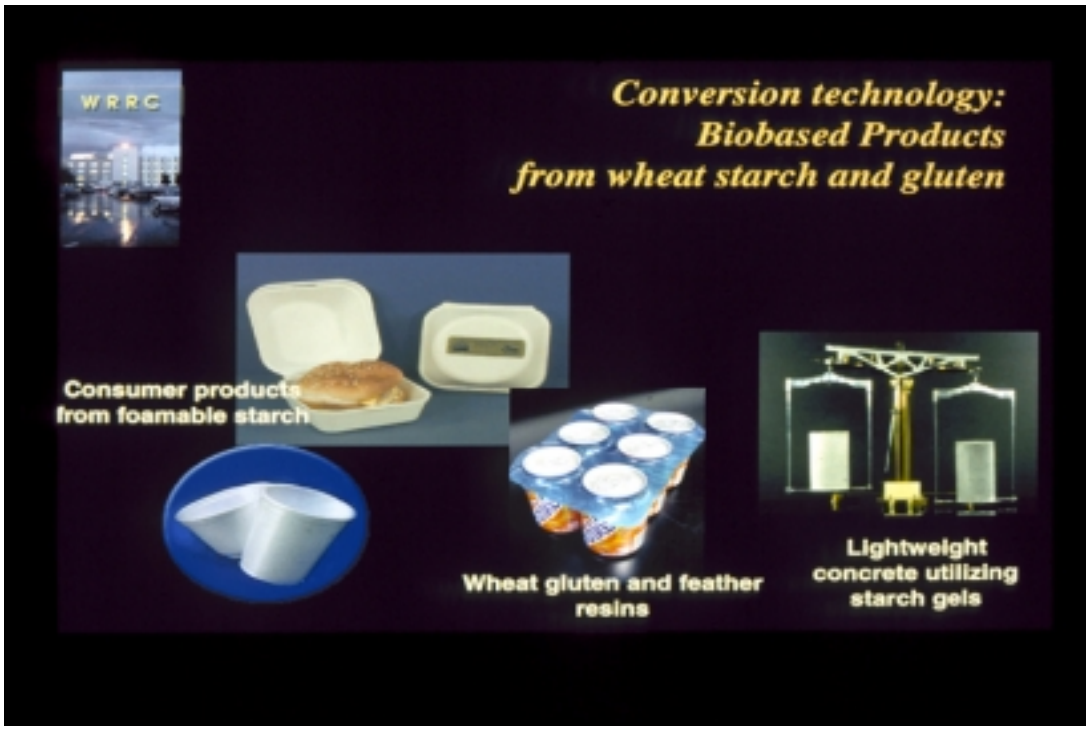
Biofuels and Biobased Products Research

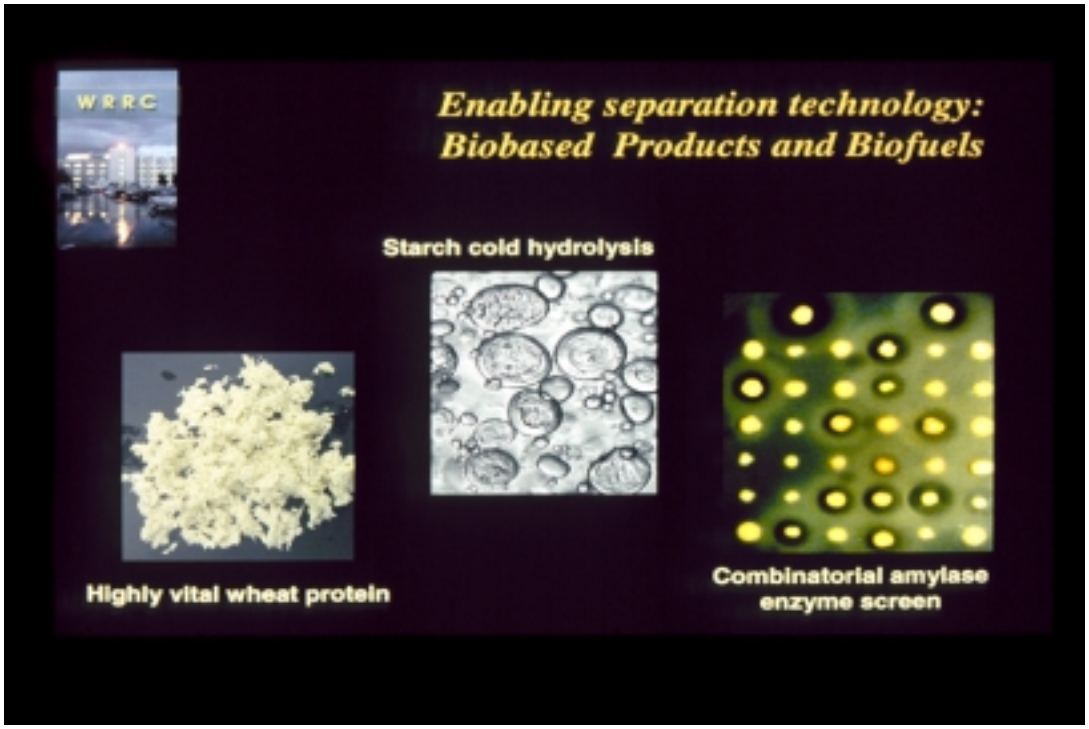
Western Regional Research Center

United States Department of Agriculture
Agricultural Research Service
Pacific West Area

Albany, CA


WRRC
Biobased products from new crops
Toxin-free castor as a source of industrial oils
Hypoallergenic rubber products from Guayule


WRRC
Conversion technology: Biobased Products from wheat starch and gluten
Consumer products from foamable starch
Wheat gluten and feather resins
Lightweight concrete utilizing starch gels


WRRC
Enabling separation technology:
Biobased Products and Biofuels
Starch cold hydrolysis
Highly vital wheat protein
Combinatorial amylase
enzyme screen


SRRC Program Emphasis
- Cotton Textile chemistry, engineering,
fiber quality and bioscience
- Food processing, sensory quality,
safety and utilization
- Sugarcane enhancement and quality
- Formosan subterranean termite control

SRRC - Examples of Biobased Research Results

- Non-food uses of sucrose - new liquid epoxies that bind wood, metal, glass, concrete, etc.
  - Base coats, primers and adhesives for composite materials like particle boarding or boat hulls
- By-products of nut shellers, grain millers, oilseed crushers, sugar refiners - convert to value-added absorbents for water treatment - drinking water and industrial wastewater
- Vegetable soybean oil - chemical and enzymatic conversion of unconjugated linoleic, linolenic acids to conjugated unsaturated fatty acids (CUFA) to form "drying oils" such as Tung oil for industrial use

ERRC Biobased Processing and Products

New, low cost "green" materials to prepare pectins and hemicelluloses from citrus and sugarbeet by-products, paint additives, coatings, adhesives

ERRC Biofuels Research

- Process efficiency
  - Continuous fermentation by CO_2 stripping
  - Continuous fermentation - pervaporation
  - Low cost separation of corn zein
- Biodiesel from alternative feedstocks
- Monitoring biodiesel quality - ASTM; alternative methods, HPLC

ERRC Ethanol Co-Products

- Corn fiber oil
- Lipase and arginine from ethanol steepwater
- Corn fiber gum
- Corn fiber hemicellulose
- Zein wax-coated paper

Interagency Cooperative Studies

USDA, ARS, ERRC and DOE, NREL

- Modeling corn to ethanol and stover to ethanol processes
- Economic factors associated with starch and cellulosic material processes
- Identify fine chemicals, phytosterols, to tocopherol, in stover and stover residues from ethanol processes
- Estimate value and production costs of co-products

Tools for Enhanced Transfer Technology

(1986 Technology Transfer Act - President Reagan)

- Cooperative Research and Development Agreement (CRADA)
- Confidentiality Agreements
- Memorandum of Understanding
- Specific Cooperative Agreements
- Trust Fund Projects

In a typical year, 400 technical/scientific papers are published, 78 patent applications are filled and an additional 36 invention disclosures are prepared by researchers at the four Regional Research Centers.


Biobased
Products
&
Biofuels

Forest Service Biomass Research & Development Programs

By
Howard N. Rosen
USDA Forest Service
Energy Coordinator

At the Strategic Partnerships Workshop, Golden, Colorado

Forest Service - Basics

- Mission—ensure for present and future generations the long-term health, diversity, and productivity of the land
- Formed 1905, Forest Transfer Act
- Manages 8½% of U.S. land mass or 192 million acres
- Over 30,000 employees,$3 billion budget, & $800 million revenues in FY 2000
- Biobased Products Research from 1910 at Forest Products Lab in Madison, WI

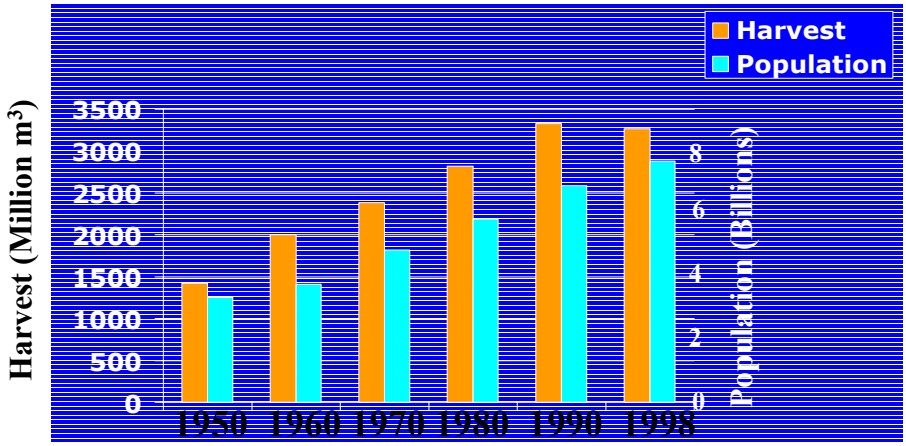
Opportunity Knocks

- Most severe fire season in 50 years
- Energy shortages (California)
- Change in political parties in the White House
- Laws encouraging the use of biobased products

Supply/Demand

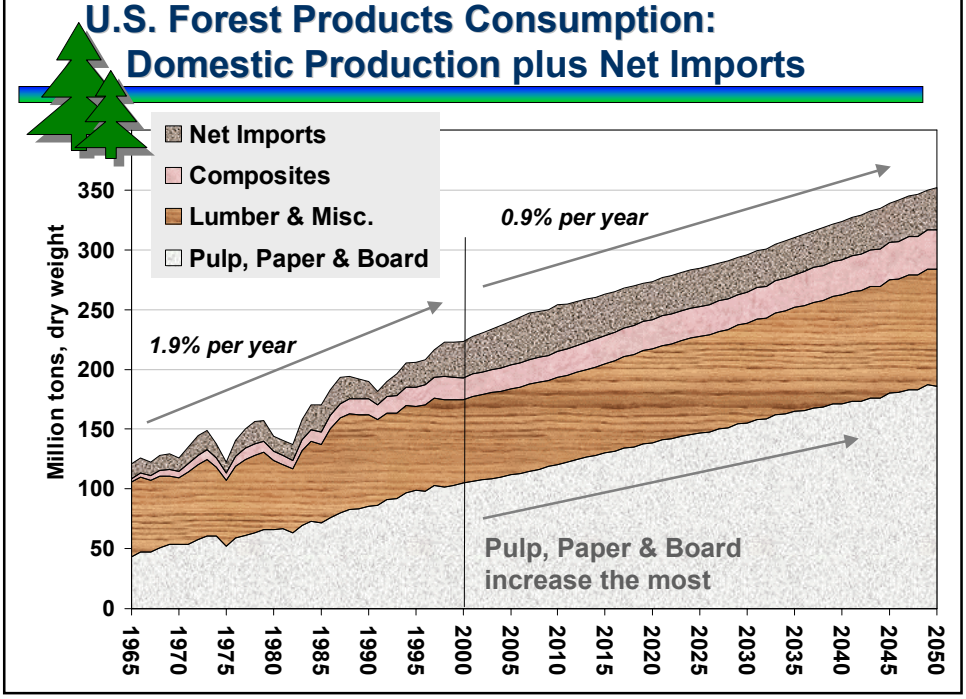
- Third country in volume of standing timber
- Timber growth still exceeds cut
- Use 25% of all energy generated in the world
- Approximately 3 quads, or 3% is biomass energy, mostly from forest biomass
- Per capita yearly consumption of wood and fiber products in U.S. (2.1 cu. met.) is 4 times world average

Global Wood Harvest and Population, 1950 to 1998



Source: FAO (2000)

U.S. Forest Products Consumption: Domestic Production plus Net Imports



Our Crowded Forests

Ross' Hole, Montana

1895

1980

Fire Problems

Seven million acres of public land burned in 2000

Funding :$1.1 billion FS
FY 2001 :$0.9 billion DOI

National Fire Plan

- Over $1 billion fighting fires in 2000
- $1.1 billion additional for Forest Service in FY 2001
  - -$20.5 million for Economic Action Programs and Pilot Projects
  - -Potential for forest biomass to energy projects

Forest Service Biobased Products and Bioenergy Basic Program

Funded at $9.5 million in FY 2001

- Growing Feedstock (short rotation)
- Removal (harvesting methods)
- Conversion (lumber, composites, chemicals, energy, pulp, paper)

Biobased Products and Bioenergy FY 2001 Funding - New

Small Diameter and Low Value Sources - $3 million

- Products and Utilization $1.2M
- Forest Management $1.3M
- Economics and Social $0.5M

Short Rotation Woody Crop

Hybrid Poplar Plantation
Potlach, Corp in Eastern, Oregon

The Future

Priority Research Areas

- New woody cropping systems
- Management, harvest, and utilization of small-diameter timbers
- Products from low value wood-based material
- Technologies for conversion of woody biomass to chemicals, fiber, and composites

Strategic Partnerships Workshop

Forest Service Labs Biobased Products and Bioenergy program

T.W. Jeffries
Lakewood, Colorado
April 11-12, 2001

The USDA, Forest Service Forest Products Laboratory

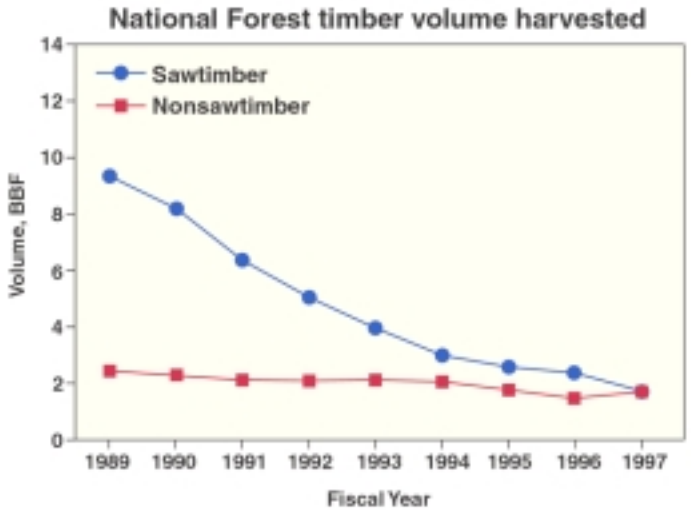
- **Long and distinguished history in the development of biofuels and chemicals**
- **Record of innovative, problem-solving research**
- **Excellent analytical and engineering facilities and extensive expertise**
- **Strong ties to forest managers and the forest products industry**

U.S. Forest Products Laboratory
Founded in 1910

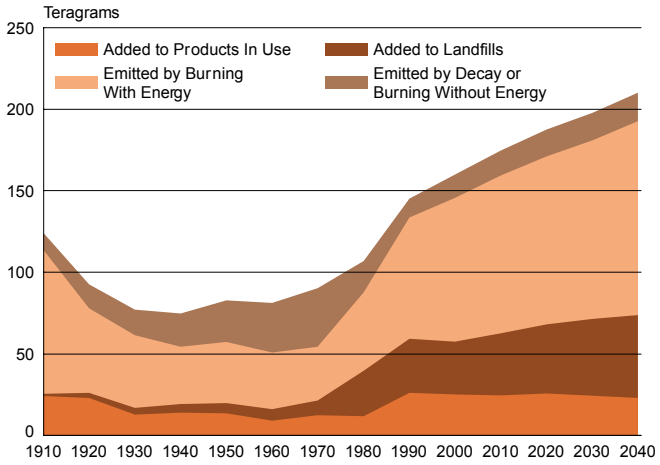
Our research has helped establish biobased products as a significant component of our nation's economy

- **Paper manufacture -- $153 billion**
- **Wood products -- $98 billion**
- **Furniture and related -- $57 billion**
- **Total of more than $300 billion annually**
- **Amounted to 9% of total US manufacturing shipments in 1996**

Recovery of higher value material is declining



Forest products store carbon after harvest

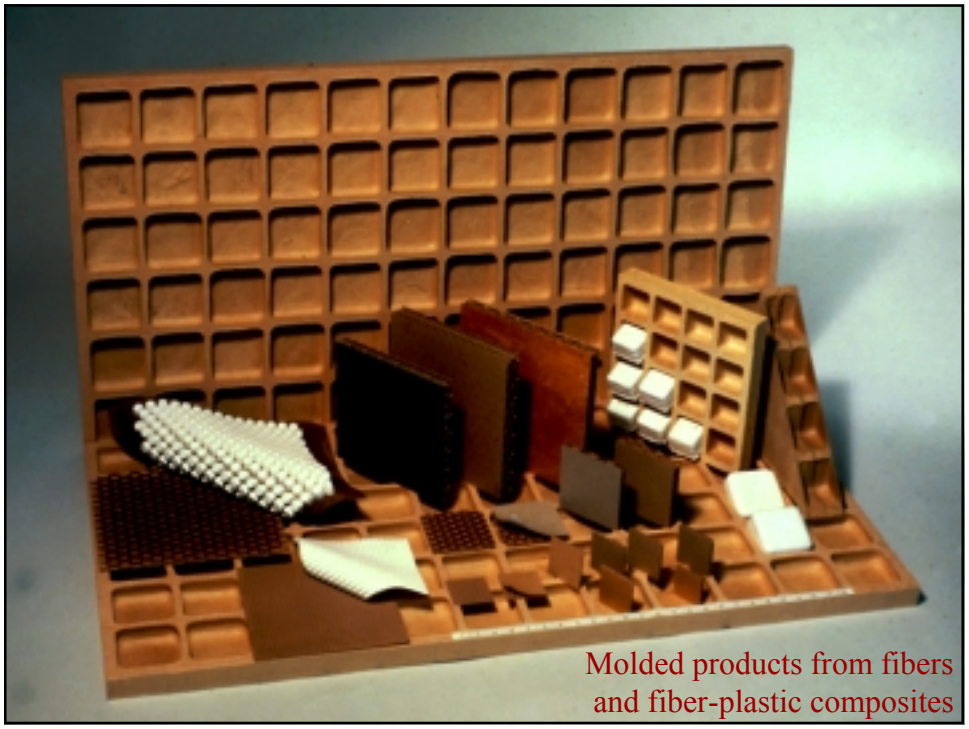


Higher value products from wood

- Solid wood products
- Composite products
- Fiber products
- Fuels and chemicals
- Extractive chemicals
- Biopolymer precursors
- Adhesives
- Dissolving pulps
- Pharmaceuticals

Use of arches in
Contemporary construction

Beams and structural elements
from fingered segments



Molded products from fibers and fiber-plastic composites

New higher value products from wood

- **Feedstocks do not have appropriate properties for traditional wood products**
- **New products are needed that will enable the economic extraction of low value materials from overstocked stands**
- **Biodegradable paper coatings, fillers, block copolymers, ethanol, polymer precursors**

FPL has a long history with biobased products and bioenergy

- **Ethanol**
  - **1915-1920**
  - **1943-1945**
  - **1980-present**
- **Chemicals**
  - **Extractives**
  - **Black liquor**
  - **Lignin chemistry**
  - **Pharmaceuticals**
- **Structural**
  - **Plywood, veneer**
  - **Oriented strand board**
  - **Laminated structures**
  - **Composites**
- **Paper and fiber board**
  - **Recycling**
  - **Use of hardwood fibers**

