Bioenergy and Biobased Products

U.S. Departments of Agriculture and U.S. Department of Energy Programs

and Other Related Government Programs and Activities

Background Materials for the DOE National Bioenergy Center Strategic Partnerships Workshop April 11-12, 2001 Colorado

Bioenergy and Biobased Products

U.S. Departments of Agriculture and U.S. Department of Energy Programs and Other Related Government Programs and Activities

Background Materials

Table of Contents

Topic	Page Number	Contact Person
Strategic Plan Bases for Plan	1-18	Doug Kaempf – DOE (202) 586-5264 Ron Buckhalt – USDA (301) 504-6905 Helena Chum – NREL (303) 275-2949
Agriculture – Introduction	19-20	
USDA – Agricultural Research Service (ARS) – Product Quality/New Products & Processes (#306)	21-34	Frank Flora – 301-504-6245
USDA – ARS – Energy Research (#307)	35-56	Don Erbach – 301-504-4610
USDA – Cooperative State Research, Education and Extension Service (CSREES) programs	57-69	Hongda Chen – 202-401-6497
USDA – Forest Service Programs	70-80	Howard Rosen – 202-205-1557
USDA – A Systematic Approach to Developing Biobased Products and Bioenergy Markets	81-83	Marvin Duncan – 202-401-0532
Energy – Introduction	84-93	
DOE – Biopower Program	94-104	Raymond Costello – 202-586-4898
DOE – Biofuels Program	105-115	Valerie Sarisky-Reed – 202-586-5618
DOE – Industries of the Future - Agriculture - Forest Products	 116-133 134-143	Mark Paster – 202-586-2821
DOE – Energy Biosciences	144-149	Greg Dilworth – 301-903-2873
Environmental Protection Agency Programs	150	
Pollution into Products: Demand-Based Climate Mitigation	151-167	Donn Viviani – 202-260-2767
Other Government Programs not featured	168	

Bioenergy and Biobased Products U.S. Departments of Agriculture and Energy Programs

Background Materials

Strategic Partnerships Meeting

hosted by the

DOE National Bioenergy Center

at National Renewable Energy Laboratory

Colorado, April 11-12, 2001

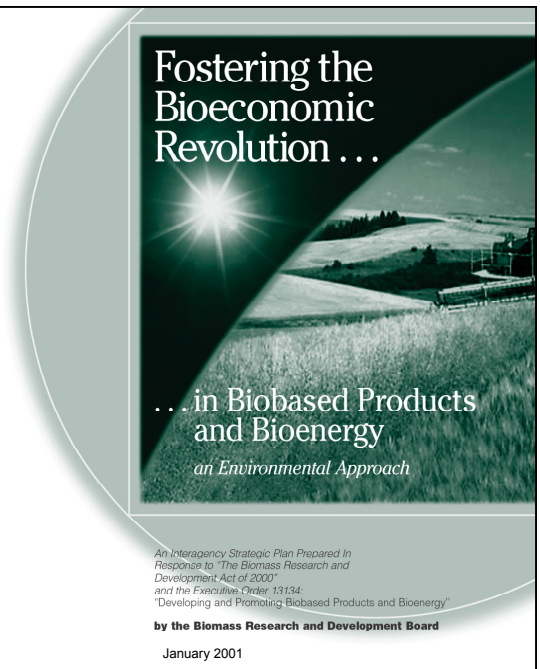
Some Reading Materials

- http://www.bioproducts-bioenergy.gov/
  - Biomass R&D Board Activities
  - Board Strategic Plan
  - Biomass R&D Technical Advisory Committee
  - Publications - Report to the President
  - Biomass Research and Development Act of 2000

Biomass Research and Development Board
Co-chairs
USDA
DOE

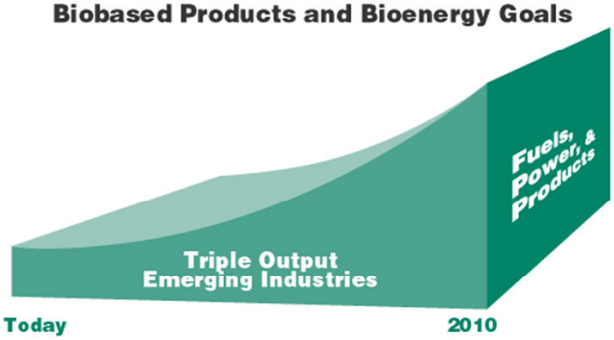
Member Agencies
NSF
EPA
DOI
OSTP

Participating Agencies
DOC
FEE
OMB
Treasury
TVA



See: http://www.bioproducts-bioenergy.gov

Biobased Products and Bioenergy Goals



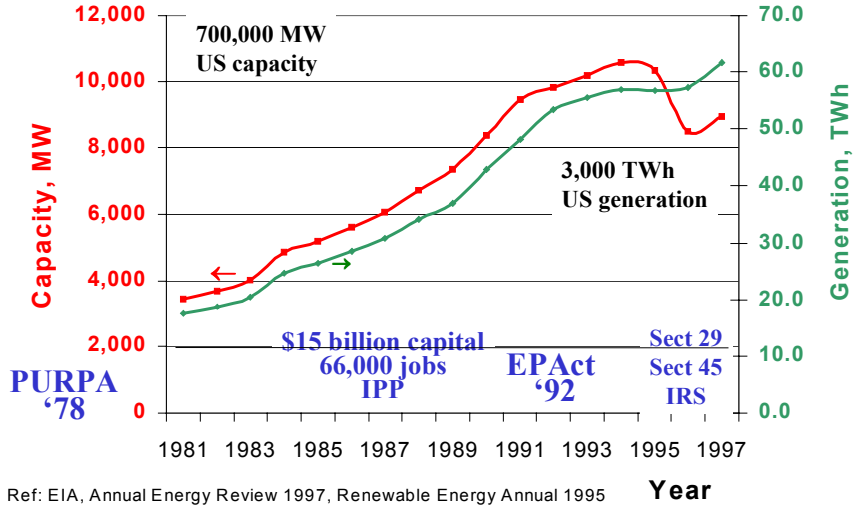
Current baseline for emerging industries:
- ethanol, 1.5 billion gallons
- biodiesel, 6 million gallons
- electricity, 60 billion kWh (from 10 thousand megawatts of capacity)
- emerging products, 10-15 billion pounds (5 - 7.5 million tons).

Figure 1. Biobased Products and Bioenergy Goals: Consistent with federal resource conservation and environmental policies, triple output of emerging industries in fuels, power, and products and facilitate an increase in efficiency of use in mature industries, with special attention to application of new and emerging technologies. (Note: triple refers to specific fuels, power, and products output or any combination)

Baseline

Bi kWh=TWh

Bioenergy Electricity Generation, 1981 - 1997

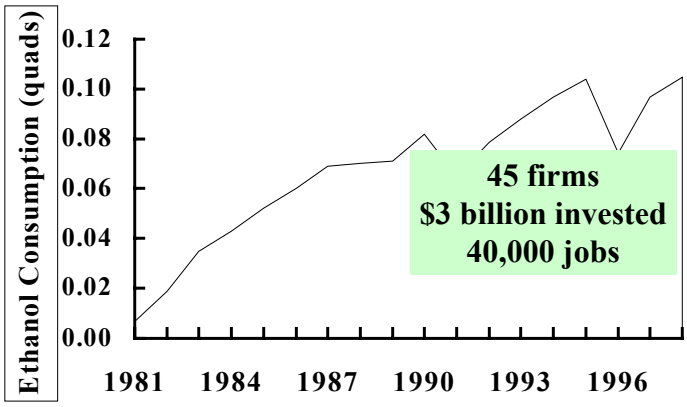


Ref: EIA, Annual Energy Review 1997, Renewable Energy Annual 1995

Portugal: 9,000 MW; 39 TWh; UK: 69,700 MW; 343 TWh

NREL

Baseline
Historical Ethanol Consumption



1.5 billion gallons or equivalent to 1% of gasoline with ethanol from cornstarch

~$750 million/yr excise tax exemption '99

Replace MTBE?

2000 installed capacity about 2.25 billion gallons

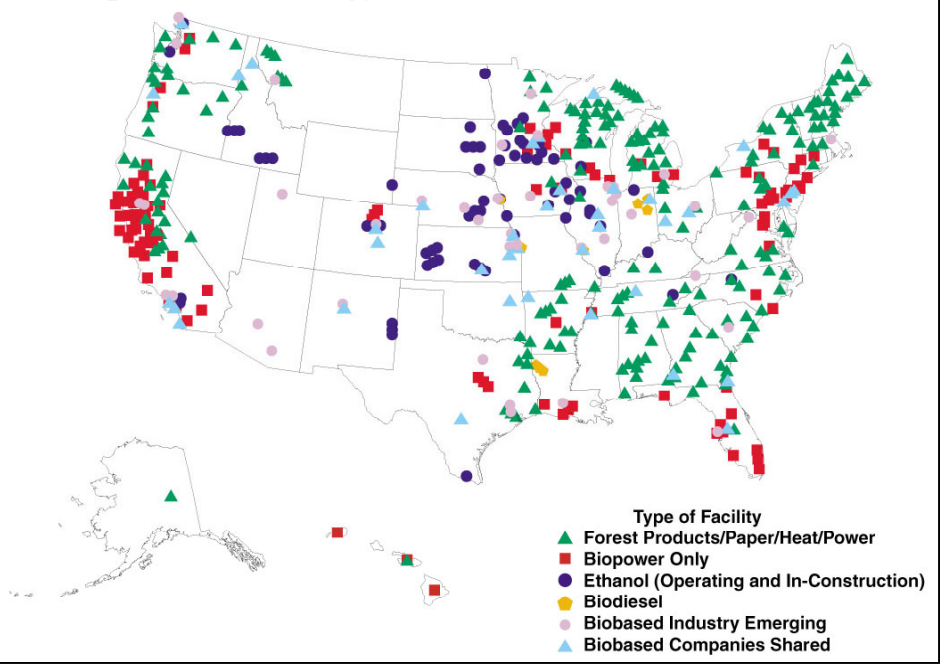
Ref: Energy Information Administration, http://www.eia.doe.gov/pub/energy.overview/aer98/txt/aer1003.txt

Ethanol in Brazil 2-3 times U.S. volume

TABLE 1 Biobased Products Categories and Examples

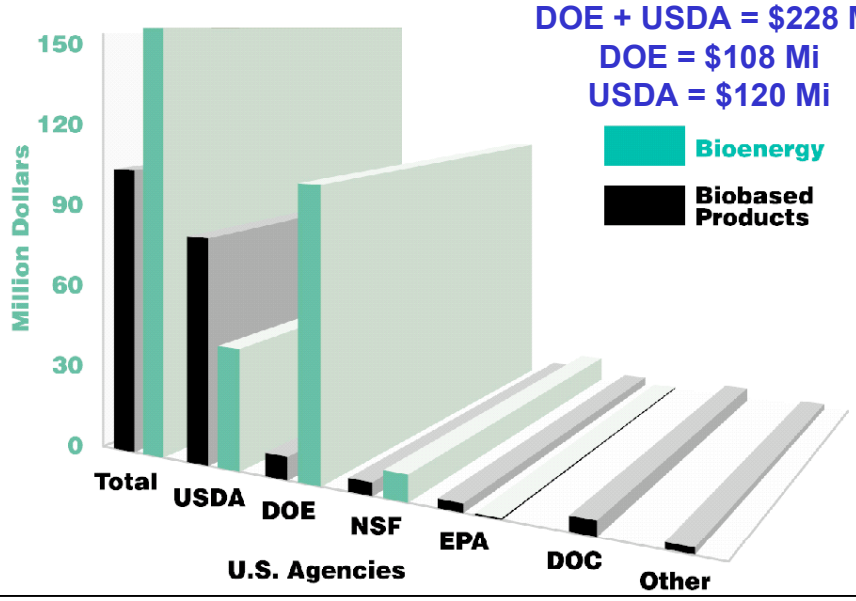
Number	Product Category	Examples of Biobased Products
	Established Biobased Industry	
1	Paper and packaging	Writing papers, newsprint, magazines, and packaging cartons
2	Wood-based composite materials and structures	Lumber, plywood, flooring, furniture, laminates, engineered wall systems, wood/polymer and structural composites, and lignin-based polymers
	Emerging Biobased Industry	
3	Plant-based plastics and polymers and films	Polylactide plastic, starch biodegradable polymers, spider silk polymers
4	Lubricants and functional fluids products	Biodegradable soybean oil-derived lubricants, used grease-refined products
5	Inks	Soybean-derived inks
6	Enzymes	Cellulase for orange juice clarification and stone-washed jeans, amylase for corn industry, enzymes for nutrition enhancement, novel property enzymes
7	Renewable alternative fiber papers and packaging	Kenaf, milkweed, and other agriculture products used for fibers, packaging, and products
	Shared by Biobased Companies and other Manufacturing Industries	
8	Absorbents, adsorbents, and masonry and road materials	Odor control, spill absorbents, animal bedding, pet litter, biocement support, roofing, insulation, road oil, and asphalt
9	Adhesives and bonding products	Sealants, glues for building products, glues for envelopes, wall paper adhesives, soy-based adhesives, marine glues
10	Biocontrol products	Soil amendments, such as topsoil, aggregate, and enrichment, fertilizer and pesticide carriers
11	Solvents, chemical intermediates, and cleaning agents	Methyltetrahydrofuran from levulinic acid, methanol from sythesis gas, cleaners, conditioners, and surfactants
12	Coatings and paints	Paints using cellulose-derived water soluble polymers
13	Cosmetics and personal-care products	Biobased products in toothpaste, lotions, and shampoos
14	Landscaping products	Decorative bark, railroad ties
15	New fibers, fillers, yarn, and insulation	Cotton fibers and rayon (cellulose derivative) textiles. New insulation using cotton processing trash and recycled textile fibers, filler for auto fenders, and panels for vehicle liners
16	Pharmaceuticals and veterinary products	Taxol for cancer treatment