Conversion technologies

- **Acid hydrolysis**
  - **FPL dilute acid hydrolysis studies**
  - **Collaboration with TVA**
  - **NREL pilot plant**
- **Enzymatic hydrolysis**
  - **FPL research on cellulases**
  - **Lignin degradation - *Phanerochaete***
- **Pentose fermentation for ethanol**

Our current funding for biobased products

- Use of juniper in western rangelands
- Red pine and jack pine thinnings in paper and paperboard
- Strength and stiffness of Ponderosa pine
- Using small diameter timber in wood fiber/plastic composites
- Fermentation of pentose sugars

Current biobased products

- Small diameter timber
- Structural members from underutilized Ponderosa pine
- Improved use of red and jack pine in paper and paperboard
- Wood fiber-plastic composites

Current bioenergy

- Fermentation of five and six carbon sugars by recombinant yeasts
- Metabolic modeling and large-scale engineering of pathways
- Novel enzymes obtained from genomes of biodegradative fungi
- Novel biochemical mechanisms for cellulose decomposition

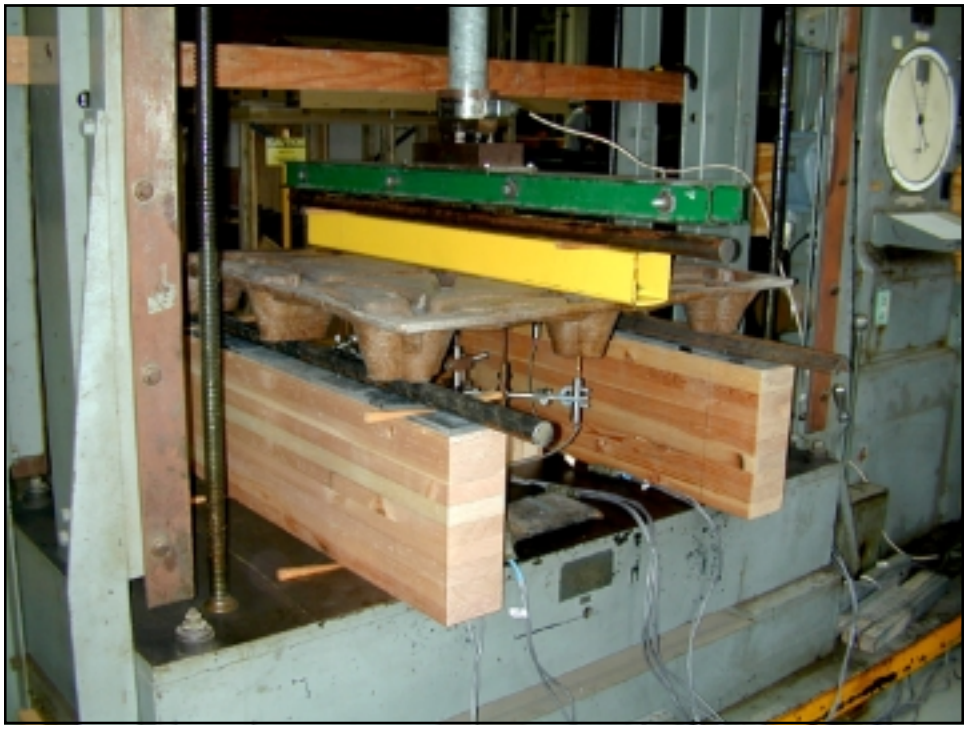
Future: biorefining

- ***Current processes yield less than 50%***
- ***High yield process for recovering fiber, chemicals and fuels from wood***
- ***Based on combined chemomechanical, biochemical and extractive recovery***
- ***Obtain highest combined value from feedstock***
- ***Initially focus on separation technologies***

Analytical and test facilities

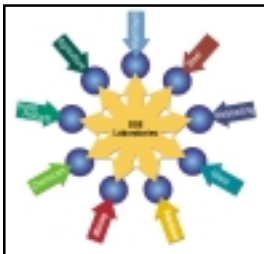
- Paper test laboratory
- Complete chemical analysis support
  - GC/MS; HPLC/MS; IR; NMR, Plasma
- Engineering mechanics lab
  - Large scale test machines
  - Frame test facility
  - Composites facilities
- Extensive microbial research collections

Forest Products Laboratory
Pilot Plant



Conclusion:

- The Forest Products Laboratory has a long history in biomaterials and bioenergy
- We have an effective, ongoing program
- We have the potential to make significant contributions to the ecological and economical use of biobased products and bioenergy



How Can You Most Effectively Work With DOE's National Labs?

William Schertz
Laboratory Coordinating Council
DOE National Bioenergy Center
Strategic Partnerships Workshop
April 11 - 12, 2001
Lakewood, Colorado

Visit us at http://www.oit.doe.gov/LCC


Agriculture


Mining


Metal Casting


Aluminum

Industries of the Future


Steel


Chemicals


Petroleum

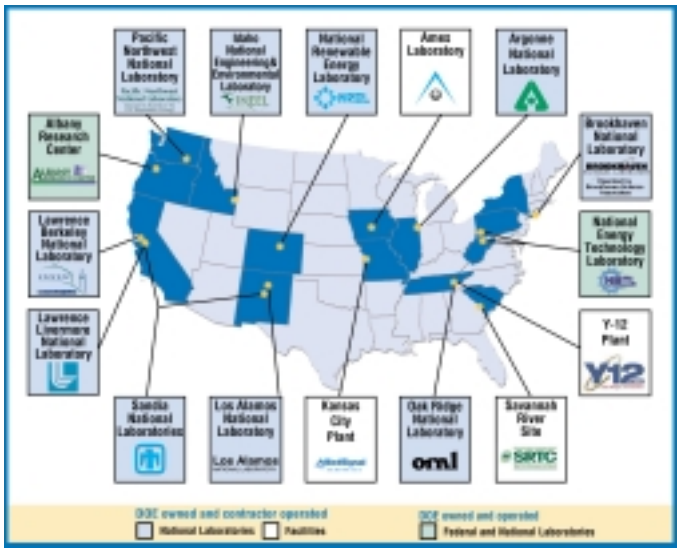

Forest Products


Glass

Laboratory Coordinating Council

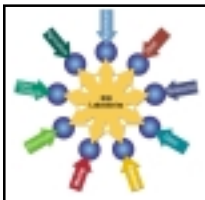
Fostering and Facilitating Collaborative R&D in Support of the U.S. Department of Energy Industries of the Future Initiatives

Visit us at http://www.oit.doe.gov/LCC

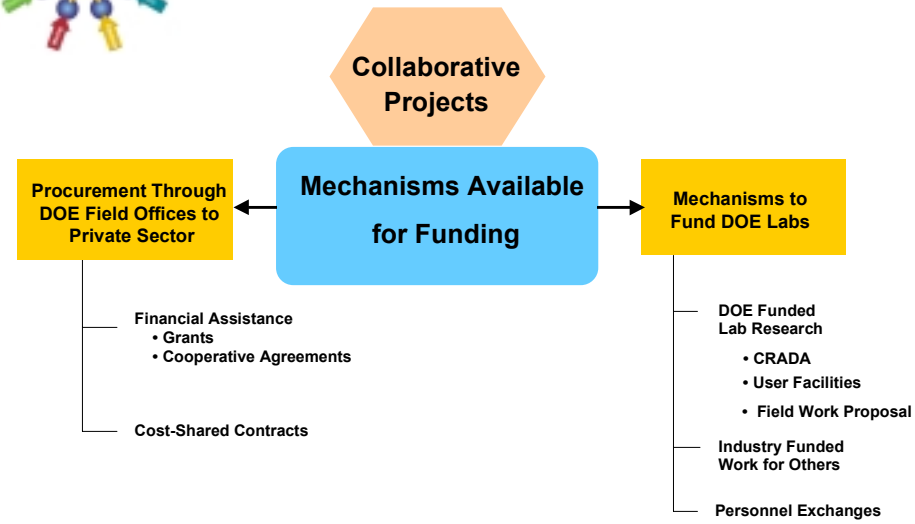


Laboratory Coordinating Council

- Support DOE's Industries of the Future initiatives
- Provide technical input to industry for developing technology roadmaps in cooperation with industry
- Simplify access to laboratories and facilities through a clear, flexible structure that is responsive to needs
- ***Stimulate and foster collaborations with industry and academia***



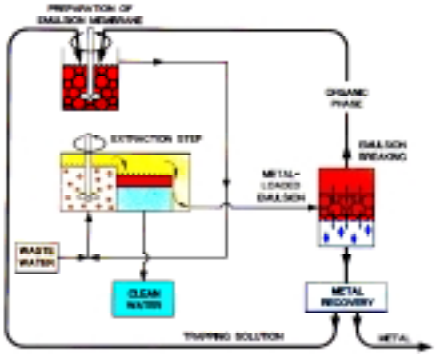
Partnering with Industries of the Future



Agreements for Collaboration

Type of Agreement	Description	Protection of Information	Intellectual Property
CRADA - Cooperative Research and Development Agreement	Sets terms of collaboration with industry for R&D activities	May protect information generated under CRADA for up to 5 years; proprietary data protected	Each party retains title to own inventions. Option for royalty-bearing exclusive license to industry in field of use
WFO Non-Federal Work for Others	Permits industry and non-profit organizations to access unique research efforts at DOE laboratories	Data rights negotiable from fully proprietary to all parties can use data without restriction.	Title may go to sponsor under a DOE class waiver if DOE is not funding closely-related work at the laboratory
User Facilities Agreement	Provides access to certain dedicated DOE laboratory facilities	Proprietary and nonproprietary agreements possible	User inventions go to the user under a DOE class waiver

Waste waters from processing operations are a challenge to the industry. ARC has developed technology which can both mitigate the problem and recover valuable by-products



Liquid emulsion membrane technologies (LEM) have been demonstrated for copper recovery, uranium from AMD waters, and as part of an integrated treatment system for pulp and paper operations

ALBANY RESEARCH CENTER

Refractory Materials for Biomass Gasification Technologies

Refractory samples after exposure to simulated Biomass gasification environment

ALBANY RESEARCH CENTER

National Awards Related to Biobased Research at Argonne Include:

- President's Green Chemistry Challenge
- Discover Award for Technology Innovation
- DOE/OIT Technology of the Year (Finalist)
- Thiele Award (AiChE – Chemical Engineering)
- Federal Laboratory Consortium Award for Technology Transfer
- R&D 100 Award
- 3rd largest NIST/ATP award to date ($31.3 million total)

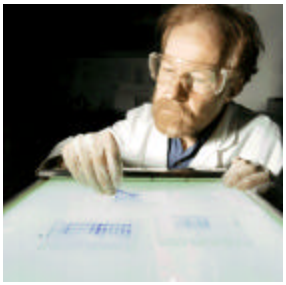
Biobased Materials Strategic Initiative "Green" Solvent – Ethyl Lactate Process

Pilot Scale Electrodialysis System used for industrial processing

Pervaporation-assisted esterification pilot unit

- "Green" Solvents Technology developed using advanced membranes technologies for bioprocessing
- Three companies were formed as a result
  - A specialty polymer company
  - Electrodialysis for industrial processes
  - Vertec Biosolvents is licensee with exclusive marketing arrangement with ADM
- Could replace up to 85% of toxic and chlorinated petrochemical solvents on a cost basis.

Biocatalytic Operating Systems
Vitamin C from Corn



- $31.3 million NIST/ATP Program –3rd largest awarded in history of ATP program
- Argonne is Joint Venture Partner with Eastman Chemical, Genencor, Electrosynthesis, and Microgenomics
- Argonne contributions included pathway engineering, enzyme recruitment from unculturables, enzyme stabilization, & issues related to biocatalytic systems.
- Plans announced to build fermentation-based plant with lowest-cost process to replace chemical process by 2003.
- Enzyme-based systems needed for 'designer' proteins but not yet feasible
- Limitations include cofactor costs and inability to engineer multi-enzyme sequential reactions.

Brookhaven National Laboratory
Core Competencies--Agriculture

- Molecular and Structural Biology
  - Transfer and Expression of Genetic Material
  - Protein/complex structure determination by X-ray crystallography
  - Enzyme or protein activity/performance enhancement through genetic engineering
- Classical Microbiology
  - Approaches to screening, classifying, enhancing microbial cultures
- Genetics and Genomics
  - Classical and molecular methods for analysis of crop traits
  - Techniques for crop trait improvement

Brookhaven National Laboratory
Core Competencies--Forest Products

- Sustainable Forestry
- Human and Environmental Effects
- Energy & Environmental Tradeoffs
- Reduction of Impacts of Liquid Effluents
- Energy Conservation
- Combined Cycle Cogeneration
- Environmental Related Sensors

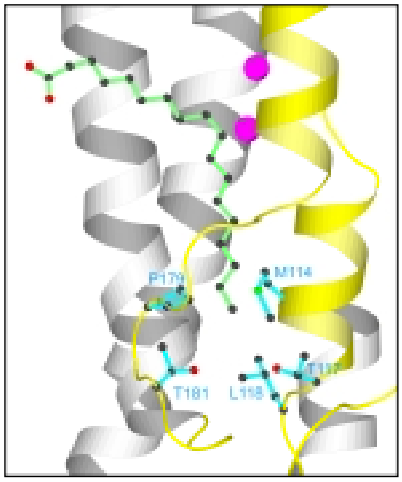
Brookhaven Science Associates
U.S. Department of Energy

Enzyme Activity Enhancement & Modification

Soluble Acyl ACP-Desaturase

Structure-Function

- Wild Type Activity--Regio-specific insertion of first double bond in saturated fatty acid chains of specific lengths
- Structural studies identified amino acids important for chain length- and regio-specificity
- Site directed mutagenesis created enzymes with selectively altered regio- and chain length specificities for producing crop-based "designer" fatty acids to replace petrochemicals



Brookhaven Science Associates
U.S. Department of Energy

BROOKHAVEN NATIONAL LABORATORY

Carbon Cycle/Forestry Management

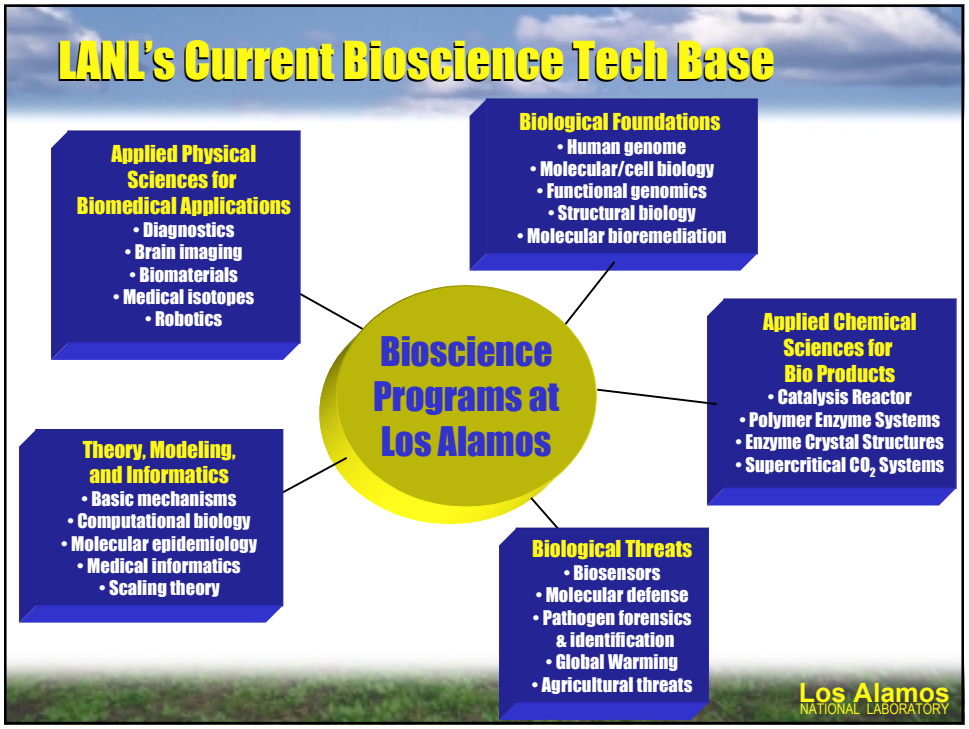
Free Air Carbon Enrichment (FACE)

Forest-Atmospheric Carbon Transfer and Storage (FACTS-1)

- User Facility built by BNL in North Carolina
- Exposure CO_2 levels projected for year 2050 caused a 25% increase in growth rates

Brookhaven Science Associates
U.S. Department of Energy

BROOKHAVEN NATIONAL LABORATORY


LANL's Current Bioscience Tech Base
Biological Foundations
• Human genome
• Molecular/cell biology
• Functional genomics
• Structural biology
• Molecular bioremediation
Applied Physical Sciences for Biomedical Applications
• Diagnostics
• Brain imaging
• Biomaterials
• Medical isotopes
• Robotics
Bioscience Programs at Los Alamos
Applied Chemical Sciences for Bio Products
• Catalysis Reactor
• Polymer Enzyme Systems
• Enzyme Crystal Structures
• Supercritical CO_2 Systems
Theory, Modeling, and Informatics
• Basic mechanisms
• Computational biology
• Molecular epidemiology
• Medical informatics
• Scaling theory
Biological Threats
• Biosensors
• Molecular defense
• Pathogen forensics & identification
• Global Warming
• Agricultural threats
Los Alamos
NATIONAL LABORATORY


The Los Alamos Strategy
Bio-Sciences
Physical Sciences
Modeling & Simulation
Potential Breakthroughs
Los Alamos
NATIONAL LABORATORY

IRIS: Infrared Imaging System for 100% Paper Moisture Measurement

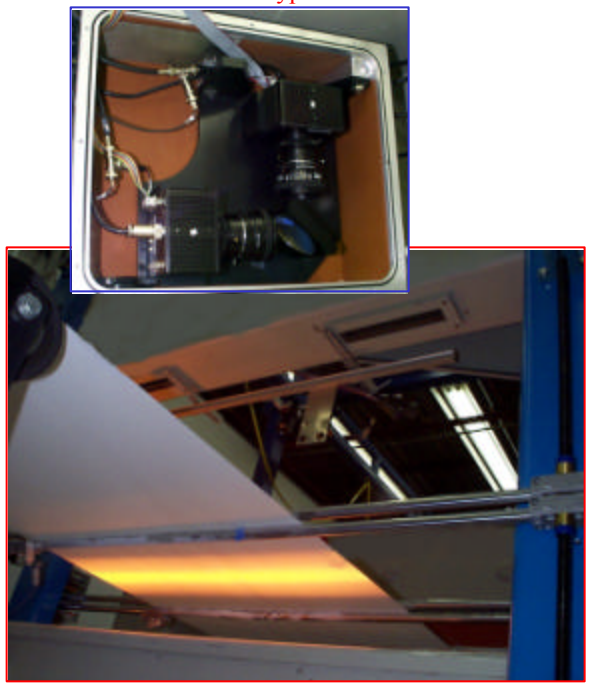
Conventional Paper Scanners

- slow mechanical systems
- sample < 2% of the sheet area
- require periodic maintenance
- limited process control

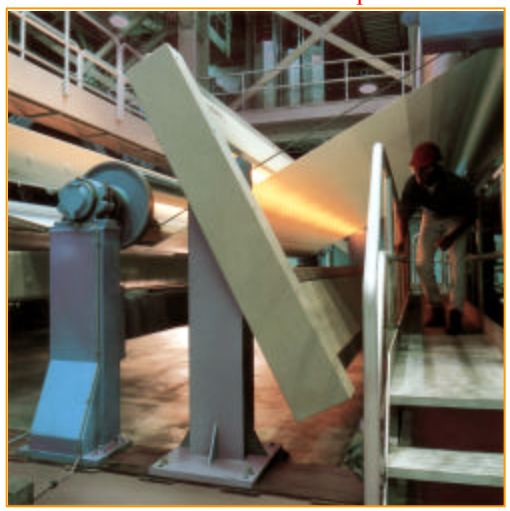
LLNL's Infrared Imaging System

- 100% coverage of the full sheet
- enables fast process control
- no moving parts