Examples of Bioenergy and Biobased Products Facilities



Key Agencies

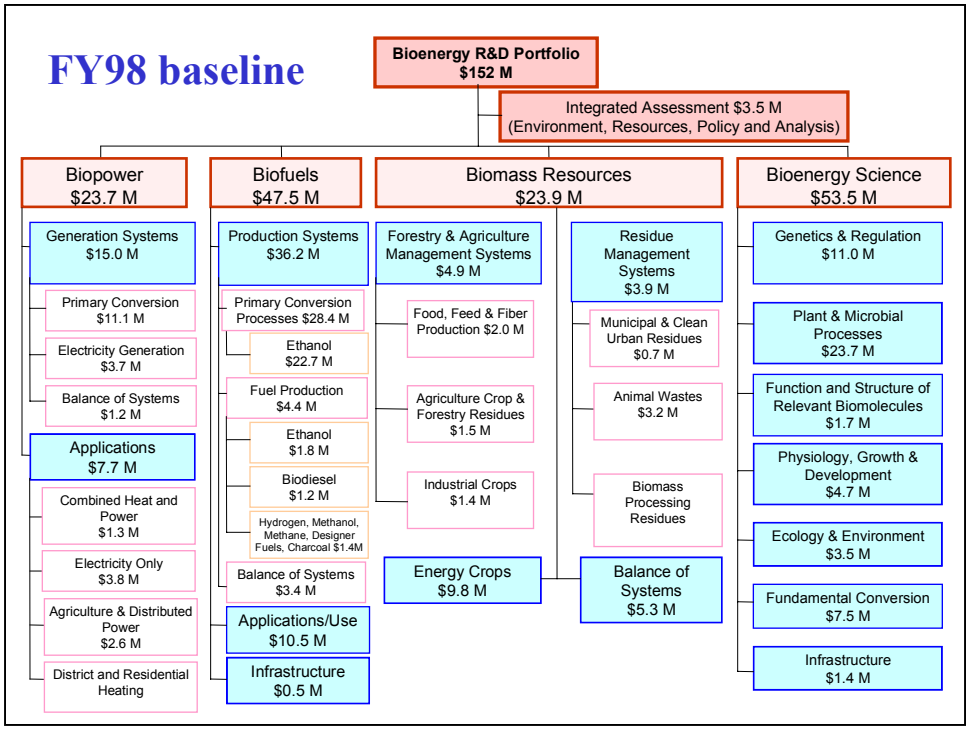
From Inventory of FY98
R&D Activities: $253 Mi
DOE + USDA = $228 Mi
DOE = $108 Mi
USDA = $120 Mi



Portfolio Analysis Methodology

- Across a systematic classification of technical lines -- Taxonomy
- Across U.S. government-programs using the Research and Development in the United States (RaDiUS) database and agencies' program information
- Across Agencies' specific databases such as Current Research Information Systems of the USDA (delay of 2 years for grant info)

Conducted by NREL and ORNL staff over a period of four months

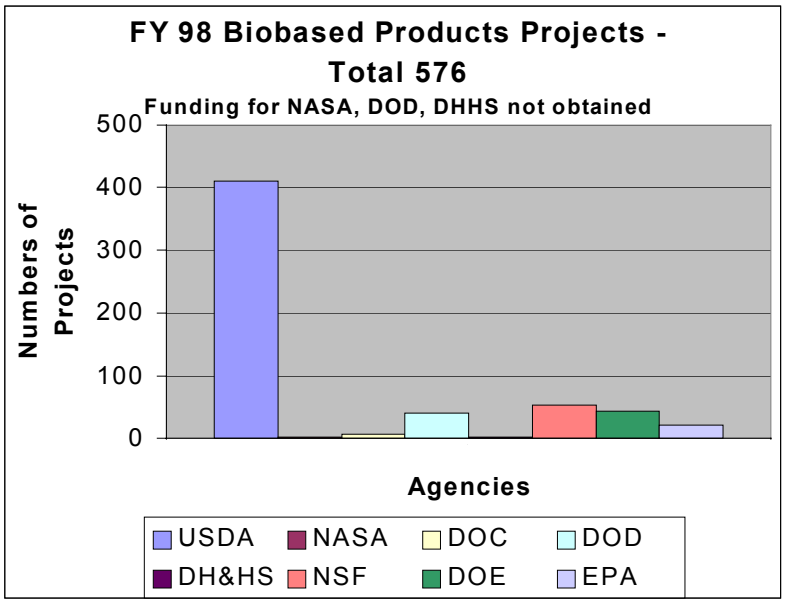


FY 98 Bioenergy Direct Projects by Phase of Research (Estimated) $152 Million (61% DOE, 32% USDA)

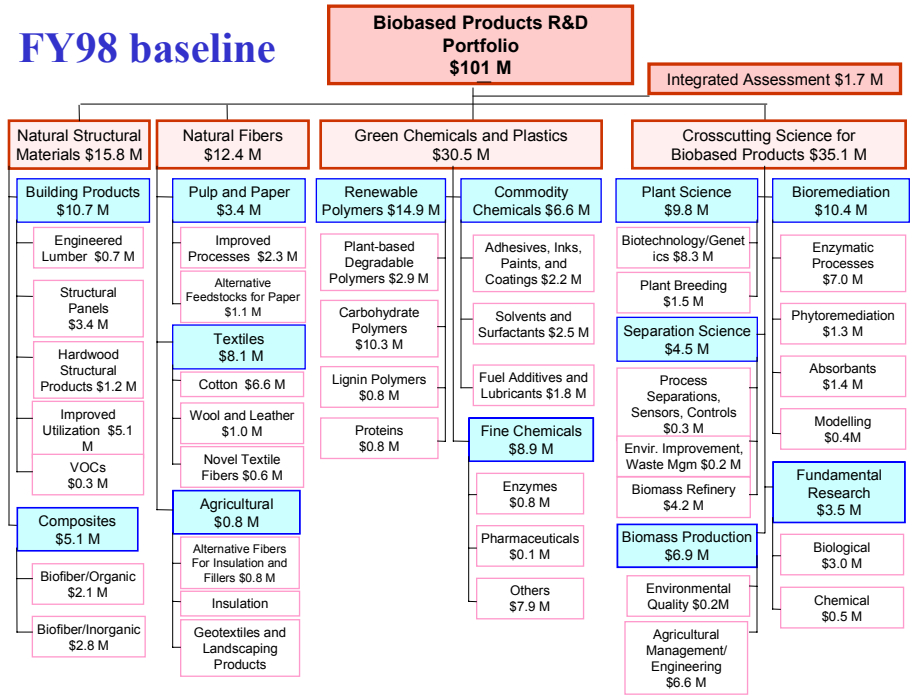
Phase	Estimated # Projects
Basic Research	400
Exploratory Projects	380
Development Projects	30
Pilot Developments in Industry	12
Integrated Assessments	28
Total # Projects	850

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		

FY Baseline data can be sorted by different technology grouping areas



FY98 baseline



Strategic Plan
Biorefinery Examples

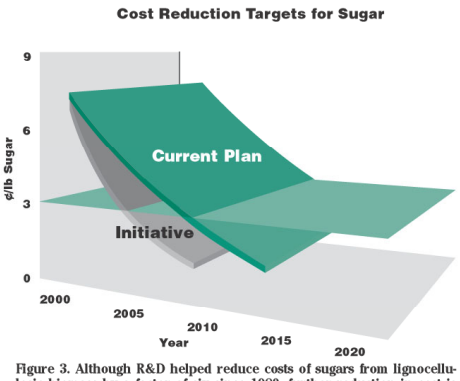


Figure 3. Although R&D helped reduce costs of sugars from lignocellulosic biomass by a factor of six since 1980, further reduction in cost is needed for widespread use of sugars for fuels, chemicals, materials, and other products.

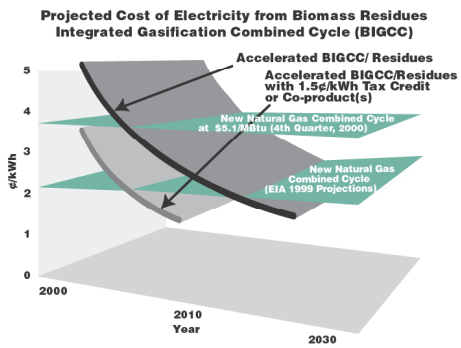


Figure 4. Accelerated R&D can reduce the cost of electricity from biomass residues compared to today's lowest electricity cost from new natural gas using combined-cycle. Biomass electricity costs could be reduced even further and become competitive earlier if coproducts are developed quickly. Alternatively, costs can be reduced earlier if production tax credits are maintained over a sufficiently long period of time to justify private-sector investment, new technology development, and adoption. (EIA is the Energy Information Administration) (Note: costs assume municipal financing).

Critical technologies need cost reduction to increase market penetration and make multiple products

New Products Needed and Cost Reduction in Crops, Short Rotation Trees, and Infrastructure for Residue Collection

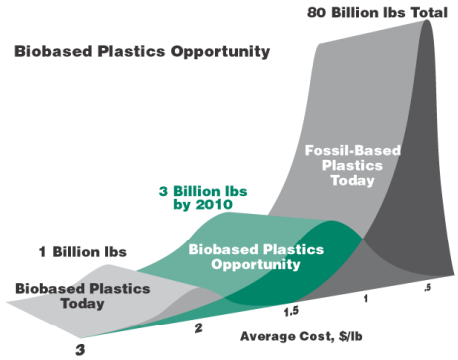


Figure 5. Pictorial example of today's costs and volumes (distribution) of biobased and fossil-derived plastics. In the future, these distributions could change markedly, as shown in the center distribution curve. Biobased products could generate 3 billion pounds or more of products covering a wide range of costs and volumes by 2010 and significantly offset petroleum use.

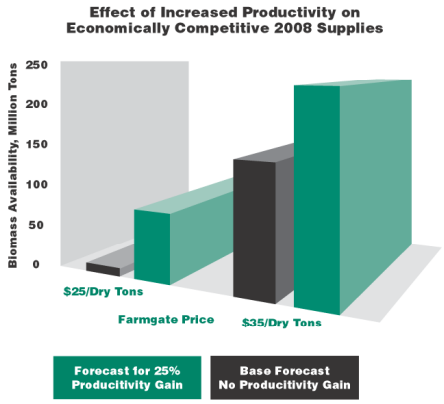


Figure 6. Plant science research is required to increase productivity and reduce uncertainty of biomass crop supplies. Productivity increases could lead to more supplies of energy crops that are economically competitive by 2008

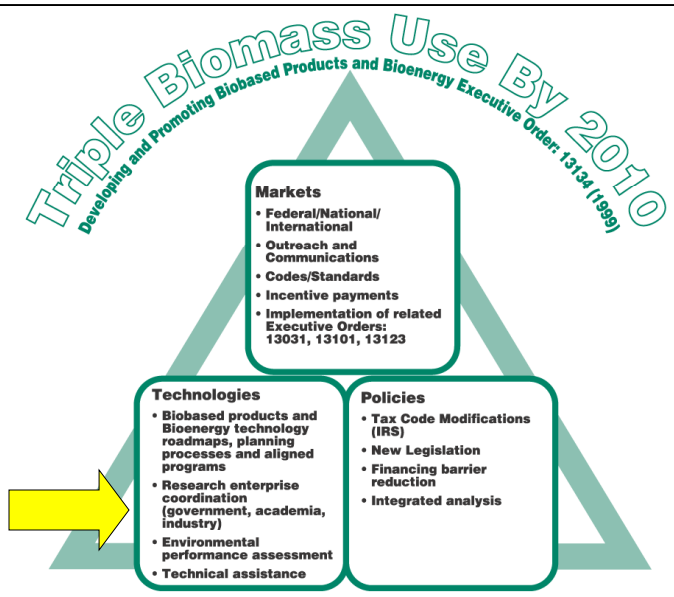


Figure 9. Examples of actions to triple biomass use by 2010. These include research, development, and demonstration in technology and product development. Among actions are coordinated policy modifications to create government markets and facilitate commercial market development. Also included are the continuing implementation of related Executive Orders (13031, Federal Alternative Fueled Vehicle Leadership; 13101, Greening the Government through Waste Prevention, Recycling, and Federal Acquisition; and 13123, Greening the Government through Efficient Energy Management).

Research Enterprise Coordination
Coordinated by DOE National Bioenergy Center

- Strategic Partnerships Meeting - April
  - Federal laboratories (both GOGO and GOCO)
  - Federal program managers
  - Opportunities for partnering and coordination
  - Identification/validation of key technical/scientific challenges
  - Outcome - Compiled Capabilities of Federal Laboratories on the National Biobased Products and Bioenergy Coordination Office Web
- Follow up meetings
  - Academia, Federal, Private sector at the 5th Biomass Conference of the Americas, Orlando, Florida, September 17-21, 2001

Special Enterprise Coordination Session

Research Enterprise Coordination Pathways Being Explored

- Universities led by Iowa State University will be meeting to coordinate their activities at national laboratory sites (proposed activity approved by the Biomass R&D Board but not yet funded).
- **Regional consortium formed** -- Iowa State University, Ames Lab, ANL, Michigan State University, University of Illinois, Purdue University, Peoria USDA Lab -- Midwest Consortium for Sustainable Bio-based Products and Bioenergy.
  - The consortium was formed to research and develop new environmentally friendly and renewable chemical products such as plastics made from soybeans, and fuel made from corn.