IRIS Prototype



Commercial IRIS Concept



Project Team

LLNL	R&D
ABB	Vendor
Westvaco	Paper mill
DOE-OIT	Sponsor

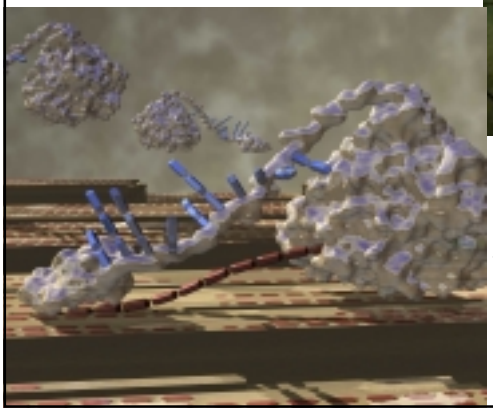
LLNL-JEH 13/3/00

Examples of Recent NREL Bioenergy and Biobased Products Accomplishments

- Biofuels - Key cellulase enzyme understanding and development of new ethanol-producing strains
- Biopower - Technical assistance to small modular biopower systems
- Forest Products - Methodology for on-line process analysis and process control from seedling to the paper product
- Agriculture - Fast methodology for screening crop varieties for special properties -- field and laboratory

Process Demonstration Unit for Biofuels and Chemicals Production

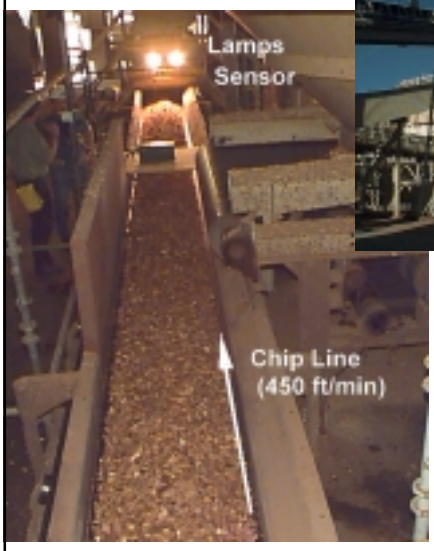
Conversion of biomass into ethanol takes place in four 2300 gallon (9000L) fermentors - it's a lot of bugs & enzymes

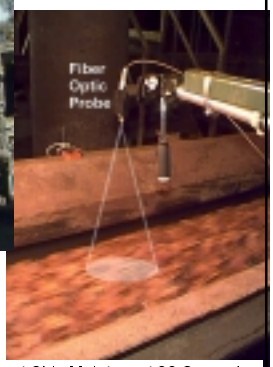


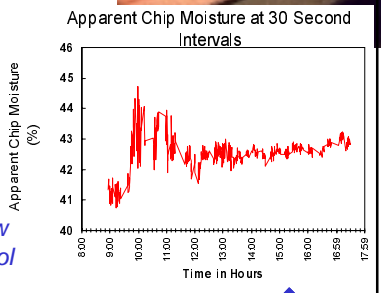
Enzymes walk down the biomass polymer degrading the long chain into bite-size chunks for microbes - New enzymes do it faster

NREL supports Community Power Corporation, Aurora, CO in assessing their 12 kWe unit for distributed power as part of DOE's Small Modular Biopower Program

- NREL provided environment, safety, and health review of the gasifier
- NREL staff provides system development technical support
- CPC's strategic partner, a major global company, is enthusiastic about the progress







Methodologies NREL developed in 3 years will allow fast and cheap chemical analysis and process control from seedlings to paper products!
Sensors and Controls Forest Products project

NREL Staff and Equipment for Bioenergy and Biobased Products

Picking a good one
You have to look at a lot of microbes to find the ones that will do the job

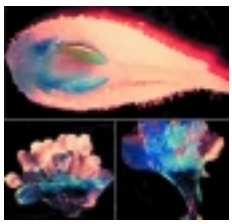
Mobile equipment Permits on-site testing for processes and process control approaches

Preselecting trees

A simple probe might tell you the quality of the tree before it is felled

Biomass Resources Research & Development

Goal: Develop new biomass resources for bioenergy and bioproducts, through research in plant genetics, molecular biology, and agronomy, and facilitate their utilization by integrated analysis, systems engineering, and sustainability research



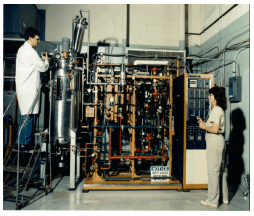
Major Activities:

- Managing biomass feedstock R&D for 2 DOE Programs ~ $7 mil, FY01
- Partnering with many universities and federal programs (>30)
- Performing plant science, ecology, soil carbon R&D for DOE
- Focusing on Energy and Environmental Systems as major ORNL Initiative

Bioconversion Research & Development

Bioprocess Systems: Research on mechanisms of biological interactions on innovative processing concepts; Development of specialized bioprocessing systems, novel bioreactor concepts, and biocatalytic reagents (enzymatic or microbial).

Biomass to fuels and chemicals (Succinic acid)
Enzymatic production of hydrogen from biomass
Anaerobic digestion of animal wastes



Applied Biotechnology: Directed R&D on biological systems to solve real-world energy problems. Intact living microorganisms as well as cell-free, enzyme, and mimetic analogs are resources for bioconversion processes.

- Application of photosynthesis to production of hydrogen
- High temperature and modified cellulases for lignocellulosic hydrolysis
- Enyzmatic redox reactions

Enabling and Related Capabilities

Advanced Materials
e.g. Carbon fiber and composites, ceramics, properties measurement

Sensors and Instrumentation
e.g. Raman spectroscopy for soil carbon analysis

Organic and Biological Mass Spectrometry
e.g. mass spectrometry-based techniques for DNA sequencing and diagnostics

Seperations Research Center
e.g. Expertise in absorption, catalysis, filtration, electrophoresis, etc.

Advanced Computing e.g. Protein structure analysis

Bioinformatics and Functional genomics
e.g. Human genome information, application to microbial genomics

Micro CAT Scan Facilities
e.g. Detecting microstructures of biological materials

Microwave/RF Microstructure Modification Facilities

PNNL Bio-Products Research

PNNL emphasizes conversion of readily available biomass resources to higher-value chemicals, fuel components, and power. Leading capabilities include:

- **Catalysis** – development of high-activity, high-selectivity catalysts for condensed phase hydrogenation and oxidation of sugars, organic acids, and vegetable oils
- **Fermentation** – discovery and development of novel eukaryotic organisms for use in fermentation systems
- **Pre-Treatment, Separations and Purification** – developing supporting processes to reduce overall biomass conversion costs and to improve final product purity and concentration

Pacific Northwest
National Laboratory

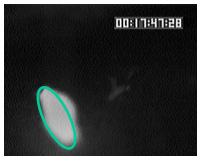
Sandia National Laboratories

- **Project Engineering:** Systems Engineering (integration, testing, planning, analysis, evaluation, manufacturing, materials, sensors, controls, MEMS)
- **Combustion Research:** Combustion Science (chemistry, kinetics, analysis, laboratory testing, sensor development, fuels characterization, ash analysis)
- **Watershed Management:** System Evaluation (water quality/quantity, forest management, fire impacts, economics, real-time monitoring)

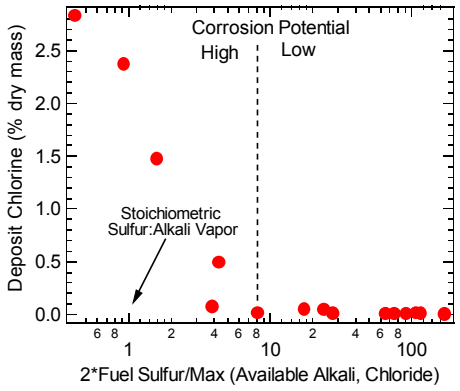
Sandia National Laboratories

Sandia National Laboratories

Guidelines for
Ash Deposition
Corrosion
NOx and SOx Formation
Char Burnout



IR Image of a burning biomass particle



Sandia National Laboratories

U.S. Environmental Protection Agency

Office of Research and Development

National Risk Management Research Laboratory

Air Pollution Prevention and Control Division

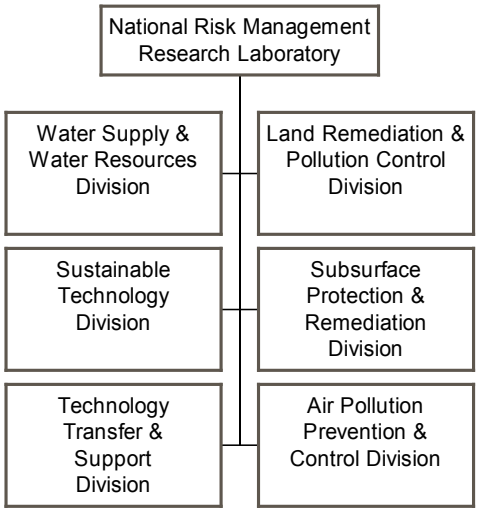
Frank T. Principotta, Director

April 11, 2001

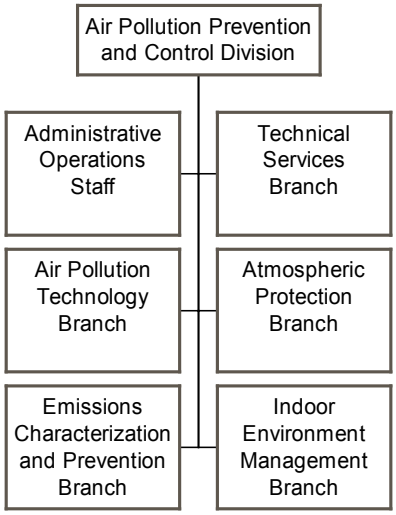
ORD Laboratories and Centers

National Health & Environmental Effects Research Laboratory	National Exposure Research Laboratory	National Risk Management Research Laboratory	National Center for Environmental Assessment	National Center for Environmental Research
Research to identify hazards & characterize "dose-response"	Research to measure, characterize, & assess exposures	Research & technology transfer to prevent, mitigate, & control pollution	Risk characterization & research on risk assessment methods	Extramural grants, peer review

National Risk Management Research Laboratory (NRMRL)



Air Pollution Prevention and Control Division (APPCD)



APPCD Mission

- To research, develop, & demonstrate air pollution prevention & control technologies
  - Power plants
  - Manufacturing & processing industries
  - Incinerators
  - Indoor environments
  - Sources of greenhouse gases
- Characterize & assess all sources of air pollutants
- Verify the performance of innovative technologies

(continued)

APPCD Mission (continued)

- Staffed primarily by engineers, physical scientists, & technicians, the Division:
  - Conducts fundamental research to define the mechanisms by which processes, equipment, & fuel combustion produce air pollution;
  - Develops & improves air pollution control equipment;
  - Seeks means of preventing or reducing pollution through product substitution or changes in industrial & energy production processes; and
  - Develops predictive models & emissions estimation methodologies.

(continued)

APPCD Mission (continued)

- The Division concentrates efforts in six main program areas:
  - Air toxics
  - Fine particles
  - Indoor air quality
  - Ozone non-attainment
    - Nitrogen Oxides (NOx) & Volatile Organic Compounds (VOCs)
  - Global climate change
  - Environmental Technology Verification (ETV)

Air Toxics

- Technologies & pollution prevention approaches to reduce emissions of air toxics regulated under Title III of the Clean Air Act Amendments
- In-house combustion research including:
  - Mercury control
  - Dioxin source characterization & control
  - Metal emission characterization
  - Hazardous waste incineration

Fine Particles

- Characterize outdoor & indoor sources of fine Particulate Matter (PM);
  - Field studies of emissions to support regulatory activities
  - Investigation of relationship between outdoor & indoor concentrations of particles
  - Characterization of fine PM from fossil fuel combustion
  - Measurement & analysis of emissions from woodstoves & fireplaces
  - Characterization of indoor sources of particles
- Evaluate the performance of upgraded particle control devices
  - Development of fine PM technology

Indoor Air Quality

- Test methods, emissions factors, & source/sink models developed and validated in full-scale environment
  - Source characterization & emissions testing
  - Indoor air quality evaluation & prediction
  - Ventilation
  - Air cleaners evaluation
  - Pollution prevention

Ozone Non-Attainment

- This program supports ORD's overall ozone non-attainment strategy by:
  - Developing innovative NOx & VOC control technologies;
  - Enhancing & developing emissions estimation methodologies;
  - Developing the Biogenic Emission Inventory System (BEIS);
  - Evaluating the Mobile Modal Model approach; and
  - Developing pollution prevention approaches for VOCs & other ozone precursors.

Global Climate Change

- This program conducts technology assessments of prevention, mitigation, & adaptation options for greenhouse gases (carbon dioxide, methane, CFCs, HFCs, nitrous oxide) with emphasis on:
  - Evaluating greenhouse gas prevention & mitigation technologies for key sources;
  - Conducting comparative analyses of projected performance & cost of greenhouse gas prevention, mitigation, & adaptation options; and
  - Evaluation of options for adaptation to selected global change impacts; e.g., tropospheric ozone impacts.

Environmental Technology Verification

The goal of the ETV program is to promote commercialization of improved environmental technologies through performance verification by independent third parties.

- APPCD verification activities
  - Indoor air products
  - P2/Innovative coating and coating equipment
  - Air pollution control technologies
  - Global climate change technologies
- Other verification pilots
  - Drinking water systems
  - Metal finishing
  - Wet water flow technology
  - Surface water protection technology
  - Pollution prevention

Selected APPCD Achievements

- **1970's**
  - NOx control - Fundamental research & technology development
  - Flue gas desulfurization - Technology development
- **1980's**
  - Radon mitigation - Technology development
  - Indoor air characterization - Fundamental research & model development
- **1990's**
  - Municipal waste new source performance standard - Agency support
  - Dioxins from incinerators - Fundamental research & technology development
  - CFC replacements - Pollution prevention via chemical alternative
  - VOC emissions from forests - Source characterization

Recent Accomplishments

- Trucks evaluated in APPCD's on-road testing program demonstrated much higher emissions than FTP (Federal Test Procedure) engine dynamometer tests. Communications with OMS led to discovery of industry tampering via "defeat devices." As a result, EPA and DOT settled with engine manufacturers: to pay $83 million in fines and $1 billion on environmental improvements.
- Agency used results of APPCD's 300 MW boiler demo in the Ukraine as basis for its cyclone and wet-bottom coal utility boiler NSPS. Courts ruled in favor of EPA in using such results to base standard.
- APPCD has been enhancing the understanding of what factors influence formation & emission of dioxins, and related compounds, from combustion sources. Factors include: flue gas temperature, catalytic surfaces, and SO_2 concentrations. (continued)

Recent Accomplishments (continued)

- APPCD, working collaboratively with NERL & NCAR, has developed the Biogenic Inventory System (BEIS) Model. This model more accurately predicts emissions of isoprene (VOC) emissions from forests. Results have been used by the Ozone Transport Analysis Group (OTAG) to quantify biogenic estimates to allow for ozone modeling in Eastern US and by OAQPS to the proposed Regional Transport regulations.
- Recent testing has indicated high indoor levels of fine particles associated with the burning of candles (multiple wicks) and incense.
- APPCD is in the final stage of developing a decision tool utilizing LCA principles to allow decision makers to evaluate major municipal solid waste management options. Options can be compared relative to environmental impacts & costs.

Summary of Program Presentations

for the

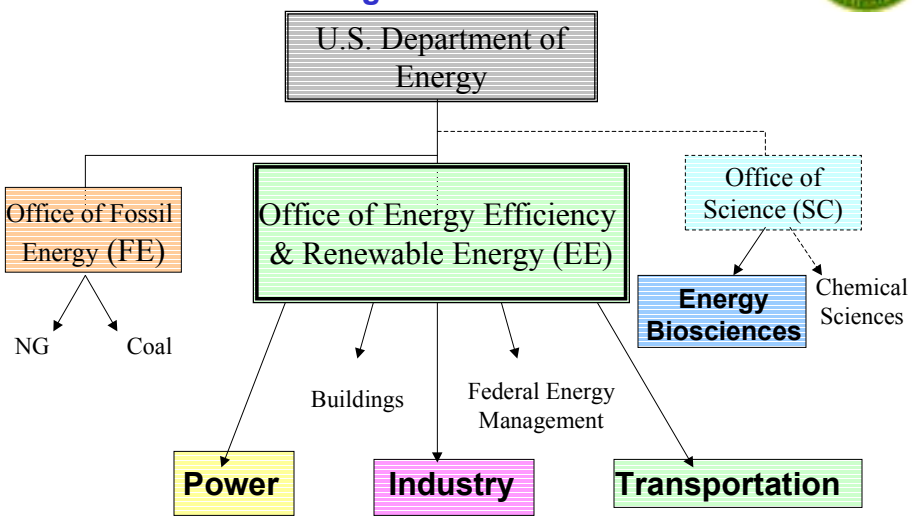
DOE National Bioenergy Center

Strategic Partnerships Workshop

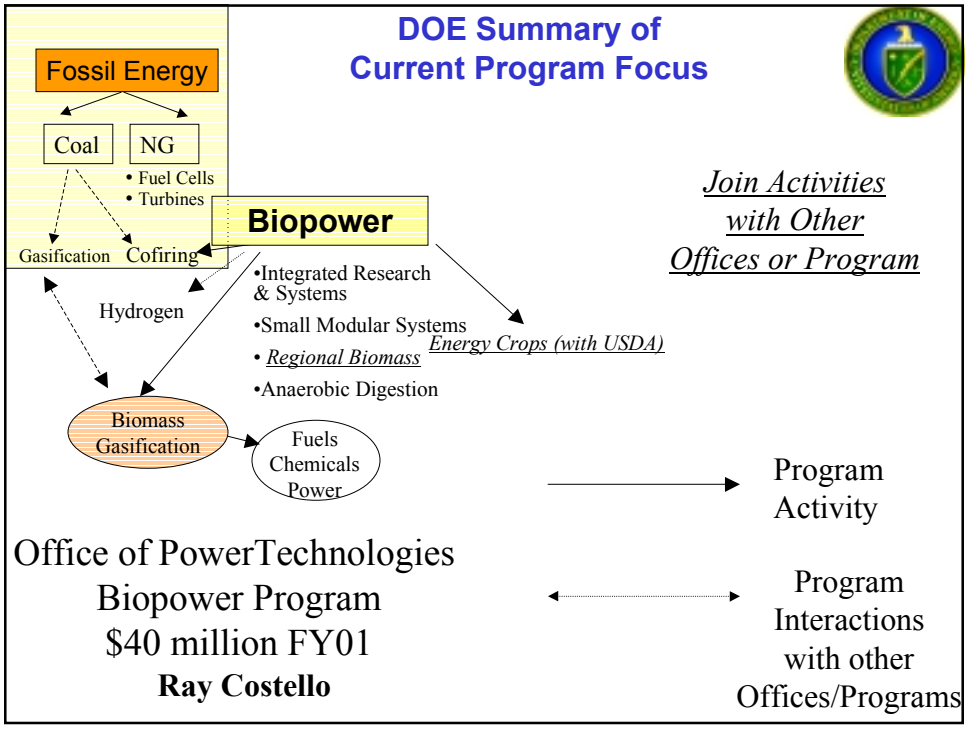
April 11 - 12, 2001

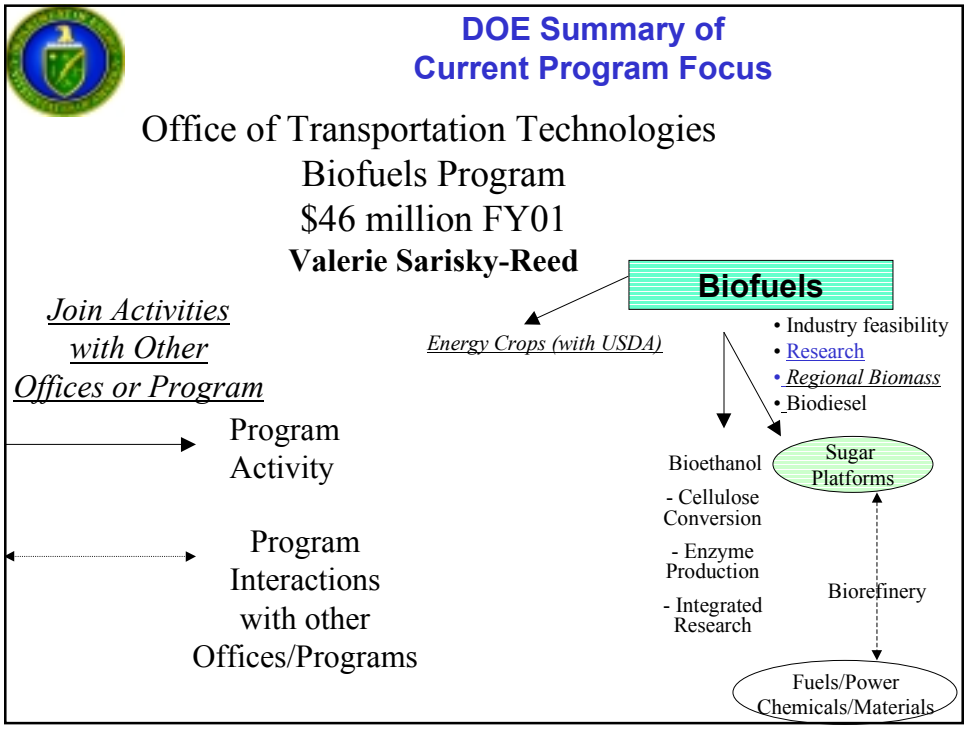
Colorado

Bioenergy and Biobased Products R&D Programs at DOE



Doug Kaempf, National Biobased Products and Bioenergy Coordination Office Co-Chair

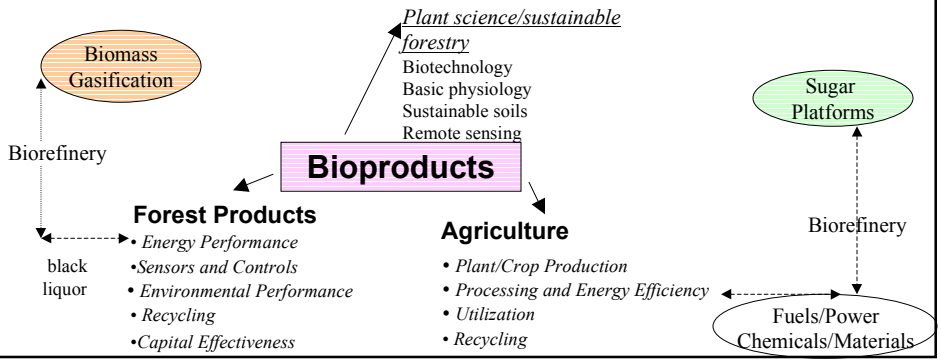

DOE Summary of
Current Program Focus
Fossil Energy
Coal
NG
• Fuel Cells
• Turbines
Gasification
Cofiring
Biopower
Hydrogen
•Integrated Research & Systems
•Small Modular Systems
• Regional Biomass
•Anaerobic Digestion
Energy Crops (with USDA)
Biomass Gasification
Fuels Chemicals Power
Join Activities with Other Offices or Program
Program Activity
Program Interactions with other Offices/Programs
Office of PowerTechnologies
Biopower Program
$40 million FY01
Ray Costello


DOE Summary of
Current Program Focus
Office of Transportation Technologies
Biofuels Program
$46 million FY01
Valerie Sarisky-Reed
Biofuels
Energy Crops (with USDA)
• Industry feasibility
• Research
• Regional Biomass
• Biodiesel
Bioethanol
- Cellulose Conversion
- Enzyme Production
- Integrated Research
Sugar Platforms
Biorefinery
Fuels/Power Chemicals/Materials
Join Activities with Other Offices or Program
Program Activity
Program Interactions with other Offices/Programs

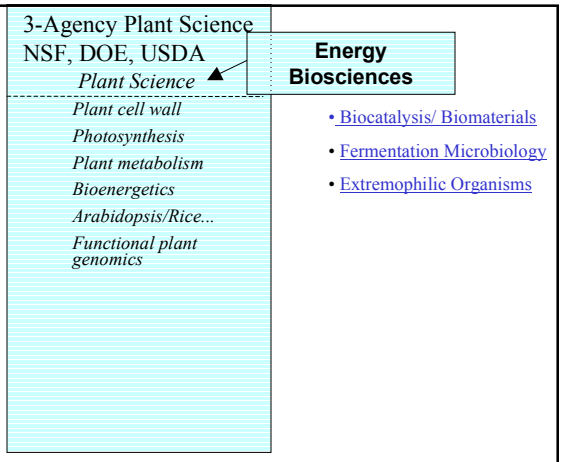
DOE Summary of Current Program Focus

Office of Industrial Technologies
Industries of the Future Program
Forest Products and Agriculture
$22 million FY01
Mark Paster

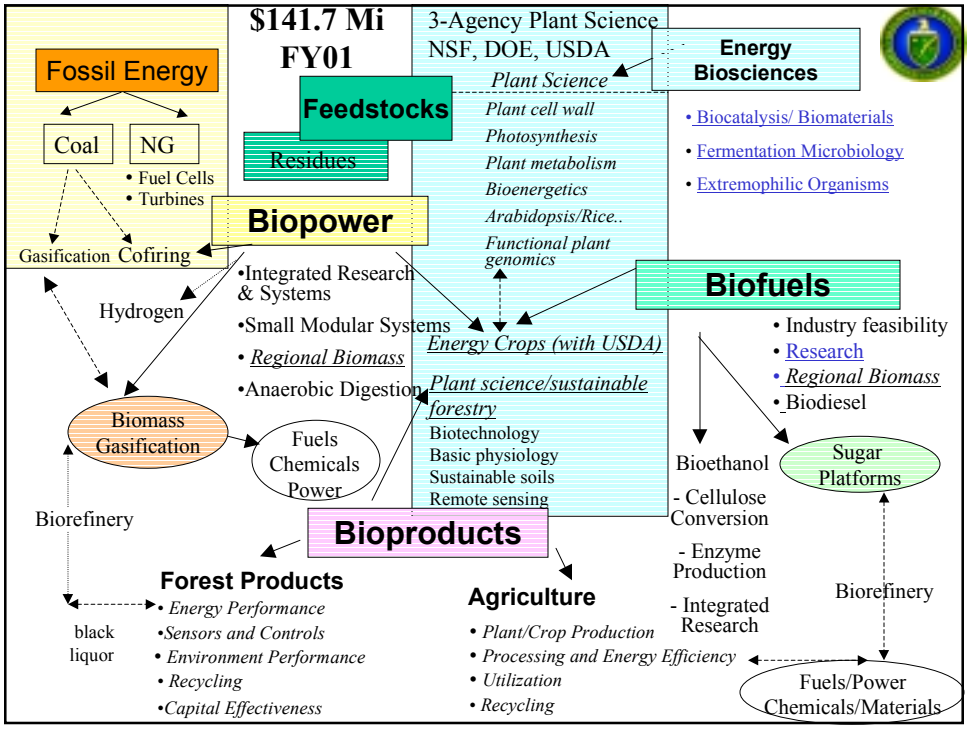
Elements of the Program are the Current Technology Roadmap or Portfolio areas

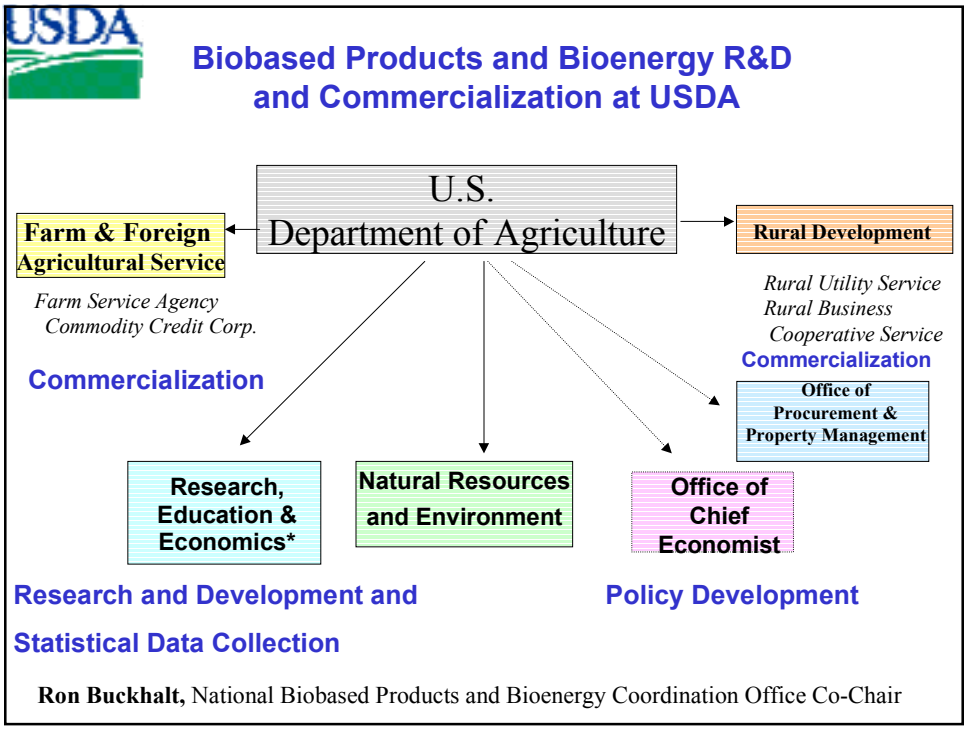


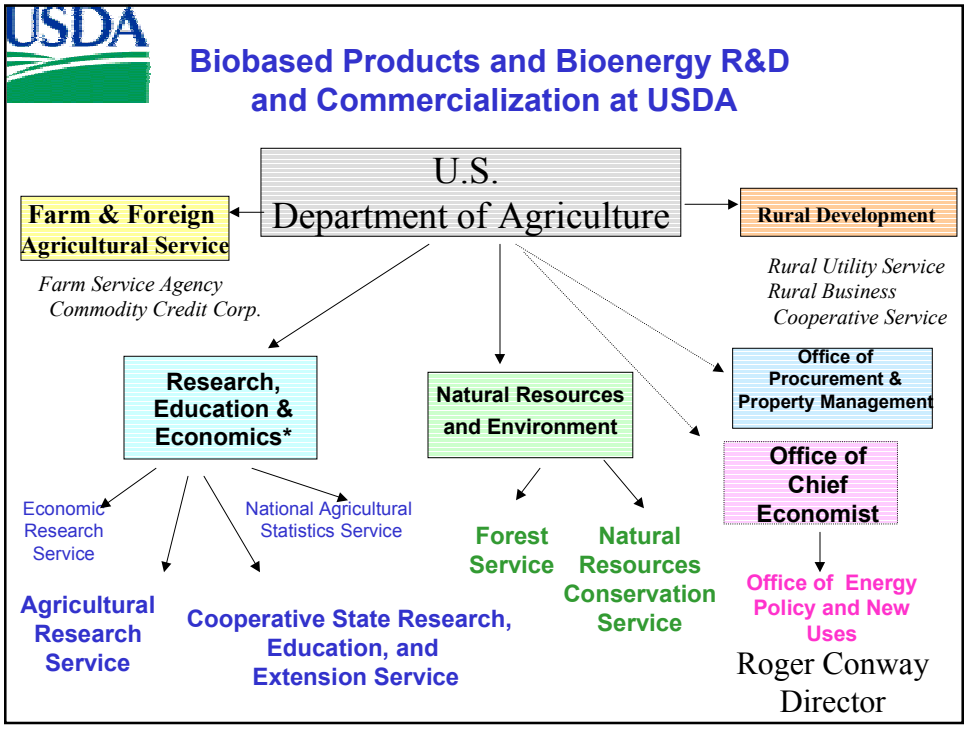
DOE Office of Science Summary of Current Program Focus

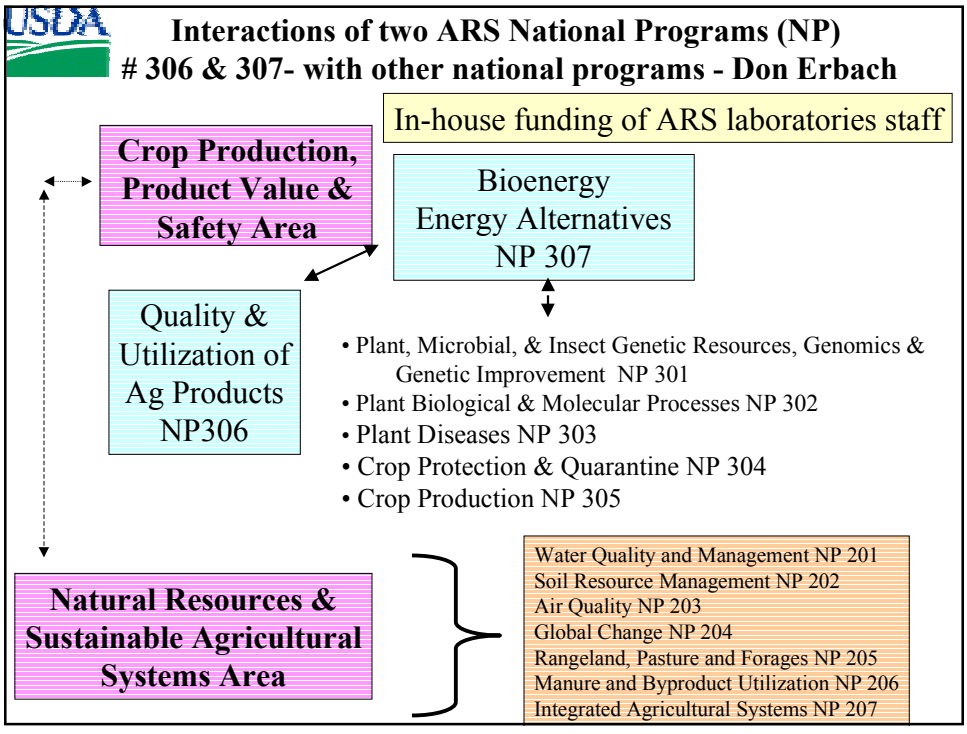


Energy Biosciences Program
$33.7 Mi FY01
Greg Dilworth


$141.7 Mi
FY01
3-Agency Plant Science
NSF, DOE, USDA
Plant Science
Energy Biosciences
Fossil Energy
Coal
NG
• Fuel Cells
• Turbines
Feedstocks
Residues
Plant cell wall
Photosynthesis
Plant metabolism
Bioenergetics
Arabidopsis/Rice..
Functional plant genomics
• Biocatalysis/ Biomaterials
• Fermentation Microbiology
• Extremophilic Organisms
Biopower
Gasification
Cofiring
Hydrogen
•Integrated Research & Systems
•Small Modular Systems
• Regional Biomass
•Anaerobic Digestion
Biofuels
Energy Crops (with USDA)
Plant science/sustainable forestry
Biotechnology
Basic physiology
Sustainable soils
Remote sensing
• Industry feasibility
• Research
• Regional Biomass
• Biodiesel
Biomass Gasification
Fuels Chemicals Power
Bioethanol
- Cellulose Conversion
- Enzyme Production
- Integrated Research
Sugar Platforms
Biorefinery
Bioproducts
Forest Products
• Energy Performance
•Sensors and Controls
• Environment Performance
• Recycling
•Capital Effectiveness
black liquor
Agriculture
• Plant/Crop Production
• Processing and Energy Efficiency
• Utilization
• Recycling
Biorefinery
Fuels/Power Chemicals/Materials


USDA
Biobased Products and Bioenergy R&D and Commercialization at USDA
U.S. Department of Agriculture
Farm & Foreign Agricultural Service
Farm Service Agency
Commodity Credit Corp.
Commercialization
Rural Development
Rural Utility Service
Rural Business
Cooperative Service
Commercialization
Office of Procurement & Property Management
Research, Education & Economics*
Natural Resources and Environment
Office of Chief Economist
Research and Development and Statistical Data Collection
Policy Development
Ron Buckhalt, National Biobased Products and Bioenergy Coordination Office Co-Chair


Biobased Products and Bioenergy R&D and Commercialization at USDA
U.S. Department of Agriculture
Farm & Foreign Agricultural Service
Farm Service Agency
Commodity Credit Corp.
Rural Development
Rural Utility Service
Rural Business
Cooperative Service
Research, Education & Economics*
Natural Resources and Environment
Office of Procurement & Property Management
Office of Chief Economist
Economic Research Service
National Agricultural Statistics Service
Forest Service
Natural Resources Conservation Service
Office of Energy Policy and New Uses
Agricultural Research Service
Cooperative State Research, Education, and Extension Service
Roger Conway
Director


Interactions of two ARS National Programs (NP)
306 & 307- with other national programs - Don Erbach
In-house funding of ARS laboratories staff
Crop Production, Product Value & Safety Area
Bioenergy Energy Alternatives NP 307
Quality & Utilization of Ag Products NP306
• Plant, Microbial, & Insect Genetic Resources, Genomics & Genetic Improvement NP 301
• Plant Biological & Molecular Processes NP 302
• Plant Diseases NP 303
• Crop Protection & Quarantine NP 304
• Crop Production NP 305
Natural Resources & Sustainable Agricultural Systems Area
Water Quality and Management NP 201
Soil Resource Management NP 202
Air Quality NP 203
Global Change NP 204
Rangeland, Pasture and Forages NP 205
Manure and Byproduct Utilization NP 206
Integrated Agricultural Systems NP 207

ARS NP 306 - Product Quality/New Products & Processes
Current Focus Areas - $48.6 Mi, 74 projects - Frank Flora

Research Areas	Corn	Wheat	Soybean	Cotton
Improved Processing	- Mutant amylase enzymes		- Oil chem modification	
	- Coproducts of fuel ethanol production			
	- Cost reduction starch to ethanol			
Fractionation Technologies for Multiple Products				
	- Corn fractions improved separation	Protein and starch separation		
	- Corn fiber processing to ethanol and value added products			
KEY PRODUCT CATEGORIES				
Plant-based Plastics/Polymers	-Enzymatic modification to functional polymers			- Various
	-Biodegradable starch products			
Lubricants/Functional fluids			Industrial drying oils	
Inks			- Soybean inks	
Enzymes	-Cellulases, Amylases, Xylanases, Pectinases…			
Alternative Fibers				New uses
Absorbents/Adsorbents	- Corn residues			New products
Composites	- From corn constituents/residues	-Various		-Various
Adhesives/Bonding Products	- From sucrose (new epoxies)			
Biocontrol Products	- Insecticidal volatile attractants		-Biosurfactants	
Solvents/Cleaners/Chemical intermediates	- Various fermentation products		- Various products	
Cosmetic/Personal Care	-Stabilizers, viscosity control, dispersants		-New formulations	
Health Care Products			-New formulations	

ARS NP 307 - Bioenergy and Energy Alternatives
Current Focus - Don Erbach

Bioenergy
Energy Alternatives
NP 307

- Ethanol
- Biodiesel
- Energy Crops (Switchgrass)
- Energy Alternatives for Rural Practices
  - Water pumping & remote power
  - -Wind/hybrid &
  - -Wind stand alone

Cooperative State Research, Education and Extension Service - CSREES (total funding $561 Mi; Biofuel, bioenergy, chemicals, and materials $22.5 Mi) -- Hongda Chen

CSREES	FY01 Total Mi $	Biofuel, bioenergy, chemicals, materials: FY 00 Mi$**
Formula funding	$226.0	$4.2
Special	$83.0	$6.0
National Research Initiative*	$99.0	$2.3
Initiative for Future Agriculture & Food Systems (IFAFS)	$115.0	$9.0
SBIR	$12.0	$1.0
High Education	$26.0	
Total	$561.0	$22.5