Examples of Actions to Reach the National Goal

To assess and enable the country to accrue all the benefits from the increased use of biobased products and bioenergy, combined actions by several agencies are necessary. Table 2 shows the agencies involved in these actions

TABLE 2 Agencies Participating, in the Implementation of the National Goals

Goals and Actions	DOE	USDA	EPA	NSF	DOC/NIST	DOI	TREASURY	OSTP	FEE	GSA	TVA
Technology Development Goals											
1. Technology Cost Reduction	X	X	X		X			X			X
2. Critical Technology Demonstration	X	X			X			X	X		
3. Environmental/Ecosystem Impact	X	X	X		X	X		X	X		X
4. Innovative Science & Technology	X	X	X	X	X			X			X
Public Policy and Markets Goals											
5. Coordinated Policies	X	X	X				X	X	X		X
6. Increase Federal Market Pull	X	X	X		X		X	X	X	X	X
7. Increase Commercial Market Pull	X	X	X		X		X	X	X		X
Examples of Actions											
Tax Code Modifications	X	X	X				X	X	X		
New Legislation	X	X	X				X	X			
Financing Barrier Reduction	X	X	X		X		X	X	X		X
Federal Markets	X	X	X			X		X	X	X	
National/International Markets	X	X	X		X			X	X		
Outreach and Communications	X	X	X			X		X	X		X
Codes/Standards	X	X	X		X						
Incentive Payments	X	X					X	X			X
Related Executive Orders: 13101		X	X						X		
Related Executive Orders: 13031, 13123	X		X						X		

Acronyms

DOE	U.S. Department of Energy
USDA	U.S. Department of Agriculture
EPA	Environmental Protection Agency
NSF	National Science Foundation
DOC	Department of Commerce
NIST	National Institute of Standards and Technologies
DOI	Department of Interior
TREASURY	Department of the Treasury
OSTP	Office of Science and Technology Policy
FEE	Federal Environmental Executive
GSA	General Services Administration
TVA	Tennessee Valley Authority

Executive Orders

13031	Federal Alternative Fueled Vehicle Leadership
13101	Greening the Government through Waste Prevention, Recycling and Federal Acquisition
13123	Greening the Government through Energy Efficiency Management

Strategic Plan "*Fostering the Bioeconomic Revolution in Biobased Products and Bioenergy.*"

GOAL 1: Reduce costs of technologies by two- to ten-fold for integrated supply, conversion, manufacturing and application systems for biobased products and bioenergy by 2010.

- Implement and strengthen coordinated federal R&D programs and justify integrated funding requests across federal departments and agencies.
- Conduct competitive solicitations on key R&D issues, and ensure that solicitations reach a "critical RD&D mass" to achieve the goal.
- Develop resource-efficient, environmentally sound, high productivity feedstock production systems.

GOAL 2: Demonstrate critical integrated biobased products and bioenergy systems for fuels, heat, power, chemicals and materials between 2002-2008 so they may contribute to the tripling goal by 2010.

- Identify the scientific and technological resources that will be needed. Fully utilize relevant existing facilities (federal, state, academia and private).
- Craft public-private sector partnerships to demonstrate promising technologies.
- Leverage private investments to demonstrate promising technologies.

GOAL 3: Monitor and evaluate the environmental and ecosystem impacts of biobased products and bioenergy systems at all stages of development.

- Research on areas that have substantial potential to replace fossil-based fuels.
- Establish specific review committees and open processes to oversee environmental monitoring and evaluation.
- Conduct ongoing life-cycle analyses to evaluate integrated systems and determine areas for environmental improvement.
- Utilize information technologies to assemble, analyze, and disseminate information on environmental impacts of bioenergy and biobased products.

GOAL 4: Foster innovation-driven science of biomass feedstocks, biobased products, and bioenergy and quickly incorporate these scientific results in the relevant technology development activities.

- Strengthen and integrate basic scientific research and grant programs.
- Enhance human resource development.
- Strengthen partnerships between the public and private sectors.
- Evaluate biannually the federal, state, and private sector biobased products and bioenergy R&D portfolio to identify gaps in frontier science and technology.
- Identify opportunities for technology transfer from other functional genomics and metabolic engineering R&D, such as on human systems.
- Identify R&D issues that would greatly benefit from dedicated Centers of Excellence attention and, where appropriate, extend existing or develop new programs that address key challenge areas.

Strategic Plan "*Fostering the Bioeconomic Revolution in Biobased Products and Bioenergy.*"

GOAL 5: Coordinate policies to achieve early market adoption and create demand.

- Identify in detail the principal barriers and systematically develop policy mechanisms to overcome them.
- Identify existing federal and state authorities that can be used to facilitate early adoption.
- Link environmental benefits to public policy development.
- Encourage standards and labels. Work with the private sector and non-governmental organizations to identify the appropriate role of government in this effort.
- Undertake educational and outreach programs to encourage consumer preference.

GOAL 6: Increase government market pull so that by 2010 bioenergy supplies five percent of the federal energy purchased or produced and biobased products supply ten percent of the relevant federal purchases.

- Inform consumers and government employees about the benefits of biobased products and bioenergy so they will support the federal market pull effort.
- Provide justification for legislative action to facilitate the purchase of biobased products and bioenergy.
- Use targeted demonstration programs that collect data over time and quantify benefits and costs of use in federal facilities.

GOAL 7: Facilitate development of commercial market pull by 2010 to triple biobased products and bioenergy use in emerging industries and to increase by 30% lumber, pulp and paper products use from mature industries.

Strategic Plan "*Fostering the Bioeconomic Revolution in Biobased Products and Bioenergy*"

Ten Strategies common to all goals

1. Use public-private partnerships to leverage tax-year dollars to the maximum extent feasible.
2. Utilize strategic planning processes with stakeholders.
3. Ensure relevance of targeted federal investments with the assistance of the Biomass Research and Development Technical Advisory Committee.
4. Use external peer review to oversee and provide independent validation of proposed plans.
5. Establish appropriate criteria for terminating unsuccessful projects and develop sunset criteria for phaseout of incentives.
6. Employ competition whenever possible.
7. Pursue multiple objectives wherever possible.
8. Take advantage of technology and information transfer mechanisms set up by agencies to increase coordination.
9. Develop education initiatives to broadly inform consumers and the general public of the benefits of increased use of biobased industrial products.
10. Establish a mechanism to measure progress via appropriate metrics tailored for each area.

Technology Development Milestones Examples

GOAL 1

- *By 2010, halve the year 2000 cost of producing sugars from lignocellulosic biomass.*
- *By 2010, develop the technologies for cost-competitive biomass gasification platforms for both power and biorefinery co-products.*
- *By 2010, develop 250 new biobased products for commercialization. This number includes at least 20 high-energy use impact biobased products.*

GOAL 2

- *By 2002, complete an inventory of public resources and facilities.*
- *By 2002, demonstrate an integrated, commercial-scale facility for multiple products. One example is to use lignocellulosic biomass to produce sugars, ethanol, and power.*
- *By 2008, demonstrate integrated gasification technologies for producing power and multiple products, including hydrogen. Implement gasification technology in three plants of the pulp and paper industry by 2010.*
- *Between 2002-2008, demonstrate rural-based processing plants for biobased products, including plants owned by farmers or farm cooperatives. Examples include composites, building materials, plastics from crop residues, and small-scale production of power using integrated gasification technology with advanced power sources.*

Technology Development Examples of Milestones

GOAL 3

- *By 2002, review environmental and ecosystem monitoring by the federal, state, and local governments agricultural forestry, and environmental agencies and private sector and non-governmental organizations.*
- *By 2002, develop tools and information resources that will facilitate identification of those biobased products and bioenergy technologies that can provide economic, agricultural, energy, and environmental benefits simultaneously and produce a plan to accelerate their development. This will help farmers identify more profitable crops and assist them in developing farm cooperatives to supply biobased products and bioenergy to new markets.*
- *On an ongoing basis, identify and implement opportunities to leverage these monitoring efforts and expertise, supplementing them as needed, to support life-cycle environmental and ecosystem monitoring of biobased product and bioenergy systems.*
- *By 2002, establish a national program initiative to promote understanding of the role of bioproducts and bioenergy in enhancing environmental sustainability in USDA's Cooperative Extension Service, in state cooperative extension service programs, and in USDA's NRCS.*
- *By 2003, evaluate current and prospective life-cycle environmental costs and benefits of key biobased products and bioenergy important to achieve the tripling goal and compare them with fossil-fuel based alternatives.*

GOAL 4

- *By 2010, develop complete functional genomics for five target feedstocks. Use thee capabilities, for instance, to double overall lignocellulosic productivity at significantly reduced inputs.*
- *By 2005, develop complete functional genomics for 10 target biocatalysts and develop associated metabolic engineering by 2010 to triple reaction rates and significantly reduce end-product inhibition.*
- *On an ongoing basis, create advanced tools for information and computing technologies including those that encourage collaborative learning and intelligence. Use them to develop functional genomics and metabolic engineering science and technology, and to provide specific information on targeted plants and organisms.*

Market and Public Policy Examples of Milestones

GOAL 5

- *By 2002, develop a coordinated proposal for modifying the tax code and other policies to encourage private-sector investments in integrated biobased products and bioenergy development and deployment and to overcome the barriers limiting development of this sector.*
- *By 2002, develop mechanisms to assist the buy-down of initial capital costs of new technologies, and mitigate risks in deploying first-of-a-kind technologies.*
- *By 2002, develop mechanisms to assist farmers nd farmer cooperative to gain economic benefits from biobsed products and bioenergy.*
- *By 2003, announce labeling programs to facilitate marketing of products and technologies. These programs will be defined with the private sector.*
- *By 2005, have federal incentives such as tax credits and appropriate tax-credit programs in place and funded. Have appropriate parallel incentive mechanisms for public power companies.*
- *By 2005, complete performance testing on those biobased products and bioenergy of primary importance to achieving the tripling goal.*

Market and Public Policy Examples of Milestones

GOAL 6

- *By 2002, publish a USDA-approved biobased products list for federal procurement.*
- *By 2002, develop legislative language and facilitate enactment of legislation to modify Section 6002 of the Resource Conservation and Recovery Act to require federal procurement officials to purchase certain levels of biobased products and bioenergy.*
- *By 2010, bioenergy accounts for 5 percent of federal energy facilities and biobased products penetrate 10 percent of federal purchases of relevant products.*
- *By 2010, work with all states to enact legislation that increases state purchases of biobased products and bioenergy.*

GOAL 7

- *By 2002, work with educators to develop K-12 classroom materials that focus on the science-based environmental sustainability attributes of biobased products and bioenergy.*
- *By 2002, establish 25 centers of excellence at colleges and universities to develop college-level classroom materials and outreach education materials focused on the role of biobased products and bioenergy in enhancing environmental sustainability.*
- *By 2005, implement cofiring in 5 percent of pulverized coal boilers. Joint DOE and EPA action with public and private electricity generators will achieve this milestone.*
- *By 2010, triple biofuels production through cooperative USDA, DOE, and EPA actions with industry.*

National Biobased Products and Bioenergy Coordination Office

Doug Kaempf - DOE Co-Chair
Ron Buckhalt - USDA Co-Chair

Ron Buckhalt - USDA Co-Chair **Doug Kaempf - DOE Co-Chair**

Progress Report April 2001

Establish the Vision	✓	Designate DOE and USDA Points of Contact	✓
Develop Roadmaps	✦	Establish Biomass R&D Board	✓
Develop Strategic Plan	✓	Establish a Technical Advisory Committee	✓
Report to Congress	✦	Carry Out Education and Outreach	$'01
Expand and Maintain Effective Partnerships	✦ ✓	Promote Advanced Technologies	$'01
National Bioenergy Center	✓		

✓ = Action Completed ✦ = Efforts Underway $'01 = Funding Awarded

Biomass Research and Development Technical Advisory Committee

CO-CHAIR:

Jack Huttner – Genencor International, Inc.

CO-CHAIR:

Glenn English – National Rural Electric Cooperative Association

Larry Bean – ***Governors' Ethanol Coalition***

Robert Boeding – ***National Corn Growers Association***

Dale Bryck – ***Natural Resources Defense Council***

Robert Dorsch – ***Dupont***

Douglas Durante – ***Clean Fuels Development Coalition***

Loyd Forrest – ***TSS Consultants***

Carolyn Fritz – ***The Dow Chemical Company***

Stephen Gatto – ***BC International***

William Guyker – ***Allegheny Power Systems***

Ronald Heck – ***Farm Corporation & American Soybean Association***

Walter Hill – ***Tuskegee University***

Roland Hwang – ***Union of Concerned Scientists***

Terri Jaffoni – ***Cargill, Inc.***

Michael Ladisch – ***Purdue University***

David Morris – ***Institute for Local Self Reliance***

William Nicholson – ***Potlach Corporation***

Edan Prabhu – ***Reflective Energies***

Roger Rivera – ***National Hispanic Environmental Council***

Jefferson Seabright – ***Texaco***

Philip Shane – ***Illinois Corn Growers Association***

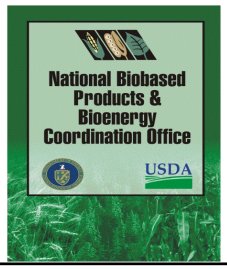
Larry Walker – ***Cornell University***

John Wooten – ***Peabody Group***

Holly YoungBear-Tibbets – ***College of the Menomiee Nation***

USDA and DOE Coordination

- **DOE & USDA Agency working groups established August, 2000**
- **National Coordination Office established February 2000**
- **Biomass R&D Board established November 2000**
- **Advisory Committee established November 2000**
- **Report to the President – Delivered in October 2000**
- **Strategic Plan – Completed March 2001**
- **Initial Report to Congress - underway**



Solicitations

- **CSREES's Initiative for Future Agriculture and Food Systems (IFAFS)**
  - 13.4 Million
  - Exploration of biobased products and bioenergy in interactive systems-based approaches.
- **USDA 25 Million in Grants for the Development of Agricultural Producer-Owned Processing Businesses**
  - The grant announced on March 6, 2001, supports independent agricultural commodity producers to process raw materials into marketable goods.
- **Biomass Research and Development Advance Biomass Power Generation Technologies (DE-PS26-01NT41130)**
  - 1 Million
  - Support improved gasification-based technologies for power, heat and co-production.
- **Power Plant Improvement Initiative, Financial Assistance, Solicitation (DE-PS26-01NT41104**
  - 95 Million
  - Research of alternative fuels in cofiring and gasification to increase the efficiency of current operating power plants.

Solicitations

- **Agriculture Industry of the Future (DE-PS07-01ID14039)**
  - 1.5 Million
  - Research, development and demonstration of technologies in plant sciences, production, processing, and utilization.
- **Biomass and Alternate Methane Fuel (BAMF) Technology Specific Super Energy Savings Performance Contract (DE-RP26-00NT40626)**
  - 4 Million
  - Biomass and alternate methane fuels utilization in federally owned facilities.
- **Innovative Technologies for Conversion of Biomass to Fuels and Chemicals**
  - 2 Million
  - Solicitation will award $2M to multiple contracts for innovative technologies for the conversion of biomass to fuels and chemicals, particularly in the areas of pretreatment and hydrolysis to sugars.
- **Biomass Research and Development Initiative/Crosscutting Technologies for Conversion of Biomass to Fuels and Chemicals (DE-PS36-01GO90000)**
  - 2 million
  - Conversion of biomass into fuels and chemicals.

Government Programs Highlighted

USDA:

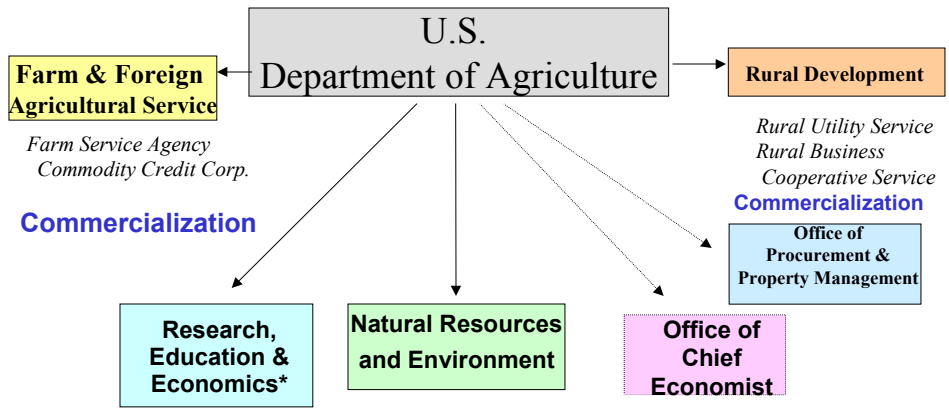
ARS - Frank Flora and Don Ehrbach

CSREES - Hongda Chen

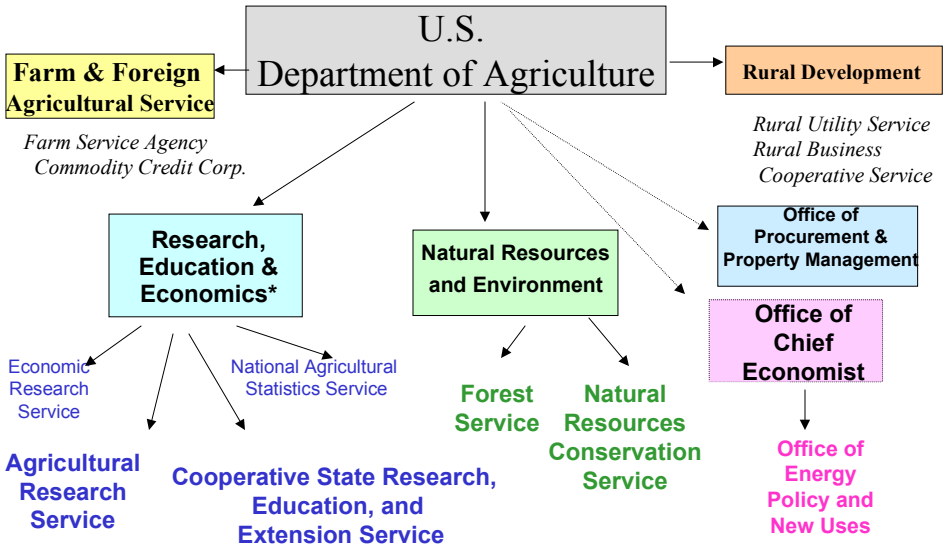
FS - Howard Rosen

Integration Considerations - Marvin Duncan

Biobased Products and Bioenergy R&D and Commercialization at USDA



Biobased Products and Bioenergy R&D and Commercialization at USDA



Departments, Agencies, Offices, Programs	Web Site
U.S. Department of Agriculture	**http://usda.gov**
Agriculture Research Service	***http://www.ars.usda.gov/***
Research in Integration of Agricultural Systems and Research Support	http://www.nps.ars.usda.gov/
Natural Resources and Sustainable Agricultural Systems	http://www.nps.ars.usda.gov/
Rangeland, Pasture, and Forages	*http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=205*
Manure and Byproduct Utilization	*http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=206*
Integrated Agricultural Systems	*http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=207*
Crop Production, Product Value, and Safety	http://www.nps.ars.usda.gov/
Plant, Microbial, and Insect Genetic Resources, Genomics, and Genetic Improvement	*http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=301*
Plant Biological and Molecular Processes	*http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=302*
★ *New Uses, Quality, and Marketability of Plant and Animal Products*	*http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=306*
★ *Bioenergy and Energy Alternatives*	*http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=307*
Federal Technology Transfer to the Private Sector	http://www.ott.ars.usda.gov/
★ ***Cooperative State Research, Education and Extension Service***	***http://www.reeusda.gov/***
Agricultural Materials	http://www.reeusda.gov/1700/programs/agri.htm
National Research Initiative	http://www.reeusda.gov/ree/nri/
Small Business Innovative Research	http://www.reeusda.gov/sbir/
McIntire-Stennis Cooperative Forestry	http://www.reeusda.gov/1700/legis/mcstenni.htm
Payments under the Hatch Act	http://www.reeusda.gov/crgam/oep/fmbstaff.htm http://www.reeusda.gov/1700/legis/hatch.htm
Payments to 1890 Colleges and Tuskegee	http://www.reeusda.gov/1700/programs/1890.htm
Special Research Grants	http://www.reeusda.gov/ree/reedir/dgz00662.htm
Initiative for Future Agriculture and Food Systems	http://www.reeusda.gov/1700/programs/IFAFS/IFAFS.htm
★ ***Forest Service***	***http://www.fs.fed.us/research***
Forest and Rangeland Research	http://www.fs.fed.us/research/rvur/
Vegetation Management and Protection Research	http://www.fs.fed.us/research/vmpr
Forest Products	http://www.fs.fed.us/research/rvur/products/index.htm
Natural Resources Conservation Service	***http://www.nrcs.usda.gov/***
Financial and Technical Assistance for Conservation	http://www.nrcs.usda.gov/NRCSProg.html
Economic Research Service	***http://www.ers.usda.gov/***
Animal and Plant Health Inspection Service	***http://www.aphis.usda.gov***
★ ***Rural Development – grants and loans***	***http://www.rurdev.usda.gov/***
★ ***Office of Energy Policy and New Uses***	***http://www.usda.gov/agency/oce/oepnu/index.htm***
Commodity Credit Corporation – market development	***http://www.fsa.usda.gov/daco/bioenergy/bioenergy.htm***

★ Highlighted in the workshop

See Appendix I. in
http://www.bioproducts-bioenergy.gov

USDA/ARS Research Program in Biobased Products

Dr. Frank Flora, National Program Leader
Product Quality/New Products & Processes
Agricultural Research Service

Strategic Partnerships Workshop
Lakewood, Colorado
April 11-12, 2001

National Program Staff

The Agricultural Research Service (ARS) is the principal inhouse research agency of the U.S. Department of Agriculture (USDA).

National Program Staff

ARS National Programs

Animal Production

- Food Animal Production (101)
- Animal Health (103)
- Arthropod Pests of Animals and Humans (104)
- Animal Well-Being and Stress Control Systems (105)
- Aquaculture (106)
- Human Nutrition (107)
- Food Safety (108) (animal & plant products)

Natural Resources

- Water Quality & Management (201)
- Soil Resource Management (202)
- Air Quality (203)
- Global Change (204)
- Rangeland, Pasture & Forages (205)
- Manure & Byproduct Utilization (206)
- Integrated Agricultural Systems (207)

Crop Production

- Plant, Microbial, & Insect Genetic Resources, Genomics and Genetic Improvement (301)
- Plant Biological & Molecular Processes (302)
- Plant Diseases (303)
- Crop Protection and Quarantine (304)
- Crop Production (305)
- Quality & Utilization of Agricultural Products (306)
- Bioenergy & Energy Alternatives (307)
- Methyl Bromide Alternatives (308)

USDA ARS

Mission of NP 306

Enhance the economic viability and competitiveness of U.S. agriculture by maintaining the quality of harvested agricultural commodities or otherwise enhancing their marketability, meeting consumer needs, developing environmentally friendly and efficient processing concepts, and expanding domestic and global market opportunities through the development of value-added food and nonfood products and processes.

USDA ARS **National Program Staff**

NP 306 Program Components

- Quality Characterization, Preservation, and Enhancement
- New Processes, New Uses, and Value-Added Biobased Products

National Program Staff

NP 306 Resources

- 137 Projects
- 266 SY's
- $75.9M

National Program Staff

ARS Biobased Emphasis

Development of industrial and bioenergy products that expand market opportunities for U.S. agriculture, replace petroleum-based products and other imported strategic materials, and meet environmental needs.

National Program Staff

ARS Investment in Non-Food and Food New Uses Research , FY2001

	$M	Projects	SY*
Non-Food	41.5	65	126
Biofuels	7.1	9	23
Food	40.4	80	133

National Program Staff

* scientist year

Customer/Stakeholder Workshops

- Relevance
- Every five years
- NP 306 (Quality/Utilization)
  -May, November, December 1999
- Basis for 5 year research plan

National Program Staff

Stakeholder Priorities for Value-Added Research

- Improved understanding of structure/function relationships
- Quality attribute identification, detection, quantification, and tracking from field to fork
- Phenotypic markers for high value traits
- New value-added biomaterials and co-products
- Products and processes with clear human health benefits

National Program Staff

Stakeholder Priorities for Value-Added Research (Continued)

- **Safer, more environmentally friendly processing technologies and products**
- **Domestic biobased replacements for imports, particularly petroleum**
- **Crops designed with specific end-use traits**

National Program Staff

ARS Emphases

- **Relevance**
- **Quality/Research Excellence**
- **Focus**
- **Coordination**
- **Partnerships**
- **Impact**

National Program Staff

USDA Regional Utilization Research Centers
Established ~ 1940

Albany, CA
New Orleans, LA
Peoria, IL
Wyndmoor, PA

National Program Staff

Current Biobased Activities- Albany, CA

- Improve grain-to-ethanol conversion efficiency by rapid screening of mutant amylase enzymes through directed molecular evolution
- Genetically engineer crops for production of critical materials (castor oil)
- Develop efficient separation technologies for wheat starch and protein for functionality
- Develop wheat biopolymer composites for industrial and food applications

National Program Staff

Current Biobased Activities- New Orleans, LA

- Biocatalytic conversion of soybean oil to industrial drying oils (tung oil)
- Develop environmentally acceptable technologies for separating corn fractions that are cost effective and that add value
- Develop composites for industrial applications using cotton and other natural fibers
- Develop adsorbents from agricultural residues
- Develop epoxies and coatings from sucrose polymers

National Program Staff

Current Biobased Activities- Peoria, IL

- Formulate insecticidal volatile attractants in biodegradable matrices made from modified polymers derived from cereal grains and other natural sources
- Develop biodegradable plastics using modified corn starch and other biopolymers
- Develop complex carbohydrate polymers for food and non-food consumer articles from corn starch and fiber, such as fat replacers, stabilizers, and thickening and viscosity control agents
- Develop functional polymers through enzymatic conversion of carbohydrates in corn

National Program Staff

Current Biobased Activities- Peoria, IL (cont.)

- Develop enzymatic and chemical methods for conversion of fuel ethanol residues into commercially valuable coproducts
- Develop stable starch-oil dispersions (Fantesk) with food, cosmetic and industrial applications
- Generate new or expanded industrial markets for polymers from cereal grains by thermomechanical modification, including steam injection cooking, extrusion and microwaving
- Identify, isolate, modify, and characterize plant proteins suitable for blending with synthetic polymers

National Program Staff

Current Biobased Activities- Peoria, IL (cont.)

- Develop technologies and processes which will impart unique properties to plant proteins, such as for use in adhesives, films, injection molding resins or ion-exchange resins
- Develop pretreatment and fermentation technologies for the conversion of corn fiber and other agricultural substrates into biofuels and value-added fermentation products
- Develop more efficient cellulases and other enzymes for conversion of renewable agricultural biomass into value-added products, including lactic acid

National Program Staff

Current Biobased Activities- Peoria, IL (cont.)

- Provide soybean composition analysis to public soybean breeders in the U.S.
- Chemical modifications of vegetable oils for improved biodiesel properties, soy inks, and lubricants
- Biocatalytic conversion of vegetable oils to value-added products (chemicals, mulch, sunscreen, antifungals)

National Program Staff

Current Biobased Activities- Wyndmoor, PA

- Develop new valuable food and industrial products from plant polysaccharides, corn and other grains
- Improve process efficiencies and otherwise reduce costs of the corn-to-ethanol conversion, including through development of valuable coproducts
- Bioconversion of fats and oils to value-added biopolymers, biosurfactants, and biodiesel

National Program Staff

Current Biobased Activities- Athens, GA

- Enhance value of fiber commodities (flax, kenaf, cotton) through microbial and enzymatic activities

National Program Staff

Current Biobased Activities- Madison, WI

- Develop fuels, construction materials, and consumer products from alfalfa and manure through fractionation and processing.