*New interagency solicitation on Metabolic Engineering
** Probably underestimated; FY99 and FY98 projects multi-year funded not included

GRANTING ARM OF USDA
and link with Land Grant institutions
Grants can be multiyear

Cooperative State Research, Education and Extension Service - CSREES - Hongda Chen (>$22.5 Mi)

CSREES Program Element	Topics
National Research Initiative	Non-food Characterization/Process/Product Research
	Improved Utilization of Wood and Wood Fiber
	Agricultural Systems
	Plant Genome and others
Initiative for Future Agriculture & Food Systems (IFAFS)	Chemicals, materials, and products from biomass; Functional genomics of biocatalysts; guayule non-allergenic products, etc.
Special	Iowa Biotechnology Consortium
Formula funding	Industrial enzymes, adhesives and packaging systems

Forest Service - FS - Biomass R&D Programs
Howard Rosen ($12.5 Mi)

- Growing Feedstock (short rotation)
- Removal (harvesting methods)
- Conversion (lumber, composites, chemicals, energy, pulp, paper)

$9.5 Mi

Small Diameter and Low Value Sources

- Products and Utilization
- Forest Management
- Economics and Social

$3 Mi

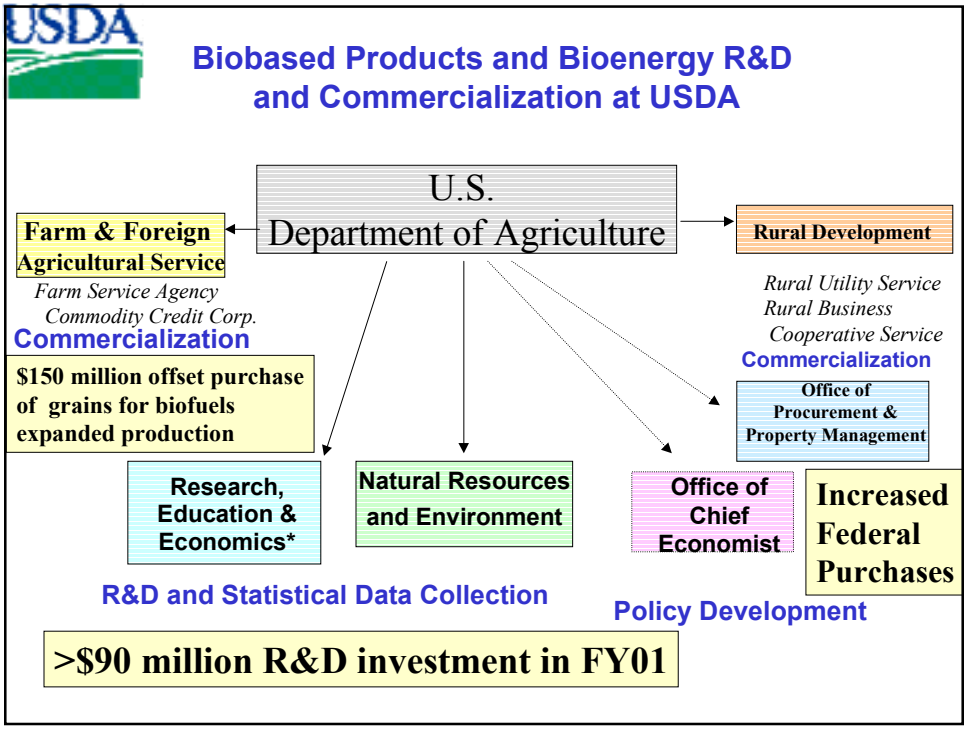
Systematic Approach to Developing Biobased Products and Bioenergy - Marvin Duncan (Office of Energy Policy and New Uses)

1.Research

- Broaden range of products
- Isolate/identify new uses for biomass products
- Reduce sugar costs
- Reduce gasification costs
- New biobased products pathways
- Perfect biorefinery concepts
- Clean biomass feedstocks
- Increase feedstock uniformity at reduced cost

2. Life Cycle Cost Analysis
3. Performance Testing
4. Regulatory Initiatives
5. Product Dev. & Comm.
6. Public Sector Incentives
7. Education & Outreach
8. Financing Issues

USDA Biobased Products & Bioenergy Coordination Council



Environmental Protection Agency	http://www.epa.gov
Industry Partnerships, Project XL	*http://www.epa.gov/ProjectXL/*
Methane Energy	*http://www.epa.gov/methane/*
Landfill Methane Outreach	http://www.epa.gov/lmop/
AgStar Partnership (joint with USDA and DOE)	http://www.epa.gov/outreach/agstar/
Office of Research and Development	*http://www.epa.gov/ORD/*
Environmental Technology Verification	http://www.epa.gov/etv/
Office of Pollution Prevention and Toxics	*http://www.epa.gov/internet/oppts/*
Green Chemistry	http://www.epa.gov/opptintr/greenchemistry/program.htm
Genetically Modified Microorganisms	http:/www.epa.gov/opptintr/biotech
Plant Pesticides	http://www.epa.gov/pesticides/biopesticides
Extramural Research and Development	*http://www.epa.gov/AthensR/extrmural/index.html*
Comprehensive Procurement Guidelines	*http://www.epa.gov/cpg*

Granting programs (Extramural, Green Chemistry)
Enabling programs (XL, Methane Energy, ETV, Procurement guidelines)
Regulatory programs (GMO, Plant Pesticides)

United States
Environmental Protection Agency

"...to protect human health and to safeguard the natural environment..."

Pollution into Products: Demand-Based Climate Mitigation -- Donn Viviani - EPA

- Linking growth (that produces CO2) to sequestering (e.g., biomass products) benefits growth and controls net emissions

- CO2 becomes a resource rather than a waste and growth is sustainable

- A closed-carbon, economic cycle, with product-sinks in gigatons and non-emitting production mechanisms

Inventory of Bioenergy and Biobased Products

Examples of Changes from FY 1998 to Present

Helena Chum
DOE National Bioenergy Center
Strategic Partnerships Meeting

Inventory of Federally Funded Bioenergy Research and Development

April, 2000

TP-570-28425 (85 pages)

Helena L. Chum, Carolyn Elam, Connie Baca-Overly, and Al Berger
National Renewable Energy Laboratory
with contributions from
NREL and ORNL Bioenergy Staff

Draft

Methodology

- Abstracts compiled and assessed (5000)
- Classification areas and taxonomy decided by a group of scientists, engineers and managers of NREL and ORNL familiar with the topics:

  Rich Bain, Kevin Craig, Janet Cushman (ORNL), David Dayton, Bob Evans, Mark Finkelstein, Mike Himmel, Ralph Overend, Gene Petersen, Cynthia Riley, Mike Seibert, Steve Thomas, Lynn Wright (ORNL), Joe Bozell, Rick Elander, Kelly Ibsen, Steve Kelley, Jim McMillan, Tom Milne, Quan Nguyen, John Sheehan, Bob Wooley, Art Wiselogel, Mark Yancey, Helena Chum, and Ming Zang

- Reviewers: Eldon Boes, Cathy Gregoire-Padro, Stan Bull (NREL); Tony Schaffhauser (ORNL); David Nahmias, John O'Sullivan, and Roberta Nichols (consultants); Del Raymond (Weyerhaeuser); Neil Rossmeissl, Ray Costello, Richard Moorer, John Ferrell, Tien Nguyen (DOE); Michael Antal (University of Hawaii).

Portfolio Analysis Methodology

- Across a systematic classification of technical lines -- Taxonomy
- Across U.S. government-programs using the RaDiUS database and agencies' program information
- Across Agencies' specific databases

RaDiUS DATABASE

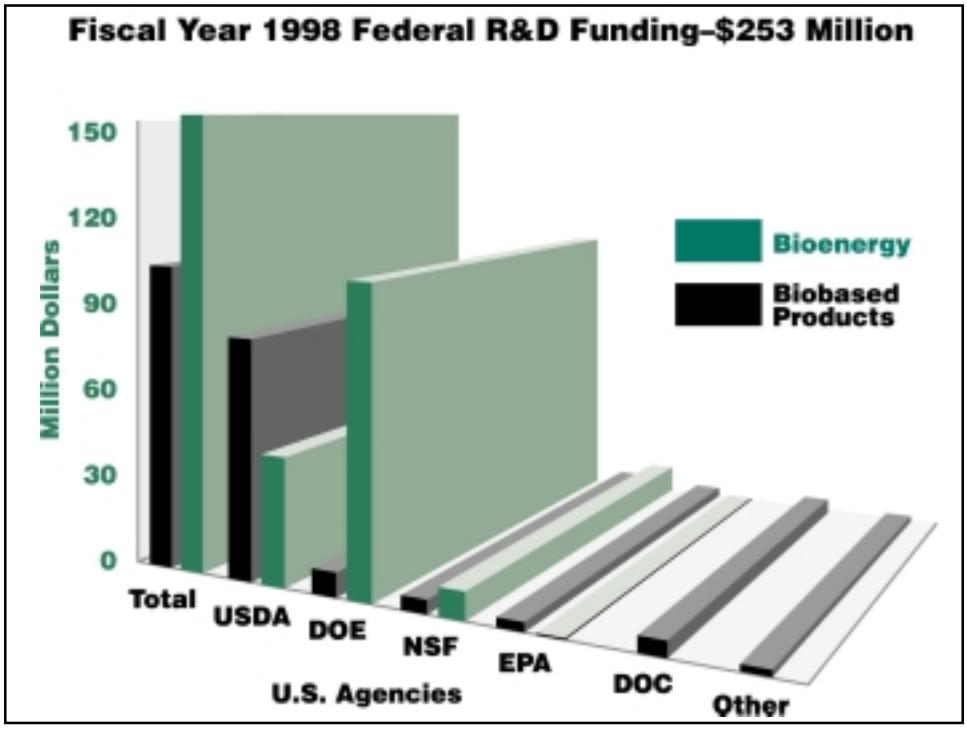
RaDiUS is the comprehensive database on Research and Development (R&D) in the United States funded by the Federal Government.

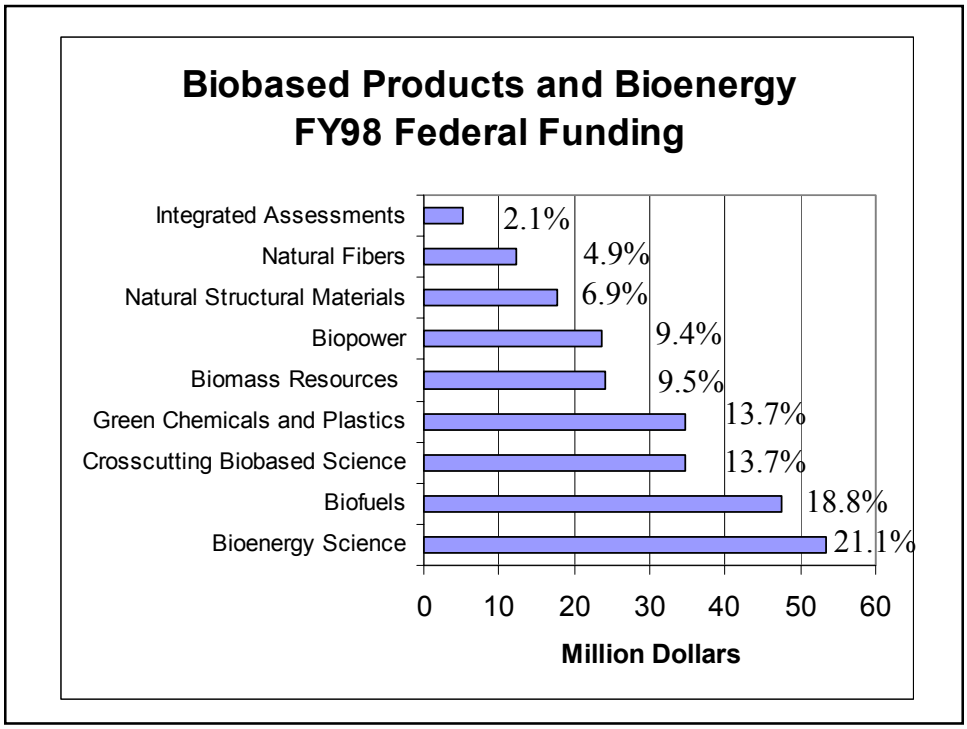
- developed by RAND to support the Science & Technology Policy Institute (S&TPI) - the federally funded research and development center - serving the White House Office of Science and Technology Policy (OSTP) and the National Science and Technology Council (NSTC).

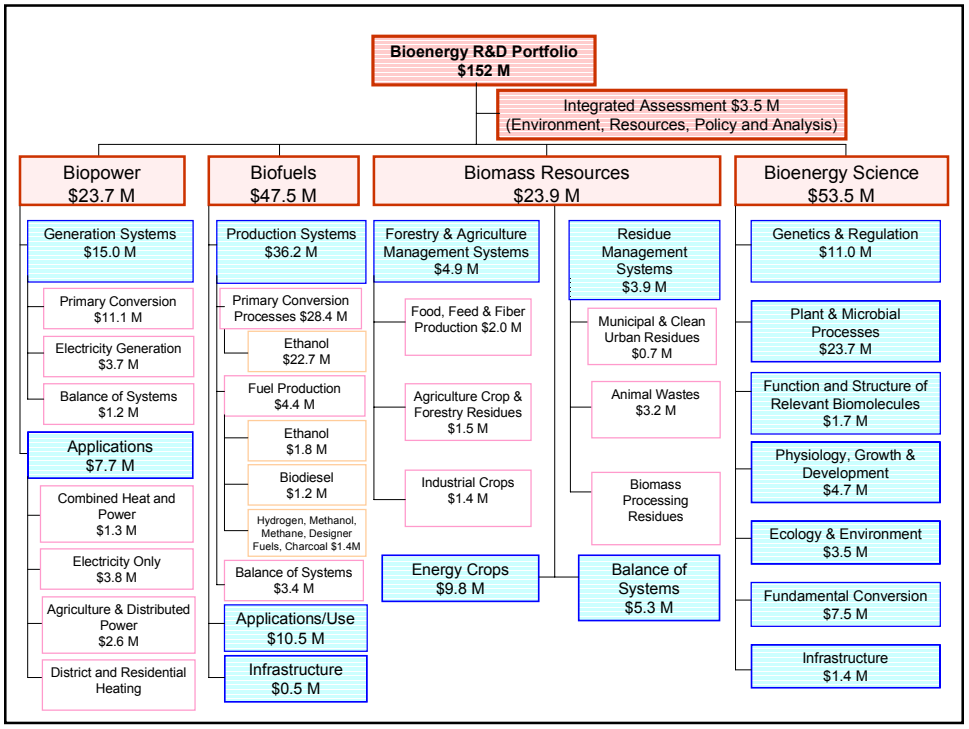
- in cooperation with the National Science Foundation (NSF)

Baseline - Why Fiscal Year 1998?

- Grant information for which the detailed description of the projects could be compiled along with funding levels. There is a two years lag for USDA data through the Current Research Information System.
- Similar grant disposition and detailed description for other agencies lagged.
- Some internal work funded by agencies and conducted by agency personnel may be missing if not contained in the databases searched.


Fiscal Year 1998 Federal R&D Funding–$253 Million
Million Dollars
150
120
90
60
30
0
Total
USDA
DOE
NSF
EPA
DOC
Other
U.S. Agencies
Bioenergy
Biobased Products

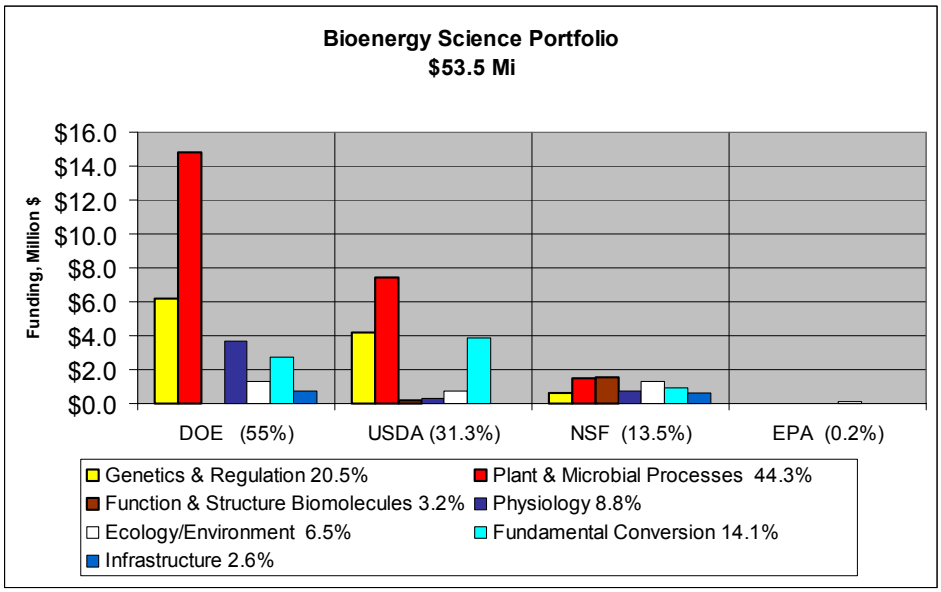

Biobased Products and Bioenergy
FY98 Federal Funding
Integrated Assessments
Natural Fibers
Natural Structural Materials
Biopower
Biomass Resources
Green Chemicals and Plastics
Crosscutting Biobased Science
Biofuels
Bioenergy Science
2.1%
4.9%
6.9%
9.4%
9.5%
13.7%
13.7%
18.8%
21.1%
0
10
20
30
40
50
60
Million Dollars

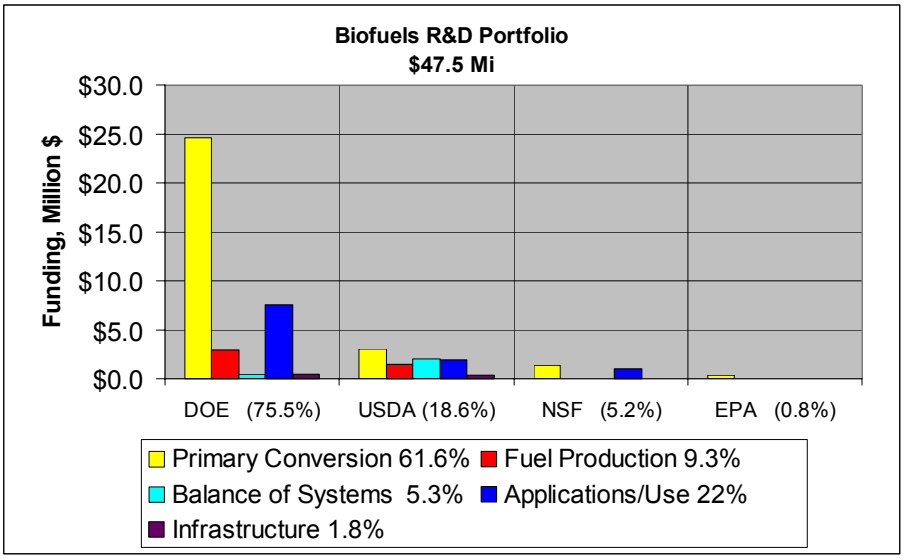


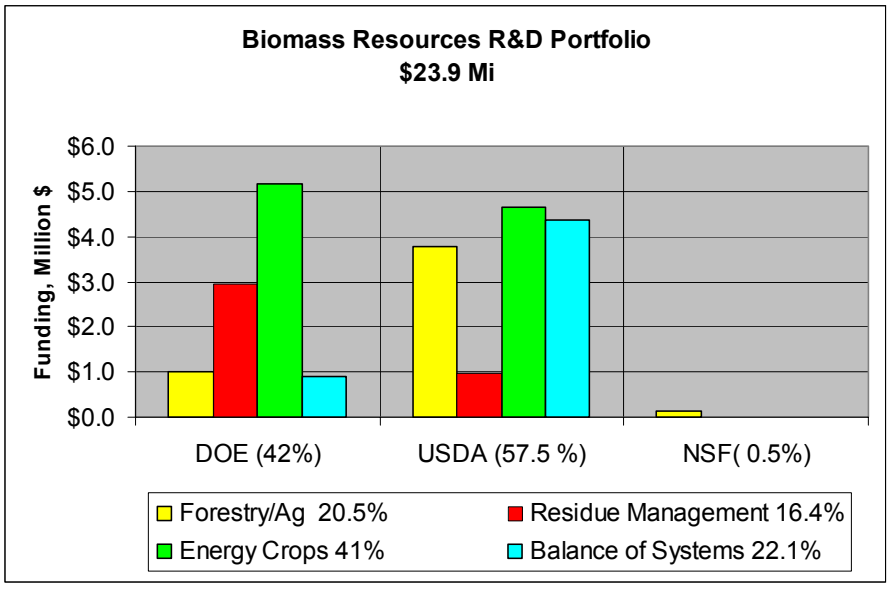
FY98 Funding Summary for Selected Technologies/Products					
		Funding in Million $			
	Total	DOE	USDA	NSF	EPA
Ethanol	$33.7	$25.6	$6.4	$1.3	$0.4
Hydrogen	$2.6	$2.5			$0.1
Biodiesel	$4.9	$3.1	$1.3	$0.4	
Pretreatment	$6.7	$3.0	$1.5	$2.2	
Enzymatic Hydrolysis	$7.1	$3.0	$2.4	$1.3	$0.4
Gasification	$8.2	$8.2		$0.0	
Cofiring	$4.5	$4.3	$0.2		