National Program Staff

FY 2001 ARS Program Enhancements ($1.9M)

- Wyndmoor, PA- Convert surplus agricultural commodities and their carbohydrate-rich processing byproducts into biobased industrial products and high-valued functional food ingredients.
- New Orleans, LA- Convert animal biosolids and other agricultural residues to value-added products such as engineered soils, ornamental horticulture fertilizer, and activated carbon.
- Albany, CA- Develop new uses for cereal crop residues, such as biodegradable packaging materials, fiber-based building materials, nanocomposites, and rice paper products from rice and wheat straw.

National Program Staff

FY 2001 ARS Program Enhancements ($1.9M) (continued)

- Winter Haven, FL- Develop stabilized bioabsorbents and other industrial products from citrus peel pectin.
- Peoria, IL- Develop new enzyme technologies to efficiently and economically convert agricultural biomass to fermentable sugars and value-added coproducts.

National Program Staff

FY2002 ARS Emphases

- Improving conversion of agricultural biomass to ethanol through discovery and development of more efficient microorganisms and enzymes, reducing costs by developing valuable coproducts, and improving biodiesel fuel quality.
- Developing biobased materials (absorbents/adsorbents, lubricants, plastics, polymers, composites, coatings, adhesives, biosurfactants) from agricultural commodities and byproducts using biotechnology, biocatalysis and other integrated technologies
- Increasing knowledge on fundamental biomaterials science leading to development of new processing technologies and new products

USDA ARS **National Program Staff**

FY2002 ARS Emphases

- Expanding development of novel crops for value-added products, including natural rubber products, new fiber products, and new biodegradable detergents
- Improving biomass for energy through genetic modification of biomass crops to facilitate conversion and improved methods for sustainable production, harvesting, handling, and storing biomass

USDA ARS **National Program Staff**

ARS National Programs Website

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

National Program Staff

Agricultural Research Service Energy Research

Don Erbach
National Program Leader
Engineering and Energy

04/11-12/01

Agricultural Research Service (ARS)

- In-house research arm of USDA
- Base funded (not a granting agency)
- Research is managed through national programs

04/11-12/01

ARS Mission

Conduct research to develop and transfer solutions to agricultural problems of high national priority

04/11-12/01

ARS Research

- Managed under 22 National Programs
- Obtain customer input to maintain relevance
- Reviewed through the Office of Scientific Quality Review to assure quality
- Transfer research findings (Office of Technology Transfer) to maximize impact and benefit

04/11-12/01

National Program 307

- Energy research in ARS is managed under National Program 307, Bioenergy and Energy Alternatives
- In the ARS Crop Production, Product Value and Safety area.

04/11-12/01

NP 307 Vision

America's energy needs met using renewable resources

04/11-12/01

NP 307 Mission

To create jobs and economic activity in America, reduce the Nation's dependence on foreign oil and improve the environment by developing alternate energy sources and increasing the use of agricultural crops as feedstocks for biofuels.

04/11-12/01

Interactions with Other ARS National Programs

Animal Production, Product Value and Safety Area

- NP 101 – Food Animal Production

04/11-12/01

Interactions with Other ARS National Programs

Crop Production, Product Value and Safety Area

Bioenergy is very closely linked to the biobased product research managed under NP 306 – Quality and Utilization of Agricultural Products

04/11-12/01

Interactions with Other ARS National Programs

The Bioenergy and Energy Alternatives National Program also interacts with these crop programs:

- NP 301 – Plant, Microbial, & Insect Genetic Resources, Genomics and Genetic Improvement
- NP 302 – Plant Biological & Molecular Processes
- NP 303 – Plant Diseases
- NP 304 – Crop Protection and Quarantine
- NP 305 – Crop Production

04/11-12/01

Interactions with Other ARS National Programs

Natural Resources and Sustainable Agricultural Systems Area

Each of the seven programs in this area contribute to or are affected by energy issues. The programs are:

04/11-12/01

Interactions with Other ARS National Programs

- NP 201 – Water Quality and Management
- NP 202 – Soil Resource Management
- NP 203 – Air Quality
- NP 204 – Global Change
- NP 205 – Rangeland, Pasture and Forages
- NP 206 – Manure & Byproduct Utilization
- NP 207 – Integrated Agricultural Systems

04/11-12/01

ARS Bioenergy and Energy Alternatives Action Plan

As with each of the other National Programs, an action plan was developed from input provided by a broad group of customers and stakeholders. This input is obtained in a variety of ways, with the biggest input coming at a national program workshop held specifically to learn about problems, issues, and concerns.

04/11-12/01

ARS Bioenergy and Energy Alternatives Action Plan

Components:

- Ethanol
- Biodiesel
- Energy Crops
- Energy Alternatives for Rural Practices

04/11-12/01

Ethanol Projects

- Eastern Regional Research Center (Wyndmoor, Pennsylvania)
  - Corn-Ethanol Process Cost Reduction
  - New Biobased Products to Increase Demand for Grains

04/11-12/01

Ethanol Projects

- National Center for Agricultural Utilization Research (Peoria, Illinois)
  - Bioprocess And Metabolic Engineering Technologies For Biofuels and Value-Added Co-Products
  - Utilization of Fuel Ethanol Residues For Value Added Co-Products

04/11-12/01

Ethanol Projects

- Western Regional Research Center (Albany, California)
  - Conversion of Crops To Products With Higher Added Value Through Directed Molecular Evolution

04/11-12/01

Ethanol Research Progress

Corn to Ethanol Process Cost Reduction

- Overcame an important barrier to, and reduced the cost of, separating zein, a major corn protein, from ethanol byproducts

04/11-12/01

Ethanol Research Progress

New Biobased Products To Increase Demand For Grains

- Demonstrated a new corn steeping process using enzymes to reduce or eliminate the need for sulfites that can produce serious environmental and health risks. The process also reduces steeping time and cost

04/11-12/01

Ethanol Research Progress

New Biobased Products To Increase Demand For Grains

- Developed a lower cost method to produce a unique cholesterol-lowering oil found in corn fiber
- Demonstrated that several types of food-grade and industrial gums that now must be imported can be obtained from various parts of the corn kernel

04/11-12/01

Ethanol Research Progress

New Biobased Products To Increase Demand For Grains

- Identified alternative milling technologies that produced germ and fiber fractions that are superior in yield of valuable phytonutrients and that increase the value of corn fiber oil, corn fiber gum, and other valuable co-products

04/11-12/01

Ethanol Research Progress

New Biobased Products To Increase Demand For Grains

- Optimized a process to produce a “quick fiber oil” with high levels of phytosterols

04/11-12/01

Ethanol Research Progress

Utilization of Fuel Ethanol Residues for Value Added Co-products

- A sequential fermentation scheme was devised for the production of the valuable sugar substitute, xylitol, from corn fiber sugars

04/11-12/01

Ethanol Research Progress

Utilization of Fuel Ethanol Residues for Value Added Co-products

- Fundamental information was learned about the mode of action of a biomass cleaving enzyme (acetylxylan esterase) and process conditions were optimized for the enzymatic production of fermentable sugars from corn fiber, an abundant byproduct of the fuel ethanol industry
- Sugars from corn fiber were successfully fermented to ethanol

04/11-12/01

Ethanol Research Progress

Utilization of Fuel Ethanol Residues for Value Added Co-products

- Biosensors are being developed that, with use of advanced computational methods, can monitor fermentable sugars derived from corn fiber to facilitate the commercialization of value-added co-products from corn

04/11-12/01

Ethanol Research Progress

Bioprocess And Metabolic Engineering Technologies For Biofuels and Value-Added co-products

- Developed a series of recombinant ethanol-producing microorganisms that use all of the sugars in a mixture at equal rates, thus increasing ethanol yields and lowering projected ethanol costs when using biomass as a feedstock

04/11-12/01

Ethanol Research Progress

Bioprocess And Metabolic Engineering Technologies For Biofuels and Value-Added Co-products

- Discovered enzymes for use in the conversion of cellulose and hemicellulose components of biomass to fermentable sugars
  - A glucose and cellobiose tolerant beta-glucosidase essential for hydrolysis of cellulose to glucose
  - A thermostable arabinofuranosidase useful for hemicellulose bioconversion

04/11-12/01

Biodiesel Projects

- National Center for Agricultural Utilization Research (Peoria, Illinois)
  - Vegetable Oil-Based Alternative Diesel Fuels, Extenders, And Additives
  - Ignition And Combustion Characteristics Of Biofuels

04/11-12/01

Biodiesel Projects

- Eastern Regional Research Center (Wyndmoor, Pennsylvania)
  - New Processes For Obtaining Higher Value-Added Products From Agricultural Lipids

04/11-12/01

Biodiesel Research Progress

Vegetable Oil-Based Alternative Diesel Fuels, Extenders, And Additives

- Modeled oxidation degradation reaction kinetics to rapidly and accurately predict the oxidative stability of biodiesel fuel formulations
- Developed accurate test method for screening fuel antioxidants in minutes rather than the hours or days required for standard test methods

04/11-12/01

Biodiesel Research Progress

Vegetable Oil-Based Alternative Diesel Fuels, Extenders, And Additives

- Showed that resistance to oxidation of biodiesel can be substantially increased by adding agents called antioxidants

04/11-12/01

Biodiesel Research Progress

Ignition And Combustion Characteristics Of Biofuels

- Identified additives to reduce NOx exhaust emissions from biodiesel use

04/11-12/01

Biodiesel Research Progress

New Processes For Obtaining Higher Value-Added Products From Agricultural Lipids

- Developed a simple two-step chemical procedure for the conversion of soapstock into simple esters for use as biodiesel
- Optimized the synthesis of ethyl esters of grease using fuel-grade alcohol

04/11-12/01

Energy Crops

- Developing Management Strategies And Plant Germplasm To Improve Great Plains And Midwestern Grasslands (Lincoln, Nebraska)
  - Genetic Improvement Of Switchgrass For Biomass Fuel And Agronomic Traits For The Northern USA
  - Genetic Improvement Of Switchgrass For Agronomic And Biomass Fuel Production Traits
  - Evaluate Switchgrass And CRP Type Grasslands For Biomass Production
  - Grassland Weed Management With Plateau

04/11-12/01

Energy-Crops Research Progress

Genetic Improvement Of Switchgrass For Biomass Fuel And Agronomic Traits For The Northern USA

- Demonstrated, by use of germplasm evaluation nurseries, the need for regional tests to determine adaptation zones for switchgrass cultivars

04/11-12/01

Energy-Crops Research Progress

Genetic Improvement Of Switchgrass For Agronomic And Biomass Fuel Production Traits

- Determined that it is highly feasible to genetically modify the feedstock quality of herbaceous plants using both conventional and molecular breeding technologies and identified nine areas in which research could be conducted to improve the conversion of herbaceous plants to bioenergy

04/11-12/01

Energy Alternatives for Rural Practices

- Renewable Energy Systems For Water Pumping And Remote Electric Power Generation (Bushland, Texas)
  - Development and Testing of Renewable Energy Technologies for Agricultural Applications
  - Wind/hybrid Control Prototype Development
  - Small Wind Systems For Water Pumping And Electric Generation

04/11-12/01

Energy Alternatives for Rural Practices Research Progress

Renewable Energy Systems For Water Pumping And Remote Electric Power Generation

- Determined that stand-alone wind systems can pump water to irrigate fruit trees and make available additional land for fruit production which is not currently being used because of non availability of pumping energy
- Demonstrated that wind-electric systems are reliable and can be used to pump water at remote locations.

04/11-12/01

Energy Alternatives for Rural Practices Research Progress

Renewable Energy Systems For Water Pumping And Remote Electric Power Generation

- Found that for a 0.75 kW AC solar power water pumping system a 50 Hz, 205 V, 3-phase electric motor instead of a 60 Hz, 230 V, 3-phase electric motor improved pumping performance resulting in a daily water volume increase of 10 to 15%

04/11-12/01

Energy Alternatives for Rural Practices Research Progress

Renewable Energy Systems For Water Pumping And Remote Electric Power Generation

- Determined that a cost effective solution for maintaining an adequate water supply for livestock is to combine a wind system with a portable generator, for low wind/high temperature months, to power a submersible motor and pump

04/11-12/01

Energy Alternatives for Rural Practices Research Progress

Wind/hybrid Control Prototype Development

- Simulated the performance of a wind/diesel electrical system suitable for a village or large farm and found that when wind power was sufficient to curtail the diesel plant, control was smooth and stable providing for the entire load without having to burn diesel and average fuel savings of 22%

04/11-12/01

ARS Bioenergy and Energy Alternatives Website

- http://www.nps.ars.usda.gov/programs/programs.htm?NPNUMBER=307
  - Action Plan
  - National Program Team
  - Locations
  - Research Projects
  - Annual Reports
  - and more

04/11-12/01

ARS Website

http://www.ars.usda.gov

04/11-12/01

United States Department of Agriculture
Cooperative State Research, Education and Extension Service

THOUGH NOT A LAB,

BUT MANY LABS

The unique partnership with the land grant institutions

Capacities of CSREES

- Provides national leadership
- Provides funding
- Research projects
- Extension and outreach
- Education
- Partnership with land grant universities

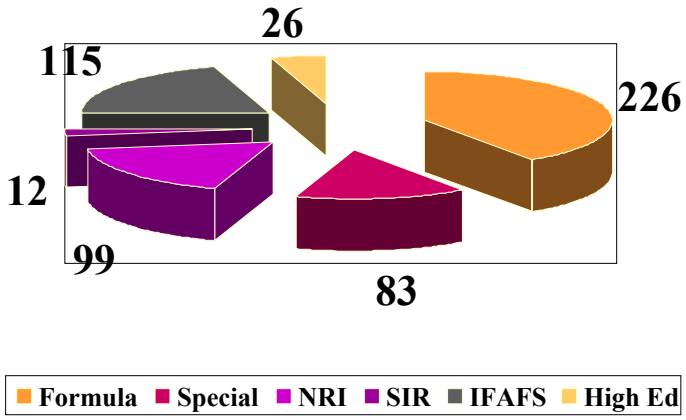
Key Contacts in CSREES

- Carmela Bailey, Program Director for New Uses of Agricultural Materials
- Jeff Conrad, Acting Division Director for Enhancing Value and Use of Agricultural and Forest Products
- Charles Cleland, Director of SBIR
- Hongda Chen, National Program Leader for Bioprocessing Engineering