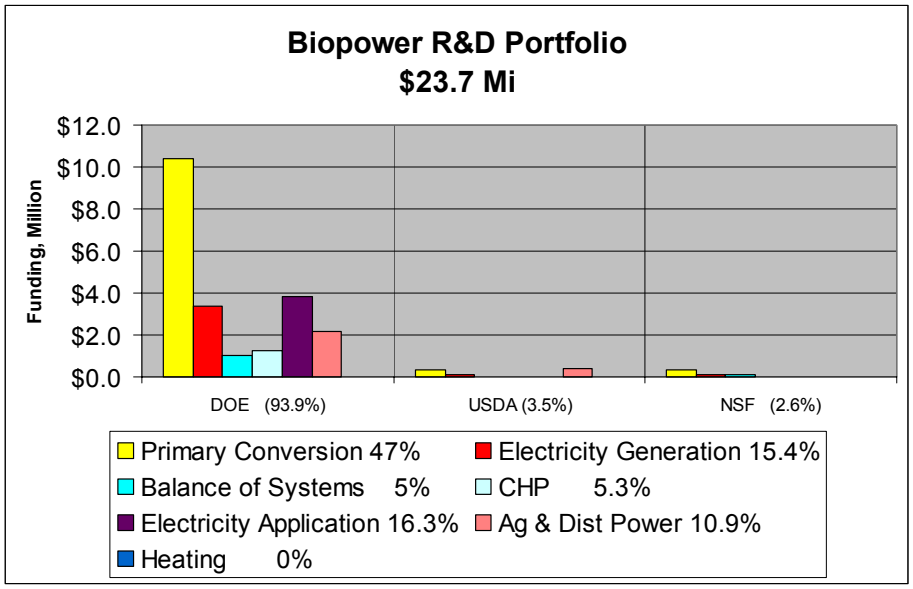
Other Federal Funding Relevant to Bioenergy

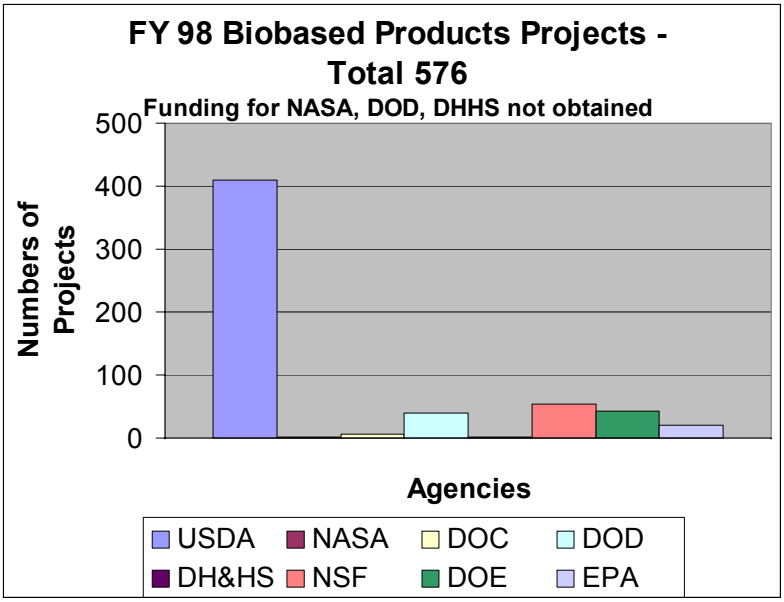
	Million $	%	Areas
DOE	15.7	17.7	Advanced turbine systems, fuel cells
USDA	43.5	48.8	Animal waste management, crop production
NSF	8.6	9.7	Basic science relevant to bioenergy
EPA	1.1	1.2	Ecology and environment
NASA	5.1	5.7	Bioregenerative Life Support system
NASA	5.0	5.6	Ecology and environment (DOD funding)
DOD	10	11.2	Applications, primarily methanol fuel cells
Total	89.1		

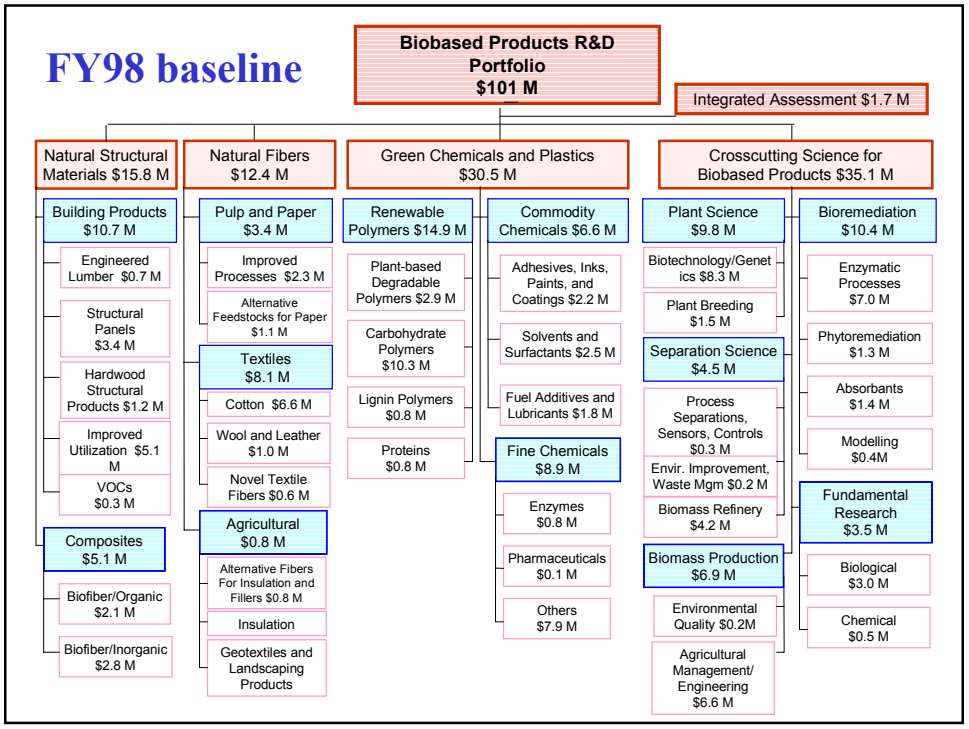


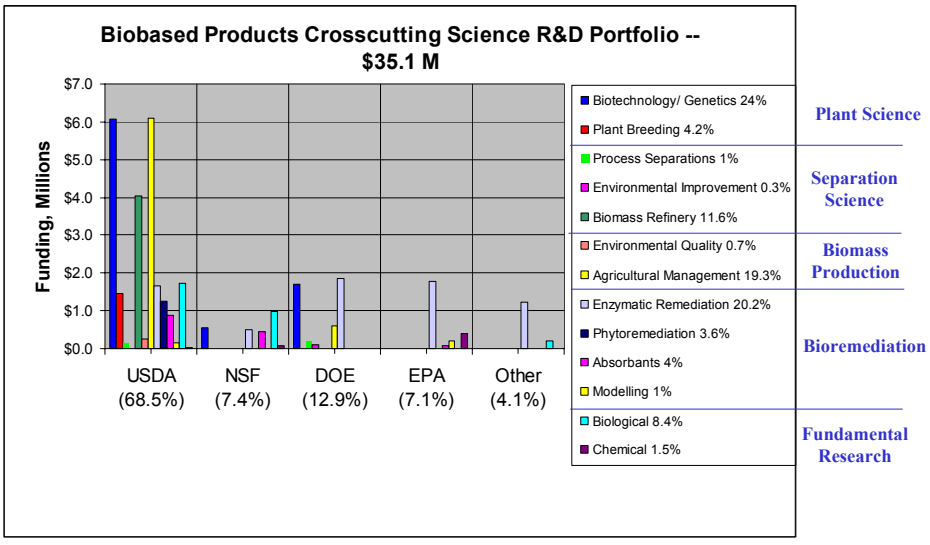

Biofuels R&D Portfolio
$47.5 Mi
Funding, Million $
$30.0
$25.0
$20.0
$15.0
$10.0
$5.0
$0.0
DOE (75.5%)
USDA (18.6%)
NSF (5.2%)
EPA (0.8%)
Primary Conversion 61.6%
Fuel Production 9.3%
Balance of Systems 5.3%
Applications/Use 22%
Infrastructure 1.8%

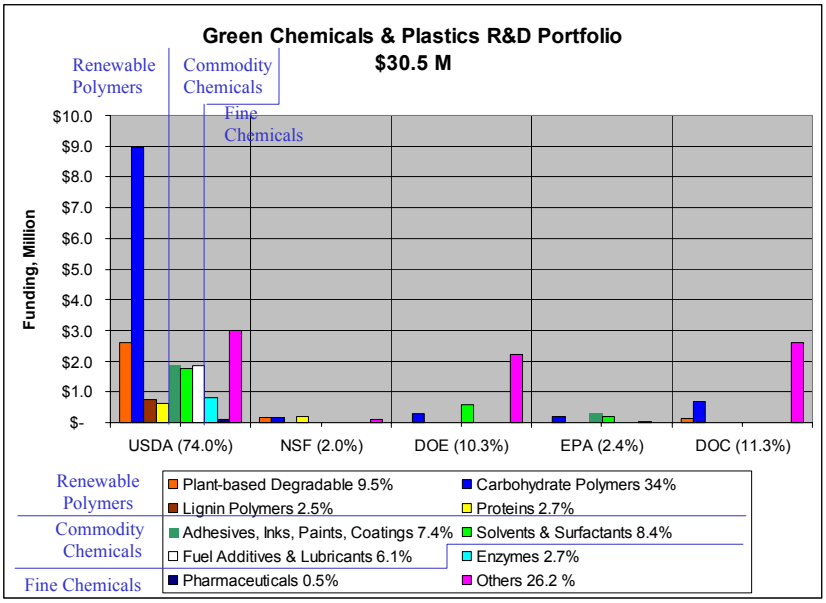

Biomass Resources R&D Portfolio
$23.9 Mi
Funding, Million $
$6.0
$5.0
$4.0
$3.0
$2.0
$1.0
$0.0
DOE (42%)
USDA (57.5 %)
NSF(0.5%)
Forestry/Ag 20.5%
Residue Management 16.4%
Energy Crops 41%
Balance of Systems 22.1%

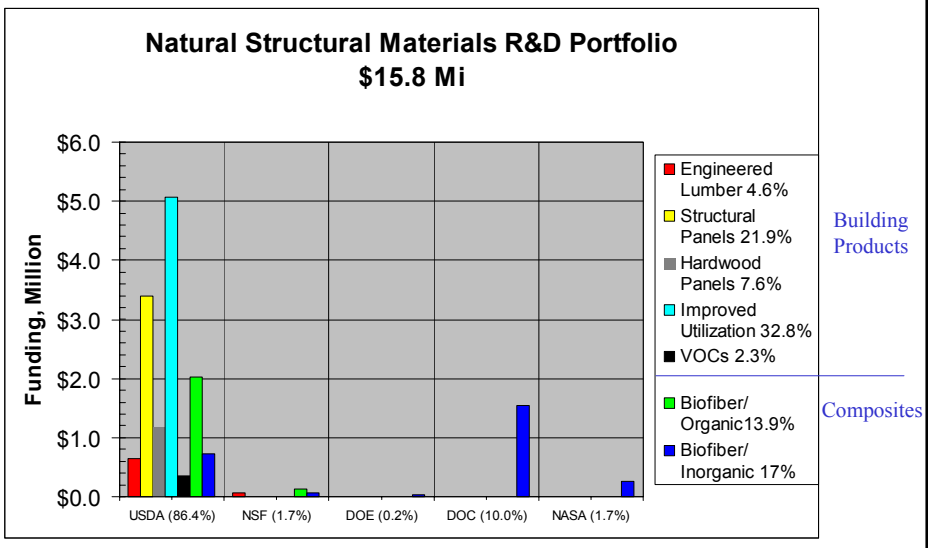

Biopower R&D Portfolio
$23.7 Mi
Funding, Million
$12.0
$10.0
$8.0
$6.0
$4.0
$2.0
$0.0
DOE (93.9%)
USDA (3.5%)
NSF (2.6%)
Primary Conversion 47%
Electricity Generation 15.4%
Balance of Systems 5%
CHP 5.3%
Electricity Application 16.3%
Ag & Dist Power 10.9%
Heating 0%

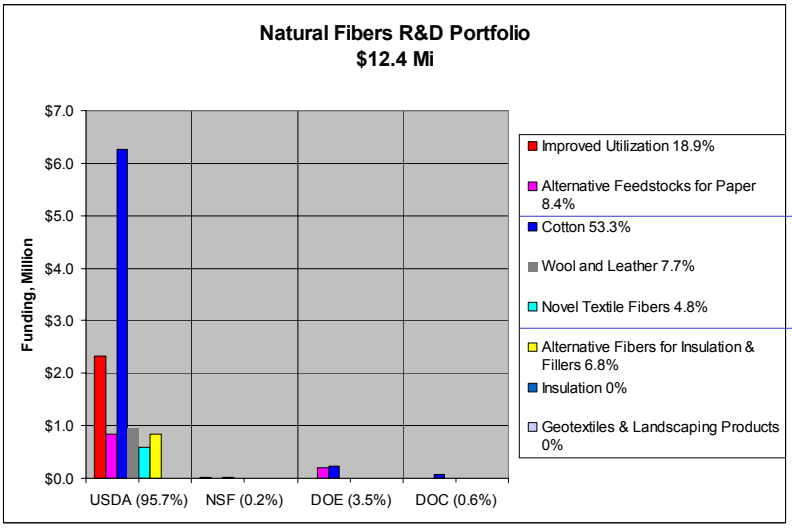

FY 98 Biobased Products Projects -
Total 576
Funding for NASA, DOD, DHHS not obtained
Numbers of Projects
500
400
300
200
100
0
Agencies
USDA
NASA
DOC
DOD
DH&HS
NSF
DOE
EPA

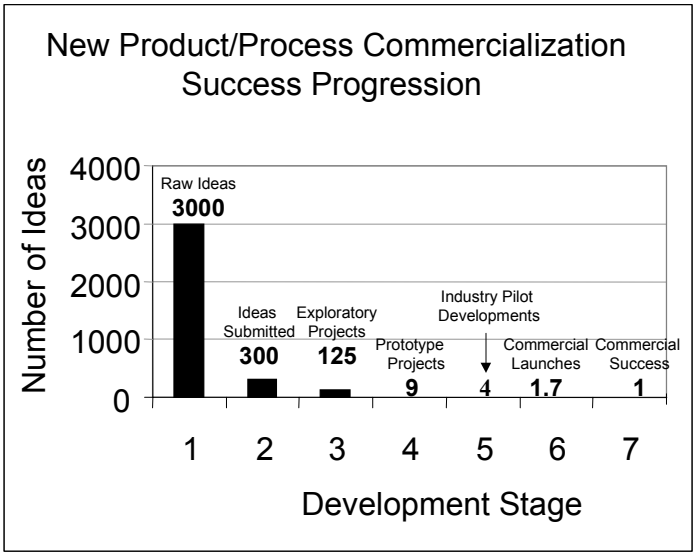

FY98 baseline
Biobased Products R&D Portfolio $101 M
Integrated Assessment $1.7 M
Natural Structural Materials $15.8 M
Natural Fibers $12.4 M
Green Chemicals and Plastics $30.5 M
Crosscutting Science for Biobased Products $35.1 M
Building Products $10.7 M
Engineered Lumber $0.7 M
Structural Panels $3.4 M
Hardwood Structural Products $1.2 M
Improved Utilization $5.1 M
VOCs $0.3 M
Composites $5.1 M
Biofiber/Organic $2.1 M
Biofiber/Inorganic $2.8 M
Pulp and Paper $3.4 M
Improved Processes $2.3 M
Alternative Feedstocks for Paper $1.1 M
Textiles $8.1 M
Cotton $6.6 M
Wool and Leather $1.0 M
Novel Textile Fibers $0.6 M
Agricultural $0.8 M
Alternative Fibers For Insulation and Fillers $0.8 M
Insulation
Geotextiles and Landscaping Products
Renewable Polymers $14.9 M
Plant-based Degradable Polymers $2.9 M
Carbohydrate Polymers $10.3 M
Lignin Polymers $0.8 M
Proteins $0.8 M
Commodity Chemicals $6.6 M
Adhesives, Inks, Paints, and Coatings $2.2 M
Solvents and Surfactants $2.5 M
Fuel Additives and Lubricants $1.8 M
Fine Chemicals $8.9 M
Enzymes $0.8 M
Pharmaceuticals $0.1 M
Others $7.9 M
Plant Science $9.8 M
Biotechnology/Genetics $8.3 M
Plant Breeding $1.5 M
Separation Science $4.5 M
Process Separations, Sensors, Controls $0.3 M
Envir. Improvement, Waste Mgm $0.2 M
Biomass Refinery $4.2 M
Biomass Production $6.9 M
Environmental Quality $0.2M
Agricultural Management/ Engineering $6.6 M
Bioremediation $10.4 M
Enzymatic Processes $7.0 M
Phytoremediation $1.3 M
Absorbants $1.4 M
Modelling $0.4M
Fundamental Research $3.5 M
Biological $3.0 M
Chemical $0.5 M


Biobased Products Crosscutting Science R&D Portfolio -- $35.1 M
Funding, Millions
$7.0
$6.0
$5.0
$4.0
$3.0
$2.0
$1.0
$0.0
USDA (68.5%)
NSF (7.4%)
DOE (12.9%)
EPA (7.1%)
Other (4.1%)
Biotechnology/ Genetics 24%
Plant Breeding 4.2%
Process Separations 1%
Environmental Improvement 0.3%
Biomass Refinery 11.6%
Environmental Quality 0.7%
Agricultural Management 19.3%
Enzymatic Remediation 20.2%
Phytoremediation 3.6%
Absorbants 4%
Modelling 1%
Biological 8.4%
Chemical 1.5%
Plant Science
Separation Science
Biomass Production
Bioremediation
Fundamental Research


Green Chemicals & Plastics R&D Portfolio
$30.5 M
Renewable Polymers
Commodity Chemicals
Fine Chemicals
Funding, Million
$10.0
$9.0
$8.0
$7.0
$6.0
$5.0
$4.0
$3.0
$2.0
$1.0
$-
USDA (74.0%)
NSF (2.0%)
DOE (10.3%)
EPA (2.4%)
DOC (11.3%)
Plant-based Degradable 9.5%
Carbohydrate Polymers 34%
Lignin Polymers 2.5%
Proteins 2.7%
Adhesives, Inks, Paints, Coatings 7.4%
Solvents & Surfactants 8.4%
Fuel Additives & Lubricants 6.1%
Enzymes 2.7%
Pharmaceuticals 0.5%
Others 26.2 %


Natural Structural Materials R&D Portfolio
$15.8 Mi
Funding, Million
$6.0
$5.0
$4.0
$3.0
$2.0
$1.0
$0.0
USDA (86.4%)
NSF (1.7%)
DOE (0.2%)
DOC (10.0%)
NASA (1.7%)
Engineered Lumber 4.6%
Structural Panels 21.9%
Hardwood Panels 7.6%
Improved Utilization 32.8%
VOCs 2.3%
Biofiber/ Organic13.9%
Biofiber/ Inorganic 17%
Building Products
Composites





G. Stevens & J. Burkey, 3000 Raw Ideas = 1 Commercial Success, Research Technology Management, Vol. 40 (3), 1997, pp. 16-27

4-22-00, Page 25

Stage of Development

1. Raw ideas generated*

2. Ideas developed from very small efforts (a person)

3. Small projects to explore ideas (1-3 persons)

4. Significant projects to verify ideas (10-20 persons)

5. Pilot scale development in industry

6. Full scale plant built and commercial sales

7. Plants working near capacity, economic profit in sight, sustainable competitive advantage

* Pharmaceuticals start with 8000 ideas

New Products/Processes are well analyzed by this relationship

- 3000:1 for new ideas
- 300:1 for when ideas become records of invention (sufficiently developed to file)
- 125:1 for exploratory projects
- 9:1 for prototype
- 4:1 for industry pilots
- 1.7:1 for commercial launches

New Products (improvements in existing products easier)

Snapshot of 1998 -- Stage of Development (Federal numbers approximate and private sector numbers are very rough estimates)	Estimated Number of Projects	Ratio to 1 market place success	Commercial Success Potential
300:1 for when ideas become records of invention (sufficiently developed to file)	200	300	0.7
125:1 for exploratory projects	250	125	2.0
9:1 for prototype	125	9	13.9
4:1 for industry pilots (rough estimate)	75	4	18.8
Seeding Potential Commercial Successes	650		35.3

Projects seed new ideas for future year developments in various categories

FY 98 Bioenergy Direct Projects by Phase of Research (Estimated) $152 Million (65.8% DOE, 27.7% USDA)

Phase	Estimated # Projects
Basic Research	400
Exploratory Projects	380
Development Projects	30
Pilot Developments in Industry	12
Integrated Assessments	28
Total # Projects	850

Table 2. Federal Bioenergy Portfolio Viewed from the Viewpoint of Commercialization Potential Using G. Stevens & J. Burkey, 3000 Raw Ideas = 1 Commercial Success, Research Technology Management, Vol. 40 (3), 1997

	Snapshot 1998		Estimated Future Seeds	
Phase	Estimated # Projects	# Potential Commercial Success	Will Generate # Raw Ideas	# Potential Commercial Success
Basic Research	400		4000	1.3
Exploratory Projects	380	3.0	1140	0.38
Prototype or Process Development Projects	30	3.3		
Pilot Developments in Industry	12	3.0		
Commercial Launch	0			
Integrated Assessments	28			
Total Projects and Upper Limit of Success Potential	850	9.4		1.7

Since bioenergy products are not necessarily cost competitive with fossil energy sources, these probabilities are upper estimates. Portfolio of FY98 could be seeding about 5 potential commercial successes.

Inventory based on review of abstracts compared to selected programs

- Inventory identified government programs that support biobased products and bioenergy although these are not their central activities. These are listed in the Appendix I of the Strategic Plan.
- Grant programs provide funding based on specific area requests and also more general calls. Principal investigators propose to multiple programs in the federal government. Inventory detects projects that would be missed by calling specific Federal program managers and asking for funding information.
- How to integrate across direct and support programs?

Examples of DOE R&D Changes FY1998 - FY2001

Technology	FY98	FY01
Gasification	$ 8.2 Mi	$22.4 Mi ~60% black liquor
Cofiring	$4.5 Mi	$12.9 Mi
Pretreatment/ Sugars Platform	$5 Mi	$14.6 Mi

Examples of USDA Changes FY98 to FY01

- Major support for commodities use for biofuels -- ethanol and biodiesel
  - $150 Mi Commodity Credit Corporation
- Support for the evaluation of the use of CRP lands for crops for bioenergy
  - 4 projects already announced (IA, NY, MN, and PA)
- Modest R&D gains

NSF Changes FY98 to FY01

- Plant Genome support increased
- Proportion of projects that support biobased products and bioenergy increasing

Interagency Collaboration Examples and Success Factors

Lynn Wright
DOE National Bioenergy Center

USDA cost-sharing crop research with DOE's Bioenergy Feedstock Development Programs (BFDPs) managed by ORNL

- Forest Service: North Central Station
  - 6 research projects, 1 industry/gov research co-operative
- Forest Service: Southern Station
  - 2 research projects, 1 industry/gov research co-operative
- Agricultural Research Service: Lincoln, NE lab
  - 3 projects of which two involve multiple ARS research sites
- Natural Resource Conservation Service: Plant Materials Centers
  - 1 project involving five centers distributed around the U.S.
- Some BFDP university contracts also involve USDA research collaboration

Characteristics of the USDA & ORNL crop research project collaborations

- USDA contributes unique expertise, facilities analysis & management leadership
- DOE/ORNL contributes $$ to USDA for materials, temporary staff, & subcontracts
- Projects address program interests of both agencies
- Interagency Agreements (IAG's) are used as vehicle for collaboration

USDA joint analysis and implementation efforts with DOE/ORNL

- Forest Products Lab
  - joint analysis of woody crop market penetration
- USDA Office of Energy
  - joint modification and use of USDA's Agricultural Demand Sector model (POLYSYS)
- USDA Resource Conservation Districts
  - managers and collaborators on 2 Biomass Power for Rural Development integrated projects and 1 woody crop scale-up trial
- USDA Economic Research Service
  - informal collaborations
- USDA Farm Services Agency (planned)
  - 2 or 4 new bioenergy projects

Characteristics of the USDA & ORNL joint analysis and implementation efforts

- Both USDA and DOE/ORNL contribute expertise
- DOE/ORNL may or may not contribute $$ to USDA for subcontracts & materials
- Collaborators are usually drawn together as a result of common interests and networking
- Both IAG's and informal agreements are used as vehicles for collaboration

Other DOE Lab Collaboration Examples

- DOE lab (ORNL and NREL), Forest Service, university and industry projects funded by DOE's Office of Industrial Technologies and DOE's OBER
  - Marker-aided Selection of hybrid poplars and loblolly pine
  - Carbon allocation in roots and stems of hybrid poplar
- ORNL, Tennessee Valley Authority, and multiple university collaborations
  - Environmental effects of energy crop production systems in south
- NREL & ORNL collaboration with USDA NRCS, ARS soils labs & Colorado State University
  - Life cycle assessment of corn stover to ethanol
- NREL staff have chaired and participated in CSREES NRI panels and projects

Factors contributing to successful collaboration

- Each partner's contribution is recognized, valued, and documented in presentations and publications
- Coordinated planning occurs annually or more frequently
- Ideas, results, and problems are discussed frequently by phone and e-mail
- Papers and reports are co-authored by staff from all partner groups.
- Reciprocal participation in program/project reviews and workshops occurs at least occasionally
- Exchange of $$ (even small amounts) helps considerably

Ongoing collaborations Federal level

- Interagency Working Groups
- Memorandum of Understanding documents
- Joint planning (e.g., Strategic Plan)
- Joint Advisory Boards (e.g., Biomass R&D Technical Advisory Committee)
- Joint Reports to Congress
- Jointly sponsored national meetings, networking
- Joint and complementary solicitations
- Staff exchanges

Collaboration options at the individual PI and project level

- Joint proposal development (new $$)
- Coordination of separate project efforts (existing $$)
  - R&D in similar areas with enhanced info exchange
    - meeting networking, exchanging papers, exchanging pre-print info
    - frequent informal exchanges - phone and e-mail
    - co-authoring papers from independent R&D
  - R&D in similar areas modified to complement other work and expand overall scope of effort
    - discussions annually at planning stages
    - frequent informal info exchange
- Join or form government/university/industry cooperatives & consortia
- Staff exchanges and sabbaticals (sponsor $$ required)

Collaboration across technologies and across stages of RD&D

- Integrated projects with multiple stakeholder participation
  - Biomass Power for Rural Development Projects
  - Several DOE Office of Industrial Technologies projects
- "R&D Centers" with multiple technology elements, vehicles for info exchange, and linkages with industry.
- Cross technology & cross RD&D stage teaming may continue from bottom up, structure rewards to encourage.
- Extensive education & outreach to all stakeholders with a focus on promising regions or localities.
- Cross agency/lab/program/project reviews & workshops.
- Federal labs partnering with land grant universities for integrated R&D and technology transfer to agricultural communities.

RENEWABLE DIESEL PROJECT

Nohemi Zerbie, DOE Office of Transportation
& K. Shaine Tyson, NREL

NBC Strategic Partnerships Workshop

April 11-12, 2001

Operated for the U.S. Department of Energy by Midwest Research Institute • Battelle • Bechtel

Program Goals

All projects meet one or more of the following:

- **Reduce the cost of renewable diesel**
- **Expand the supply**
- **Reduce barriers to expanded use**

Budget Status

- **FY 1997 - 2001 Annual Budget = $750,000**
- **FY 2002 + ?**

Renewable Diesel Fuels

- **Biodiesel**
  - Program R&D focus since 1977
- **Fischer Tropsch Fuels**
  - Evaluation of wax producing facilities with satellite cracking facilities
- **DME (di methyl ether)**
  - evaluation of propane blending and/or replacement potential
- **Ethanol-diesel blends**
  - technical support to other programs
- **Other (pyrolysis oils, DMM, DEE, alcohols….)**
  - technical evaluation

Biodiesel Project

- **Priority focus**
  - Feedstock expansion and feedstock cost minimization
  - Goals
    - 6-10 billion gallons of oil at 10 cents/lb
    - Expanding markets for meal worth 15 cents/lb or more
- **All other projects**
  - Improve technology and reduce production costs
  - Reduce market barriers
  - Expand outreach

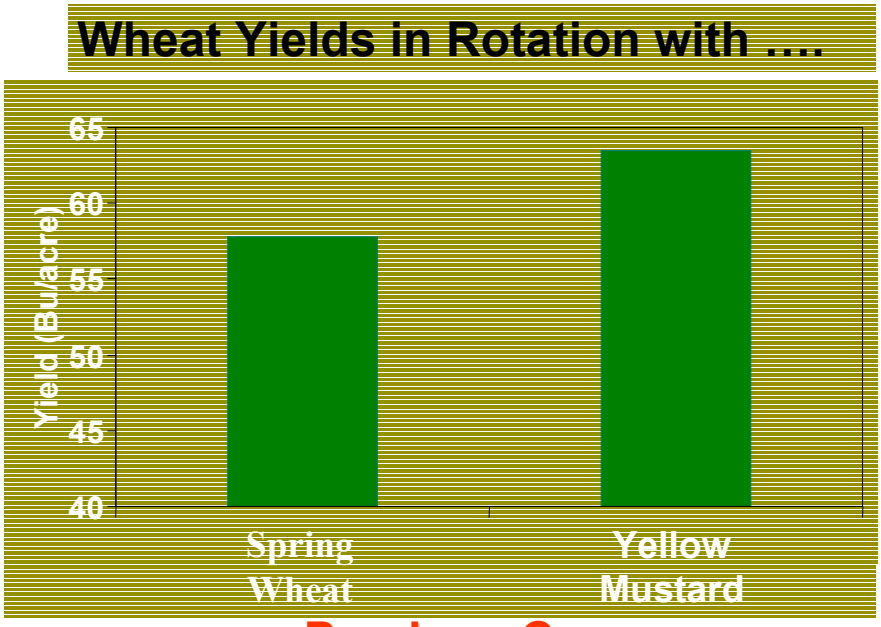
Biodiesel Production Costs

Capacity mil gal/yr	Feedstock type	Feedstock ¢/lb	FFA %	Total Cost Biodiesel $/gal ± 0.10
10	Soy	25	<1	2.36
10	Soy	17	<1	1.66
10	Yellow grease	10	<10	1.12
10	Trap grease	<5	>50	0.76
10	Mustard	10	<2	1.05

Batch processing, wet salty glycerin @ 15 ¢/lb, full capacity costs, ROR=15%

Brassica Crops

- Meal has Allelopathic compounds
- Broad-leaf crop with high biomass
- Large tap root
- Low production costs, low inputs
- Good yields in dry land farming conditions
- Yields optimization untapped potential
- Seed oils 25% to 40%
- Oils have good biodiesel qualities
- Excellent rotational benefits
- Planted and harvested with wheat equipment



Glucosinolates in *Brassica*

Species	Roots	Leaves	Seed meal
	---------- µmol/g ----------		
B. napus	5.3	8.6	99.4
B. rapa	4.6	7.4	93.0
B. juncea	10.2	18.1	216.4
S. alba	12.3	15.3	244.1

Why Organic Pesticides

- **Sustainable**
- **Internationally competitive**
- **Environmentally friendly**
- **Fewer commercial chemicals available**
- **High value market**
- **Expanding markets worldwide**

Glucosinolates in *Brassica*

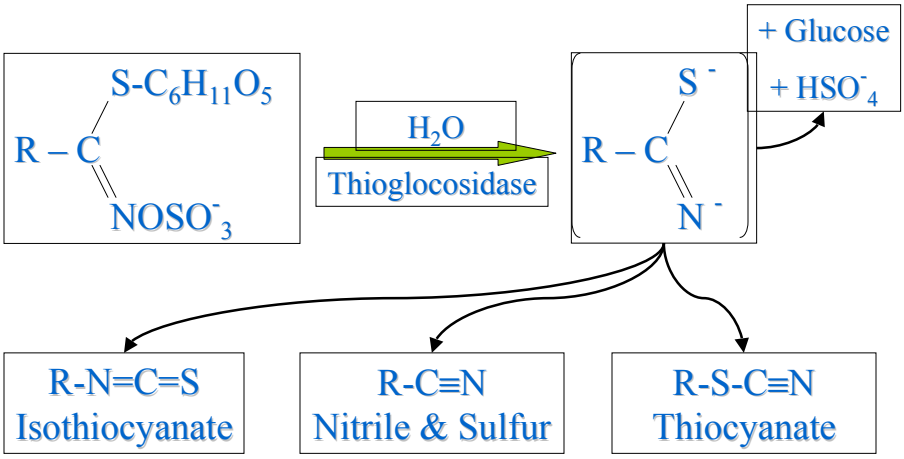
- **Isopropyl**
- **Allyl**
- **3-butenyl**
- **4-pentenyl**
- **2-OH-3-butenyl**
- **3-OH-4-pentenyl**
- **OH benzyl**
- **phenylethyl**
- **3 methylindolyl**
- **4-OH-3 methylindolyl**

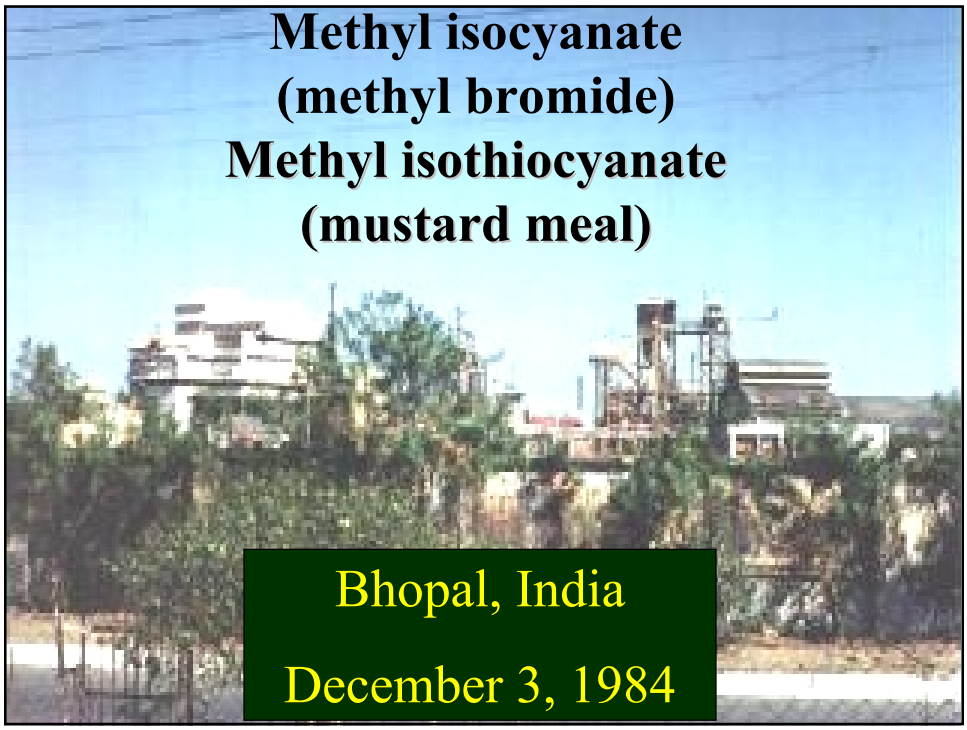
Allyls have fungicide value
Butenyls have herbicide value
Pentenyls have insecticide value

Little is known about other 200 glucosinolates

Some glucosinolates have been shown to be potent anit-carcinogenic compounds in laboratory animals.