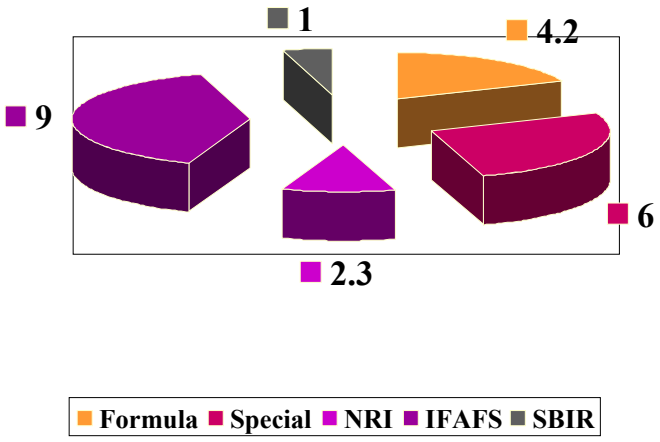
Research funding

- Formula funds
- Competitive grants (NRI, IFSFS, SBIR)
- Congressional specified grants
- High Education

Research Funding Distribution



Funding for Biofuel, Bioenergy, Chemicals, and Materials

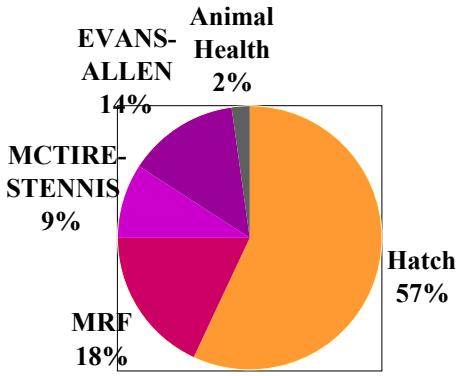


Land-Grant Colleges & Universities

- 1862, 1890, and 1994
- More than 100 Colleges and Universities
- Colleges of Agriculture, Life, and Environmental Sciences
- Departments involve in basic, biological, and social sciences in other colleges

Formula funding

- Total of $226M for FY2001



Industrial Enzymes & Chemicals

- *Ex. "Bovine rumen as a source of industrial enzymes and chemicals"*
- *Amylase and cellulase, volatile fatty acids (VFA)*
- *Biological Systems Engineering, UN*
- *Hatch*

Adhesive and Packaging System

- *Ex. "Uses of grains and by-products in edible/biodegradable feed packaging"*
- *Grain Sci. and Industry, KSU*
- *Hatch*

Production of Materials

- *Ex. "Production of activated carbon from grain"*
- *Hardness, etc., from grain kernels*
- *Chem. Engineering, KSU*
- *Hatch*

Initiative for Future Agriculture and Food Systems (IFAFS)

- **Program Code 13: New Uses for Agricultural products**
- **Panel Director:** Carmela Bailey
- Awards given in FY2000 $9M
- Number of projects funded: 8 out of 73
- http://www.reeusda.gov/1700/programs/IFAFS/ifafssum5.htm

Development of Non-allergenic Latex Products from Guayule

- Ray, D.T.
  University of Arizona, Tucson, Arizona
- $2,270,000; 48 months
- Collaborators: Texas A&M University, New Mexico State

Application of Functional Genomics to Biocatalysts for Renewable Fuels and Chemicals

- PIs: Ingram, L.O., Shanmugam, K.T., Preston , J.F., Maupin-Furlow, etc.
- University of Florida, Gainesville, Florida
- $2,000,000; 36 months
- Collaborations: Michigan State University, University of North Texas Health Science Center

National Research Initiative Grants

- **Enhancing Value and Use of Agricultural and Forest Products**
- **Acting Division Director: Conrad, Jeff**
- *Value-Added Products Research: Non-Food Characterization/Process/Product Research Program*
- *Improved Utilization of Wood and Wood Fiber Program*
- **Total awards given in FY2000: $2.6M**

Production of Chemicals

- *Ex. "Environmentally compatible synthesis of value-added chemicals from D-glucose"*
- *PHB, PAHA, L-DOPA, and vanillin*
- *Chemistry, MSU*
- *NRI Competitive Grants*

Bioconversion Process

- **"Catalytic Upgrading of Lactic Acid"**
- **The discovery and development of 2,3-pentanedione from LA**
- **Chemical Engineering, MSU**
- **NRI Competitive Grant**

Congressional Identified Research Needs

- ***Ex. "Iowa Biotechnology Consortium"***
- ***23 projects with a broad scope with emphasis on value-added products from the waste streams of food and biotechnology industries***
- ***Lead PI: Robert C. Brown, ISU***
- ***Award for FY2001: $1.46M***

Federal Administrative Grants

- Total awards of $13M in FY2001
- Ex. *"Alternative Fuels Characterization"*
- *Development of aviation grade ethanol based fuels approved by FAA*
- *Lead PI: Ted Aulich, NAFL, UND*
- *Award for the project: $242K for FY2001*

Cooperative State, Research, Education and Extension Program (CSREES), USDA

CSREES is USDA's principal link to academia and participates in a nationwide agricultural research planning and coordination system that includes State land-grant universities and the agricultural industry. As the federal partner in a cooperative system, CSREES provides leadership and funding to its university partners and other cooperators to advance research, extension, and higher education in the food and agricultural sciences and related environmental and human sciences. CSREES promotes research and development for biobased industrial products and bioenergy primarily through its Agricultural Materials Program, National Research Initiative, and Small Business Innovation Research Program.

Agricultural Materials Program

Through the Agricultural Materials Program, funding is provided for new crop development to encourage crop diversity, and for new uses for conventional crops to stimulate market expansion. Non-competitive funding through formula funding and special research grants supports a range of basic and applied research topics including plant breeding and genetics, crop production, materials processing, and product development. Products include lubricants, energy, fibers, polymers, chemicals and utilization of ag waste. Competitive funding is provided through the Initiative for Future Agriculture and Food Systems. This initiative supports applied and developmental research that integrates research, education, and extension activities to address key issues of national and regional importance, including new and alternative uses and production of agricultural commodities and products. Awards made in 2000, the first year of the initiative, address optimizing technologies for converting biomass to ethanol, developing formulations for functional fluids and greases from corn, soybeans and castor, and new crop development to supply hypoallergenic latex rubber.

National Research Initiative (NRI)

Biobased product/bioenergy research is supported primarily through the Value-Added Products Non-Food Characterization/Process/Product Research, and Improved Utilization of Wood and Wood Fiber Programs. The programs provide a bridge between basic research and near-term development and commercialization efforts. The goal of the program is to build the scientific base of knowledge to use agricultural and forest materials more fully and effectively in non-food products, to remove barriers to improve utilization of wood and wood fiber, and to improve competitive value and quality of U.S. forest products. Examples of topics supported under this program include biodegradable packaging materials and films, composites, industrial polymers, biofuels particularly ethanol, specialty chemicals, new fibers from kenaf and agricultural residues, and pharmaceuticals from forestry extracts .

Small Business Innovative Research Program (SBIR)

SBIR's Industrial Applications topic area supports research and development of new crops with potential to provide raw materials for production of industrial products, enhanced recovery of critical raw materials from agricultural commodities, improved technology for conversion of agricultural raw materials into industrial products, and enhancement of agriculturally-derived products to make them more competitive with non-agriculturally-derived alternatives. Examples of topics include oils and lubricants, natural rubber, fuels, and chemicals from starch and fibers.

HIGHLIGHTS FROM CSREES PROGRAMS ON BIOENERGY

The Initiative for Future Agriculture and Food Systems. IFAFS is a research, education and extension competitive grants program that addresses a number of critical emerging issues relevant to agriculture. In fiscal year 2000, eight awards totaling $9 M were made under the program area "New Uses for Agricultural Products." Four projects address biomass conversion to energy and complement ongoing DOE programs; two new crop development projects offer opportunities for agricultural diversification and new products; and two new uses for soybean oil address biobased product market expansion and environmental stewardship. The four bioenergy projects are briefly described:

> The University of Florida is taking advantage of *E. coli* as the workhorse of modern biotechnology and will investigate the expression of the entire *E. coli* genome during model fermentations. This functional genomic data will be used to guide the molecular tuning of recombinant biocatalysts for more efficient production of ethanol and chemicals from plant residues.
>
> The pretreatment step of lignocellulosic material is a major barrier to cost effective conversion of biomass to fuels and chemicals, and the advantages and disadvantages of one pretreatment over another have been controversial for many years. Dartmouth College is evaluating various pretreatment technologies on a uniform, consolidated basis to allow direct comparisons of material balances, energy balances, and economics. The feedstock is corn stover, and possibly a hardwood and switchgrass (time and budget permitting).
>
> Oklahoma State University is optimizing gasification/fermentation technologies to produce ethanol and chemicals. The advantage of this process over standard fermentation processes is the utilization of lignin, thereby significantly increasing ethanol yield. The economics of producing, harvesting and transporting underutilized perennial grasses and crop residues to the conversion facility are included in this study.
>
> The Agricultural Research Service Eastern Regional Laboratory is developing a modified steeping technology combined with the use of enzymes to reduce steep time and emissions in the corn wet milling process to produce ethanol and coproducts. This technology is being evaluated for economic feasibility when compared to the standard wet milling process.

contact: Carmela Bailey, Program Director for New Uses, cbailey@reeusda.gov

National Research Initiative (NRI) Competitive Grants Program. The NRI is a competitive research grants program focusing on fundamental and mission linked research. It includes a program on Non-Food Characterization/Process/Product research, a major component of which is devoted to biofuels research as well as other agriculturally-derived products. Other relevant research is supported in the Improved Utilization of Wood and Wood Fiber programs. Annual funding of approximately $4 million is directed to these two programs.

One accomplishment in the energy area is work by Lonnie Ingram of the University of Florida which was funded by NRI and its predecessor, CRGO . This research resulted in numerous patents including patent no 5,000,000 and formed the basis for the first-of-it's-kind plant to produce ethanol from cellulosic biomass. DOE also supported basic research by Ingram as well as for pilot plant construction and operation.

Contact: Jeff Conrad, Program Director, jconrad@reeusda.gov

Small Business Innovation Research (SBIR) Program. SBIR is specifically designed to support R&D and commercialization by small businesses. The SBIR's Industrial Application and Forest and Related Resources Topic Areas supported a range of biobased products and energy-related research in proof-of-concept (Phase I) as well as R&D (Phase II) projects geared toward ultimate commercialization of biobased products and technologies. Approximately $2.1 million in biobased products research was supported in FY 2000.

Contact: Charles Cleland, Director, ccleland@reeusda.gov

Interagency Metabolic Engineering Program. The USDA, NRI participates in this interagency effort to foster and support research in metabolic engineering, purposeful alteration of metabolic pathway for production of useful products. Seven different agencies are involved in this interagency program.

As a result of this effort USDA and DOE are jointly supporting a project at the University of Colorado and National Renewal Energy Laboratory to maximize ethanol production by using metabolically engineered *Zymomonas mobilis* strains from mixtures of hexose and pentose sugars. USDA and NSF are jointly funding a project at the University of Kentucky to metabolically engineer plant trichomes for production of valuable chemicals. The Metabolic Engineering Working group also sponsored a workhshop on May 31, 2000 to bring together researchers to share results and discuss future research needs for this important area of biotechnology.

Contact: Jeff Conrad, Program Director, jconrad@reeusda.gov

Special Research Grant: National Alternative Energy Laboratory

The University of North Dakota has been developing and promoting the use of biomass-derived fuels since 1991. One of the most significant achievements includes the development of aviation-grade ethanol, which was certified by the U.S. Federal Aviation Administration to be used in several Cessna engine-airframe combinations in 1999. In January 2000, the FAA further approved the use of any combination of the aviation-grade ethanol with the current standard high performance commercial aviation fuel.

contact: Hongda Chen, National Program Leader, Bioprocess Engineering, hchen@reeusda.gov