Glucosinolate Breakdown

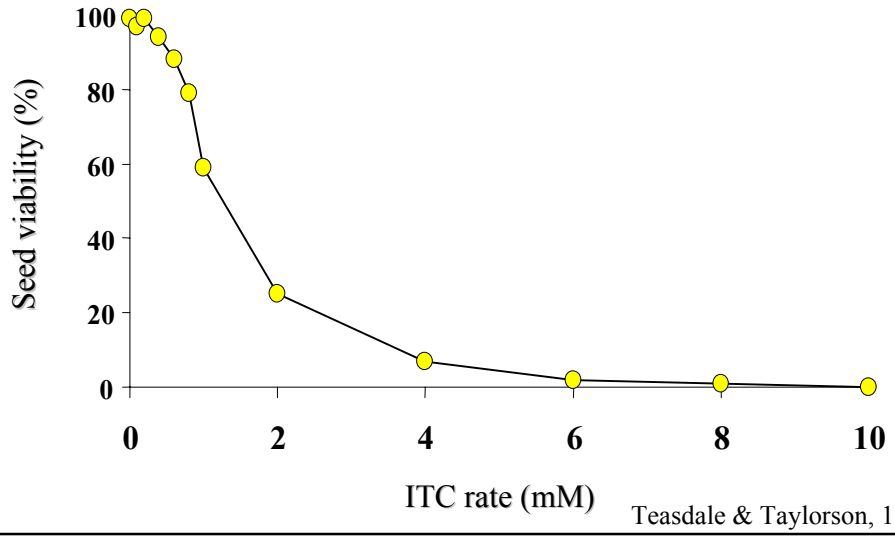




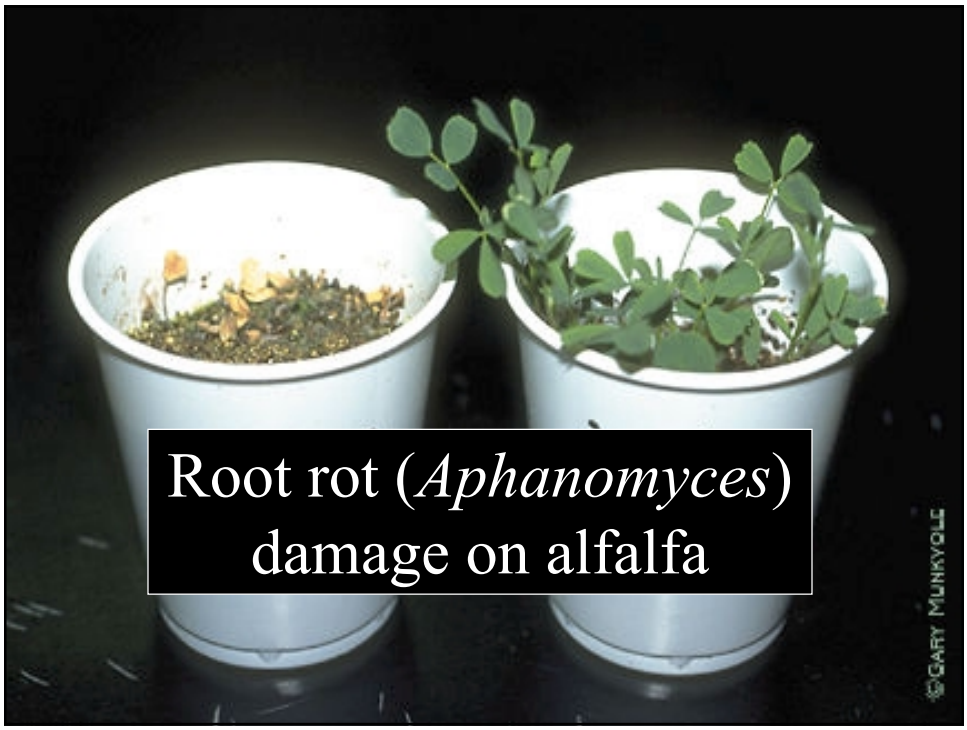
- **Many US crops require chemical soil fumigation**
- **Fumigation costs in excess of $3500 per acre**
- **EPA made methyl bromide illegal in 2000**
- **No commercially viable substitutes widespread**

Methyl Bromide Soil Fumigation

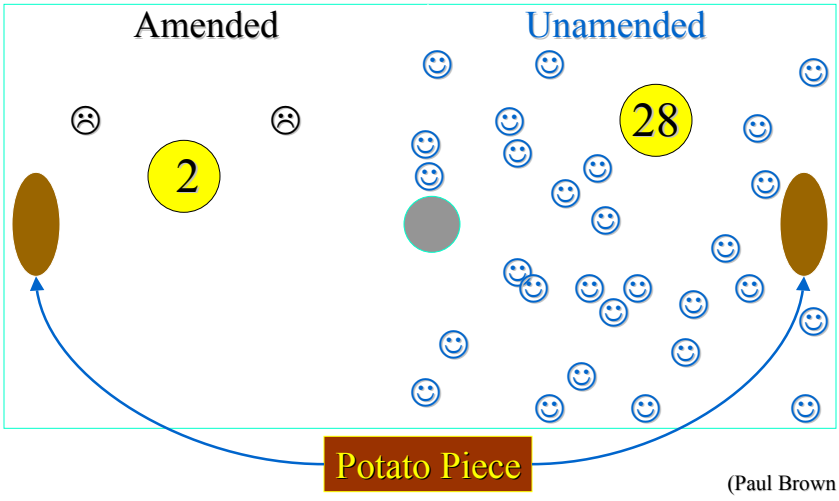
Effect of isothiocyanate on of crab grass



Teasdale & Taylorson, 1986

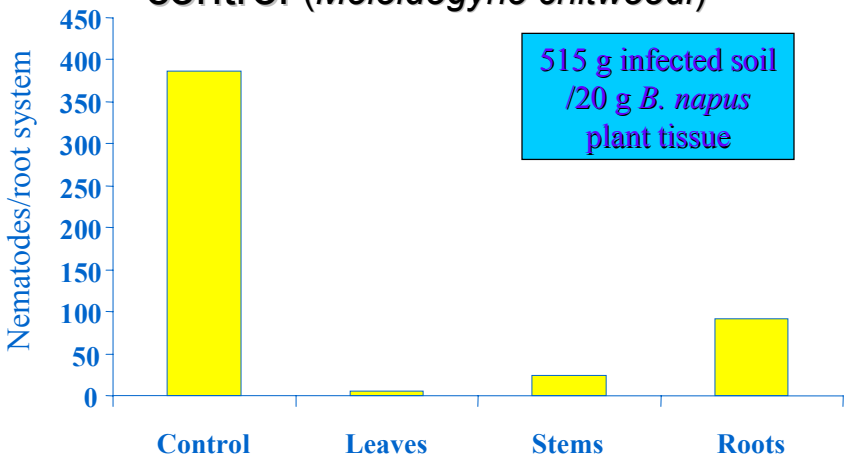


Wireworm (*Limonius infascatus*) movement

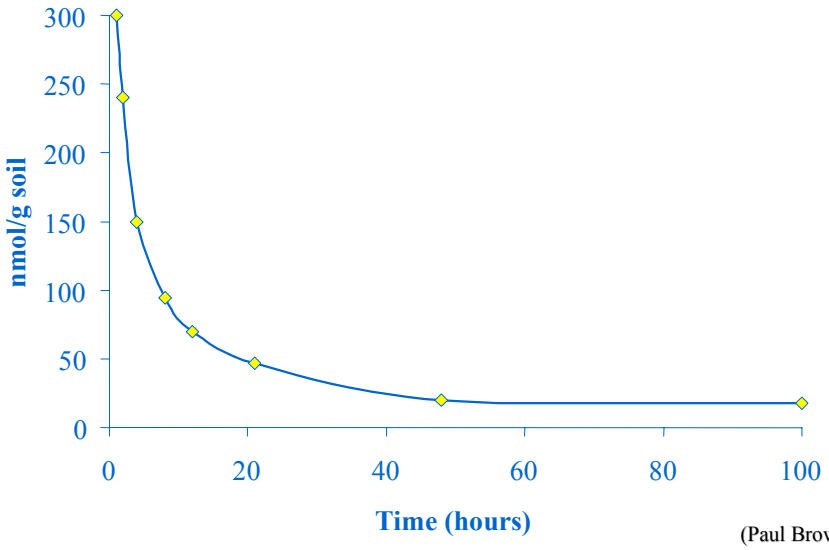


(Paul Brown et al.)

Columbian root-knot nematode control (*Meloidogyne chitwoodi*)



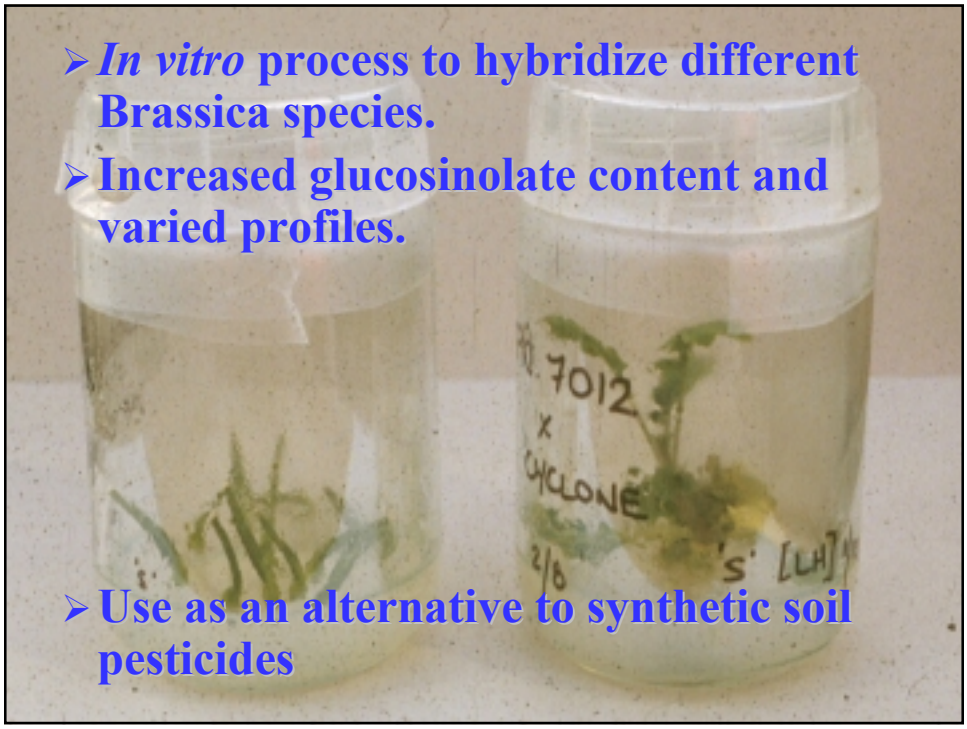
Isothiocyanates in Soil



(Paul Brown et al.)

What do we have so far?

- Glucosinolates concentrate in the meal
- Glucosinolate breakdown products kill agricultural pests
- Different *Brassica* species produce different glucosinolates
- Byproducts from specific glucosinolates have unique impacts on specific agricultural pests



- ***In vitro*** **process to hybridize different Brassica species.**
- **Increased glucosinolate content and varied profiles.**
- **Use as an alternative to synthetic soil pesticides**

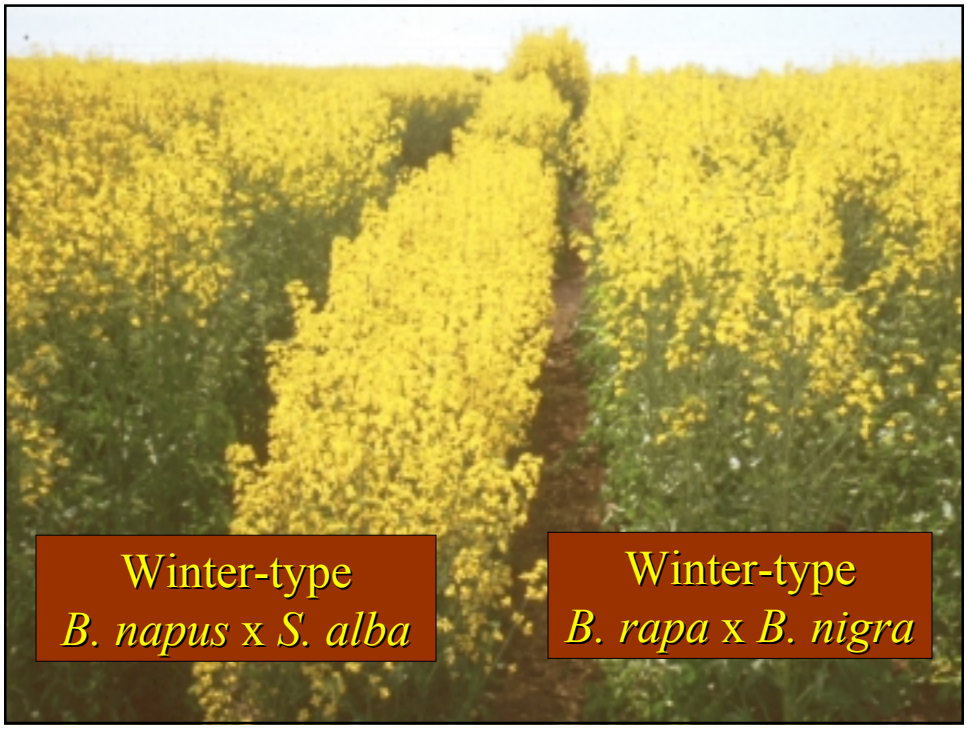

Mustard meal powder can be used directly on soils as a pesticide


Byproduct mustard oils have little or no other commercial value except for biodiesel if pesticides are major product line

Mustard Project

Develop varieties of mustard seed with:

- 25 - 40% oil content (closer to 25%)
- Oil with 90% monosaturate content
- Oil with eurcic acid > 2% and <20%
  - Inedible and not a animal feed oil, no high industrial value
- 2 tons seed per acre or more
- Low inputs (e.g., seed production costs ~ 7 cents/lb)
- Meal contains >500 µmoles/gm specific types of glucosinolates
  - Fungicide variety
  - Herbicide variety
  - Pesticide variety (nematode, wire worms, cut worms…)
- Meal value 15 cents/lb or higher
- Meal is cost competitive with commercial pesticide brands and equally effective at control



Fatty Acid Profiles

Species	Fatty Acid Profile						
	16:0	18:0	18:1	18:2	18:3	20:1	22:1
Canola	4.7	1.9	65.4	19.3	7.3	1.1	0.0
Rapeseed	2.5	0.7	11.4	10.6	9.1	5.4	55.7
H. mustard 1	4.1	3.1	40.3	7.8	1.7	6.4	25.5
H. mustard 2	2.5	2.4	56.3	5.5	2.2	4.5	20.7

Seed Meal Glucosinolate Content

Species	Total Gluc's	% Humus
B. napus 'Humus'	99.4	100.0
B. nigra x *B. rapa*	516.1	519.2
S. alba x *B. napus*	451.0	453.7

Glucosinolate Profile

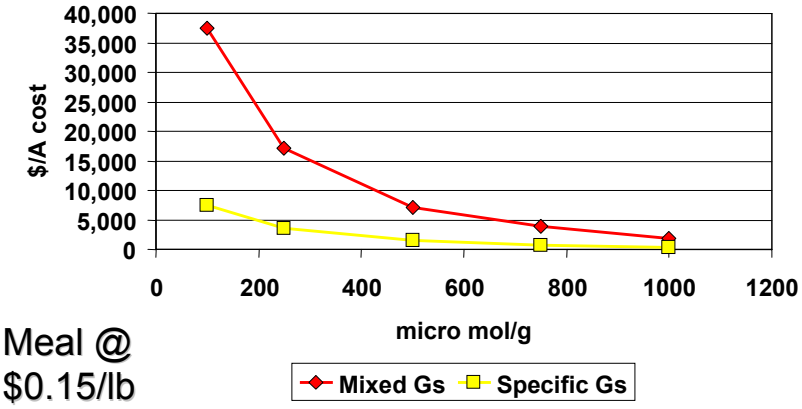
Glucosinolate Type	*B. napus* Humus	*B. nigra* x *B. rapa*	*S. alba* x *B. napus*
Allyl	0.0	205.0	0.0
3-butenyl	13.2	197.8	0.0
4-pentenyl	43.7	48.7	1.8
2-OH-3-butenyl	30.5	61.6	19.6
OH-benzyl	0.0	0.0	290.6
Phenylethyl	5.3	1.4	1.8
3-indolyimethyl	6.6	Trace	120.9
4OH3-indoylmethyl	Trace	1.4	16.1

Drive Down Application Rates

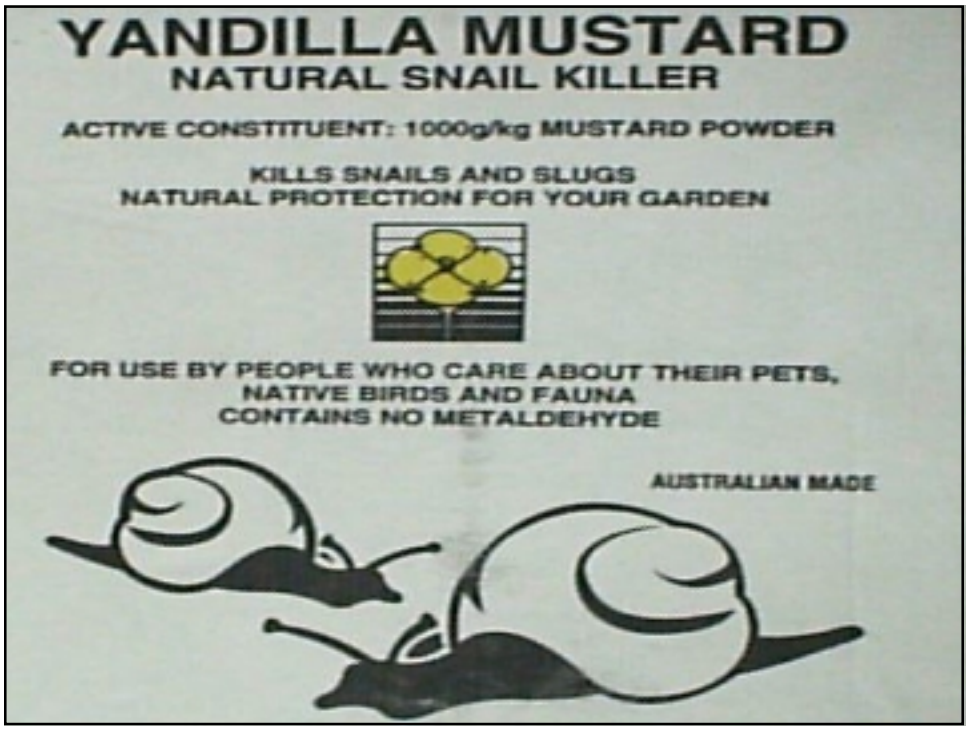
Species	Seed meal -- µmol/g --	25.0 g/m^2 - ton/acre -
B. napus	99.4	124.7
B. juncea	216.4	57.3
S. alba	244.1	57.3
B. rapa x *B. nigra*	516.1	24.0
S. alba x *B. napus*	451.0	27.5

Assume 19% of glucsinolate goes to isothiocyanate.

Glucosinolate Content vs Cost



Meal @ $0.15/lb



Isothiocyanate Extraction

Out-Year Mustard R&D

- **2001**
  - **Multi-state hybrid trials in PNW with 60 varieties**
  - **Agronomics, rotation benefits, input variation**
  - **Glucosinolate optimization, fatty acid optimization**
  - **Market analysis**
  - **Registration analysis**
- **2002**
  - **pesticide demonstration trials with industrial partners**
  - **pesticide registration R&D**
  - **Kansas and Georgia regional breeding trials**
  - **breeding work continues for optimization**

Reduce Biodiesel Costs

- **Biodiesel Technology Analysis**
  - Soy and yellow grease feedstocks
  - 3, 10, 30 mil gal/yr scales
  - baseline info on technology and costs
- **Waste Grease Composition and Pretreatment**
  - 45 samples analyzed, FFA range from 40% to 100%
  - Other impurities minor, good conversion potential
- **Trap Grease to Biodiesel Feasibility and Demonstration**
  - Demonstrate 99% conversion of 60-90% FFA feedstocks to ASTM quality biodiesel at reasonable cost
  - Consortium of regulators, sewage treatment plants, biodiesel producer, and trap grease collectors.

Barriers Projects

- **NOx Project**
  - Identify root cause of higher NOx emissions
    - polyunsaturated fatty acids
  - Identify specific pathways of NOx in combustion chemistry
    - 1 degree timing advance due to different fuel compression characteristics
    - Other factors underway
  - Identify additives that prevent NOx increase in biodiesel
    - 1% DTBP makes B20 NOx neutral with petro diesel
    - other additives being tested

Barriers Projects

- **Urban Air Quality Model Data**
  - B20 and B100 data for Mobile 5/6, OTAG, CARB models
  - SIP analysis of B20 options (PM, CO, Ozone)
- **Oxidative Stability Test Methods**
  - Recommended 3 test methods for further development
  - Refine test methods for B20 and B100
  - conduct round robin
  - ASTM inclusion
- **Life Cycle Analysis of Grease and Fat Biodiesel**
  - Partnership with Fats and Protein Research Foundation

New Markets R&D

- **Heating Oil Technology Assessment**
  - Evaluate the technical parameters for biodiesel blends with heating oil in residential and commercial boilers
  - Partners: NYSERDA, NBB, Griffin Industries, Brookhaven
- **Warwick School Dist. Demonstration**
  - Evaluate 3 biodiesel heating oil blends (10%, 15%, 20%) in three public school buildings boilers over 12 months
  - Partners: Global Companies, Brennan Oil, Rhode Island Energy Office, Warwick School District, Advanced Fuel Solutions, World Energy
- **Locomotive Emissions from B20**
  - raw data completed, report expected this year
  - Partners: CSX railroad, CARB, AAR

Outreach and Education

- **Production Accreditation**
  - **Develop 4 college level classes on biodiesel**
    - **Introduction to Biodiesel**
    - **Biodiesel Analytical Methods**
    - **Biodiesel Technology**
    - **Biodiesel Business Management**
- **Petroleum Infrastructure**
  - **Outreach with petroleum distribution industry (PMAA, …)**
  - **Analysis of integration costs**
  - **Heating oil industry outreach**
- **Annual R&D Mtg (Feb, 2001)**
- **5-6 Regional Workshops (late FY 2001)**