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

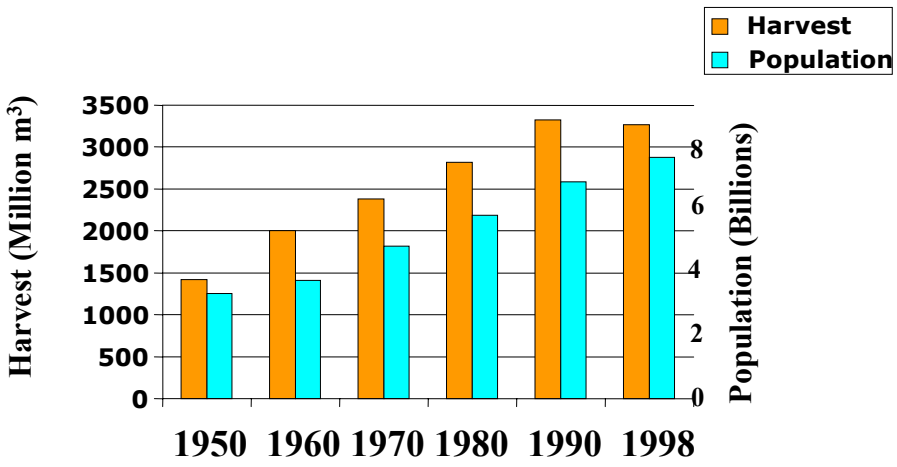
Opportunity Knocks

- 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

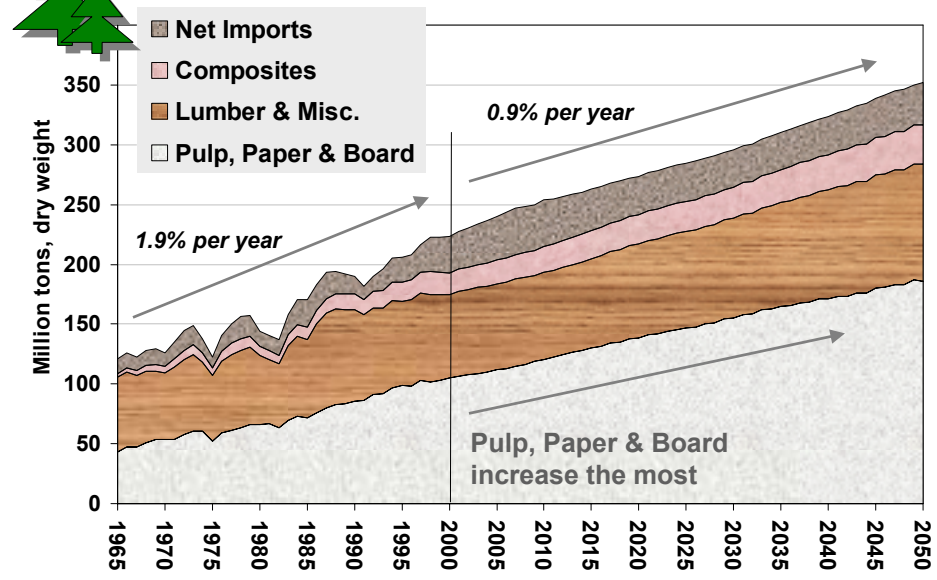
- Third country in volume of standing timber
- Timber growth still exceeds cut
- Use 25% of all energy generated in the world
- Approximately 3 quads, or 3% is biomass energy, mostly from forest biomass
- Per capita yearly consumption of wood and fiber products in U.S. (2.1 cu. met.) is 4 times world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

Biobased Products and Bioenergy Program: Small-Diameter Trees and Low-Valued Sources

Issue: Forests can provide increased renewable sources for biobased products and bioenergy. To comply with the Biomass Research and Development Act of 2000 (Public Law No. 106-224), research is needed to develop new woody crop systems, to better utilize our forest resources, and to develop value-added wood products, including bioenergy.

Background: In many regions, considerable forest land is overstocked, under-productive, and at high risk to fire, insects, and diseases, lowering the economic and social values of those forests. This land requires tree removal to reduce the fire danger and the danger of disease and insect infestation. Removal of this biomass would provide a large feedstock source for biobased products and bioenergy. Likewise, the large volume of municipal waste wood and wood fiber, much of which fills landfills, is a major problem for many cities and would provide another good feedstock.

Key points:

- Forest Service Research and Development (FS R&D) will improve our forest management and wood utilization options by integrating the use of small-diameter material for biobased products and bioenergy to extend our natural resources, provide renewable energy, increase carbon sequestration, reduce fire and pest risks, and improve forest health.

- FS R&D will improve the recycling, recovery, and processing of waste paper and solid wood products by developing new processing and products from small-diameter wood and low-value sources.

- FS R&D will collaborate with research programs in the Department of Energy, universities, and the forest industry to develop environmentally and economically acceptable production and utilization systems for a range of biobased products, including bioenergy.

FY 2001 Program Details ($3 million)

Products and Utilization -

- *Signage from juniper in woodfiber-plastic composite* - Develop the technical information and new technologies needed to utilize juniper from Western rangelands in woodfiber-plastic composites for use as signage on National Forests and other outdoor signage applications. *($250K for FPL-4706)*

- *Use of small diameter red and jack pine for paper and paperboard* - Develop the technical information and new technologies needed to utilize small diameter red pine and jack pine thinnings in paper and paperboard used in printing and writing grades as well as packaging grades. *($100K for FPL-4710)*

- *Conversion of woody biomass to ethanol* - Develop new strains of yeasts capable of efficiently and effectively fermenting five-carbon sugars derived from the hydrolysis of wood to ethanol. *($150K for FPL-4712)*

- *Strength properties of small diameter ponderosa pine* - Develop the statistical technical information on the strength and stiffness of small diameter Ponderosa Pine from the interior Western U.S. for use as air-dried dimensional lumber. *($100K for FPL-4714)*

- *Small diameter timber in woodfiber/plastic composite structural components* - Develop technical information and new technologies to grade and utilize small diameter timber from Western U.S. forests in woodfiber/plastic composite shingles for housing and other structural applications. *($200K for FPL-4716)*

- *Utilization of economically marginal woody materials* - Characterize differences between Westside (coastal) and eastside (interior) small diameter timber utilization issues in the Northwest and identify potential uses for fiber logs and other sub-merchantable timber given different economic conditions. *($200K for PNW-4865)*

- *Wood properties and biobased product potential for young small diameter southern pine under difference management* - Develop a data base of anatomical, physical, chemical and mechanical properties for small diameter southern pine growing under a range of forest management regimes and develop models for predicting these wood properties based on tree, stand and environmental variables. *($65K for SRS-4104)*

- *New products and chemicals from small-diameter timber* - Develop composite wood products from this inferior quality small diameter tree raw material. Specifically, three areas of investigation were identified that may benefit from the unique characteristics of this raw material: 1) medium-density fiberboard, 2) wood/thermoplastic polymer composites and 3) liquefied wood-derived adhesives. *($80K for SRS-4701)*

- *Identification of technologies and opportunities from small-diameter timber* - Identifying technologies and opportunities for diversifying the range of products that can be efficiently and cost-competitively produced from small-diameter timber. *($68K for SRS–4702)*

Forest Management -

- *Ecology and Management of Central Hardwood Ecosystems* - Determine the current productivity, consumption and potential productivity of wood in the North Central Region and develop silvicultural systems that integrate the demand and market opportunities for small-diameter energy fiber products. *($134K for NC-4154)*

- *Ecology and Silviculture of the Northern Lakes States Forests* - Explore commercial thinning in small diameter aspen stands to produce high quality wood biomass for industrial use. *($133K for NC-4154)*

- *Ecology and management of northern forest ecosystems* - Develop and analyze land management practices that ensure environmental performance and sustainability of biomass production and assess the impacts of biomass production on aspects of forest structure that affect biodiversity. *($67K for NE-4155)*

- *Silvicultural treatments of small diameter stands in the PNW region* - Characterize stand and management differences between the Westside (coastal) and Eastside (interior) small-diameter timber resource in the Northwest, produce a synthesis of past silvicultural research on treatment of overstocked, small-diameter stands, and identify appropriate technologies and related cost and impact data for the harvest and transport of small-diameter materials. *($200K for PNW-4163)*

- *Silvicultural management and fuel reduction* - Examine means to reduce stand density to improve the vigor of residual trees and reduce fire risk while retaining site organic matter and carbon storage. Will explore methods to increase the value of the forest stands and use of small-diameter material to offset the cost of treatment. *($135K for PSW-4155)*

- *Biobased products from the Sequoia National Monument* - Establish a small-diameter silvicultural treatment and utilization study focused on achieving ecosystem management objectives, reducing fire risk, improving forest health, and insuring ecological/economic sustainability. *($122K for PSW 4403)*

- *Ecology and Management of Northern Rocky Mountain Forests* - Develop management alternatives and approaches to sustain lodgepole pine forests, which include harvesting of small diameter timber for pulp and roundwood. *($141K for RMRS-4151)*

- *Forest Management and Ecosystem Processes in the Interior West* - Develop management options for small diameter trees in the Interior West that reduce fire risk, improve forest health, and provide value-added products. *($100K for RMRS-4155)*

- *Sustaining Alpine and Forest Ecosystems Under Atmospheric and Terrestrial Disturbances* - Develop and analyze land management practices and alternative biomass systems to ensure environmental performance and economic viability of raw material biomass input for biobased industrial products in an integrated system. *($142K for RMR-4451)*

- *Impacts of forest biobased operations on soil erosion* - Measure the impacts of onsite operations on soil erosion, soil quality, and hillside sedimentation and develop user-friendly tools to aid forest managers in planning for environmentally-benign biobased operations near small diameter thinnings. (*$100K for RMRS-4702)*

- *Forest operations for small-diameter bio-based product extraction* - Develop and evaluate alternative technologies for cost-effective systems that cut, extract, and transport small-diameter materials to a location for secondary processing. *($90K for SRS-4703)*

Economics and Social -

Integrating social and biophysical sciences for natural resource management - Incorporate the measurement and analysis of carbon sequestration and carbon cycling in the development of land management practices (including small diameter stands)

- that ensure the environmental performance and sustainability of biomass production and harvesting. *($67K for NE-4454)*

- *Economics of Eastern forest Use* - Identify technologies and opportunities for diversifying the range of products that can be efficiently and cost-competitively produced from small-diameter timber. *($66K for NE-4803)*

- *Fuel Reduction in the Tahoe Basin*– Will evaluate economic and institutional feasibility, public benefits, and policy factors that affect biomass utilization for fuel reduction in key urban interface areas in the west-slope region of the Sierra Nevada, particularly as they interact with key large-scale planning processes. *($210K for PSW-4355)*

- *Economics of Small-Diameter Utilization* - Assess the economic viability of biobased industrial products and their raw material input of biomass by investigating FIA databases to assess the characteristics of small diameter materials on public and private ownerships. *($80K for RMRS-4802)*

- *Legal and regulatory framework affecting the economics of short-rotation woody crops* - Develop an understanding about the impact of taxation schemes and environmental regulations have on the establishment of short-rotation woody crops. *($30K for SRS-4802)*

Key Contacts

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Systematic Approach To Developing Bio-product and Bio-energy Markets

USDA Biobased Products and Bioenergy Coordinating Council

Agricultural and rural interest groups have become increasingly attuned to the potential benefits from developing growing markets for bioproduct and bioenergy markets. Farmers need new sources of demand for farm commodities. Rural communities need new business activity and job creation. U.S. consumers have become increasingly interested in energy production and other products that are more friendly to the environment than are those produced from fossil fuels. Finally, high value export market demand is developing in Japan, certain other Eastern Asia countries, and Western Europe for environmentally friendly biobased products and cutting edge technology for the production of bioproducts and bioenergy. U.S. products can capture a substantial share of that market.

To date most efforts to develop bioproduct and bioenergy markets have focused on increased research, as key to achieving product development and market penetration. Research is essential to building markets. But, while essential, it is not in itself sufficient. A much more strategic, and productive, strategy would involve a systematic approach. Research efforts must be combined with a number of other activities essential to bringing new products to market and to making meaningful inroads into those markets.

Eight important steps in a systematic approach are briefly described below. Without any one of these steps, progress toward product development and market penetration is likely to be disappointing. With an appropriate balance of emphasis, results can be markedly improved.

Both public and private sector involvement are needed to achieve the desired product development and market penetration. Indeed, public sector support would provide an important catalyst to attracting private sector investment. In the absence of initial public sector support, progress toward developing and commercializing bioproducts and bioenergy will be disappointingly slow.

1. Research: Increased support for research funding is of critical importance to accomplish the following objectives:

* Markedly broaden the range of products produced from bio-feedstocks.
* Isolate and identify uses for new molecules and compounds from biomass.
* Identify ways to reduce costs of sugars from lignocellulosic biomass.
* Explore new biobased products pathways, an example being biobased plastics.
* Reduce the cost of biomass gasification.
* Perfect the bio-refinery concept.
* Find ways to clean biomass feedstocks to avoid damage to processing and utilization equipment.
* Create increased feedstocks of improved and more uniform quality at reduced cost.

2. Life Cycle Cost Analysis: It is important to understand the full costing of biobased products and bioenergy, as compared to their fossil fuel based alternatives. Attributes and costs not currently accounted for in market price determination need to be better understood and, where possible, made explicit. The following analyses are necessary:

* Life cycle costing from product acquisition to final disposal.
* Net energy balance analysis.
* Identifying and valuing unique attributes of biobased products and energy, relative to their fossil fuel alternatives.

3. Performance Testing: Without factual information on product performance and physical properties measurement, it will be difficult to develop broad market demand for bioproducts and bioenergy. Questions needing answers are:

* What are the physical properties of the product?
* Does the product perform as represented?
* What are those performance characteristics?
* Does the product meet established industry standards of performance?
* What are effective pathways to funding and accomplishing product testing for performance?

4. Regulatory Initiatives: Environmental regulation currently does not typically differentiate between fossil fuel based products and biobased products. It seems likely that such differentiation would be helpful, where warranted by scientific data, to increase market demand for biobased products and bioenergy. That differentiation may include the following strategies:

* Regulatory flexibility that encourages firms to try new technologies and products.
* Recognition of the environmental impact of bio-based products and bio-energy, compared to fossil fuel based alternatives.
* Regulatory flexibility to encourage use of best practices environmental management.

5. Product Development and Commercialization: Successful product development and product commercialization are likely to require substantial resources, even more so than research. Supportive public policies can make a critical difference. Strategies include:

* Adequate funding to bring new products to market.
* Federal and State government procurement preferences.
* Procurement regulations recognizing the value of special attributes associated with biobased products and bioenergy.
* Education efforts focused at industry.
* Education efforts focused at a broad base of consumers.
* Product promotion.

6. Public Sector Incentives: Incentives of various types are likely to be required if private sector firms are to assume the risk associated with investment in new plant and equipment to process bioproducts and generate bioenergy. These incentives include the following:

* Investment tax credits to speed the recovery of capital costs associated with new plant and equipment.
* Operating incentives to make initial production cost competitive until economies of scale can drive down costs, and/or market demand bids up prices.
* Insurance programs to reduce risk of installing new commercial scale technology.
* Other business incentives focused on non-profit firms such as Federal PMAs.
* Carbon credits for use of bioproducts and bioenergy.

7. Education and Outreach Initiatives: Raising the level of understanding about the benefits that can accrue from bioproducts and bioenergy will require a focused and long term education and outreach effort. This effort must educate the next generation of consumers, while also reaching current consumers' needs for science based and factual information. Education programs to assure the Nation of a sufficient supply of skilled workers capable of functioning in a technologically advanced workplace are necessary, as well. These initiatives include:

* Develop and distribute educational materials that explain the contributions of biobased products and bioenergy for use in K-12 classroom education.
* Establish Centers for Excellence in teaching and research about biobased products and bioenergy at a number of colleges and universities across the Nation.
* Develop and implement a program of outreach education for the general public on the contributions of biobased products and bioenergy.

8. Financing Issues: Financing issues remain to be resolved by market participants and public policy makers. These issues focus both on equity and debt capital issues that can pose barriers to essential investment in plant and equipment, as well as market development. Addressing these barriers to biobased product and energy may include the following strategies:

* Overcoming rates of return barriers on new investments in plant and equipment, through various tax and production incentives involving public sector support.
* Bridging initial equity capital gaps through public/private sector partnerships as industry begins to put new capacity in place.
* Developing cost effective risk management strategies, including insurance plans, that reduce private sector risk in new plant and equipment investment.
* Facilitating creation of private sector investment funds focused on supporting investment in technology, facilities, and market structure development.
* Creating strategic alliances to marshal private sector/ public sector cooperation, to foster technical development among private sector firms, and to better manage risk associated with processing and marketing of new products.

Government Programs Highlighted

DOE:

Biopower- Ray Costello

Biofuels - Valerie Sarisky-Reed

Agriculture and Forest Products - Mark Paster

Energy Biosciences - Greg Dillworth

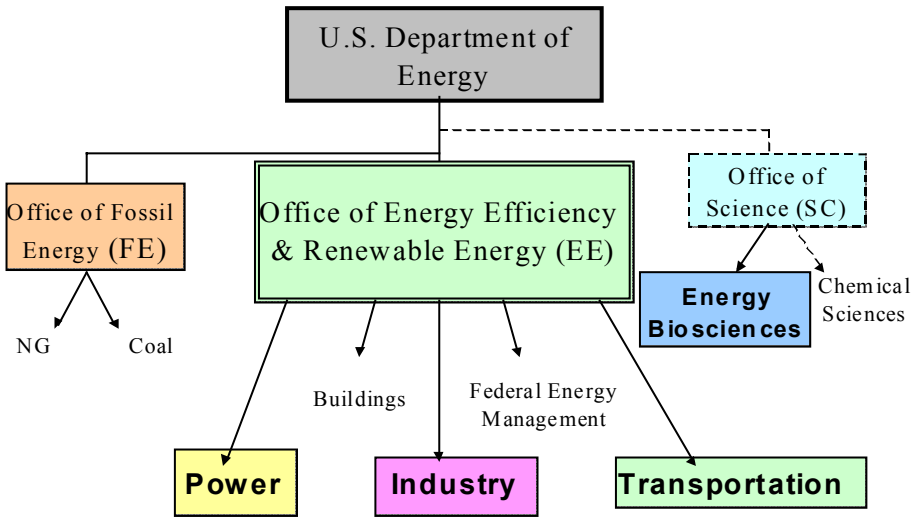
Biomass: The Basic Resource

Agriculture & Forest Products

Fuels

Electric Power

Bioenergy and Biobased Products R&D Programs at DOE

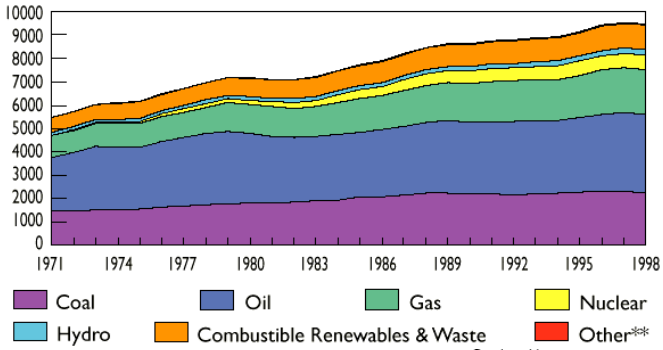


Appendix I. Federal Government Programs Relevant to Biobased Products and Bioenergy and their Web Sites

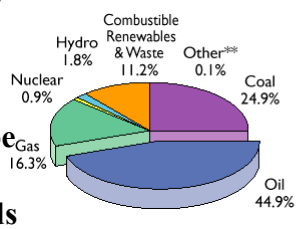
Departments, Agencies, Offices, Programs	Web Site
U.S. Department of Energy	**http://www.doe.gov/**
Energy Supply Research and Development	
Renewable Energy	
Biomass Power Systems	http://www.eren.doe.gov/biopower/flash.html
Biofuels Energy Systems	http://www.ott.doe.gov/biofuels/
Hydrogen Energy Reeearch and Development	http://www.eren.doe.gov/power/hydrogen.html
Science	***http://www.science.doe.gov***
Basic Energy Sciences	http://www.sc.doe.gov/production/bes/bes.html
Energy Biosciences	*http://www.sc.doe.gov/production/bes/Division.htm#biosciences*
Chemical Sciences	*http://www.sc.doe.gov/production/bes/Division.htm#chemical*
Engineering and Geosciences	*http://www.sc.doe.gov/production/bes/Division.htm#EngGeo*
Biological and Environmental Research	*http://www.sc.doe.gov/production/ober/ober_top.html*
Energy Conservation	***http://www.eren.doe.gov/***
Industry Sector	http://www.eren.doe.gov/EE/industrial.html
Industries of the Future – specific	
Forest Products	*http://www.oit.doe.gov/forest/*
Agriculture	*http://www.oit.doe.gov/agriculture/*
Industries of the Future – crosscutting	
Transportation	http://www.eren.doe.gov/EE/transportation.html
Fuels Utilization R&D	*http://www.ott.doe.gov/otu/afutil.html*
Fossil Energy Research and Development	***http://www.fe.doe.gov/***
Coal and Power Systems	http://www.fe.doe.gov/programs_coalpwr.html
Central Systems	http://www.fe.doe.gov/coal_power/central_power.html
Gasification Cycles	*http://www.fe.doe.gov/coal_power/gasification/index.html*
Turbines	*http://www.fe.doe.gov/coal_power/turbines/index_industrial.html*
Distributed Systems	http://www.fe.doe.gov/coal_power/distributed_power.html
Fuel Cells	*http://www.fe.doe.gov/coal_power/fuelcells/index.html*
Natural Gas	*http://www.netl.doe.gov/scng/*

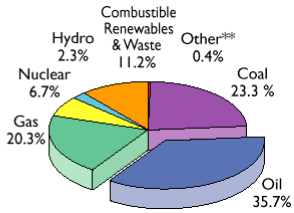
See Appendix I. in
http://www.bioproducts-bioenergy.gov

Evolution from 1971 to 1998 of World Primary Energy Supply by fuel (Mtoe) - http://www.iea.org/statist/keyworld/p_0101.html



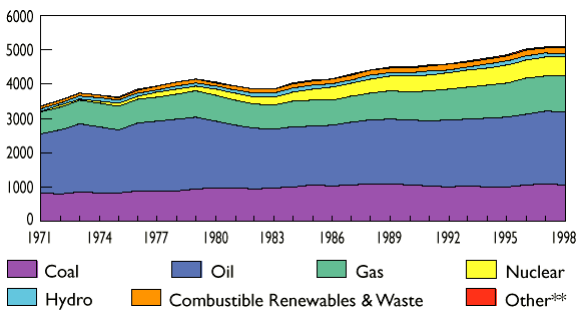
1973
6043 Mtoe
or
240 Quads



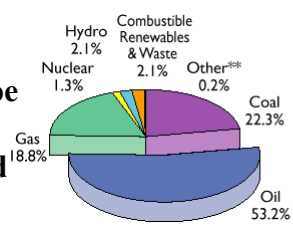


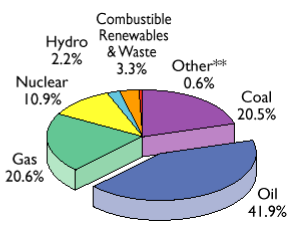
1998
9491 Mtoe
or
377 Quads

Total final consumption by fuel in the world - Evolution from 1971 to 1998 in Mtoe http://www.iea.org/statist/keyworld/p_0101.html



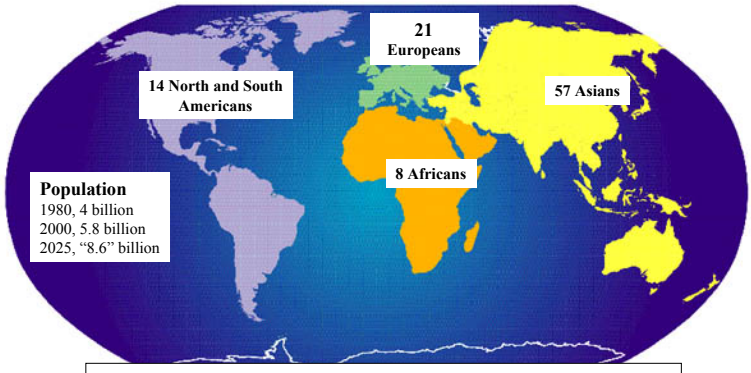
1973
4,549 Mtoe
or
180 Quad





1998
6,646 Mtoe
or
264 Quad

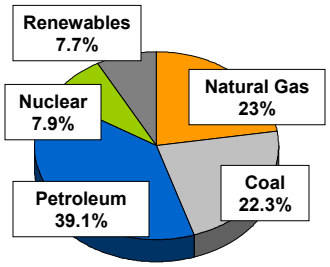
Snapshot of World Demographics
(Based on 100 People)

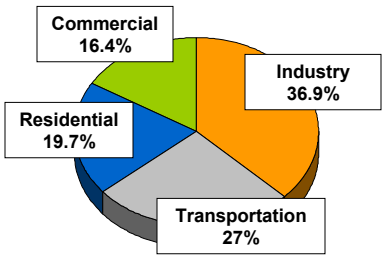


Half of wealth in hands of 6 people (all from U.S.)
30 – literate; 1 – college education; 1 – own computer

Source: Dr. J. Albrecht, IFT 1999

Facts & Figures: U.S. Energy Use

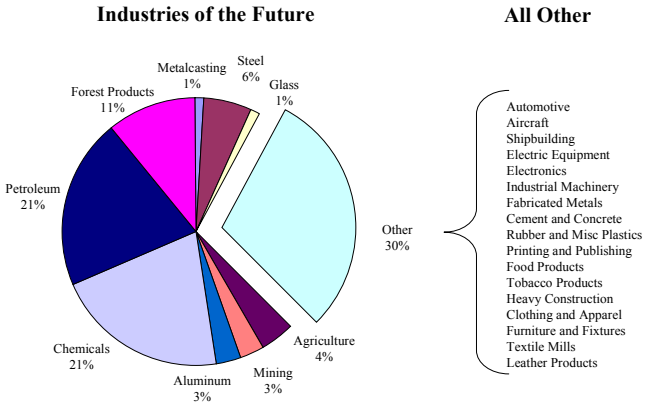




U.S. Energy Use
97 Quads
Population ~273 million
355 million Btu/capita

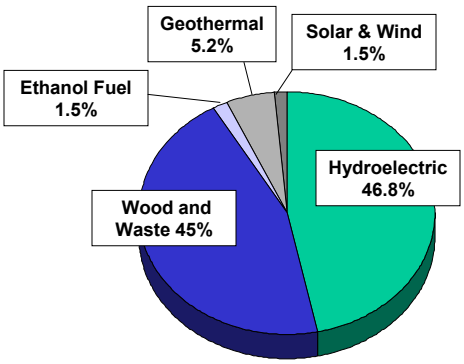
Energy Use by Industry

Total 1999 End Use: 36.7 Quads[1]



[1] Includes 2.8 quads of renewable energy used principally in the forest products industry.

U.S. Consumption of Renewable Energy



Total Renewable Energy Use 7.5 Quads

7.7% of U.S. Energy Consumption

Biobased Energy Use 3.6 Quads (3.7%)

Feedstock Energy

Fossil Energy Feedstocks (1998)

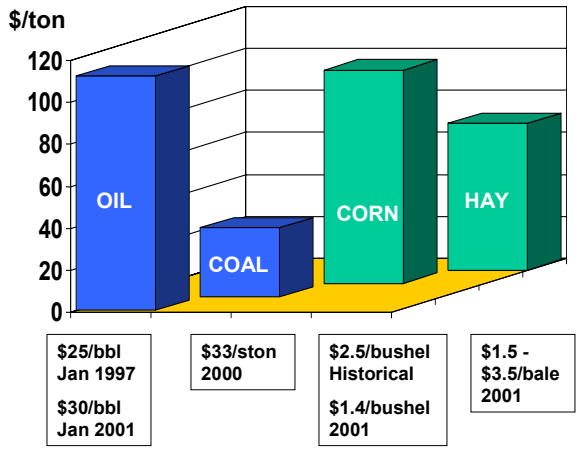
- **Chemicals ~ 3,220 trillion Btu**
- **Petroleum Refining ~ 3,748 trillion Btu***

Total: ~8 Quads

Chemicals and other products account for ~8.5 percent of U.S. fossil energy use as feedstock.

****Production of non-fuel products (lubricants, waxes, asphalt)***

Comparative Prices: Energy and Crops



National Research Council (NRC) Report on Biobased Products

- **Strongly encourages support for a transition to biobased industrial products (power, fuels, chemicals, materials)**
  - **reduce our reliance on fossil fuels**
  - **mitigation of projected global warming and other environmental issues**
  - **revitalization of rural economies**
- **Is there enough biomass for food, feed and bioproducts ? YES**
- **Is it possible ? YES but we need additional research and breakthroughs to reduce processing costs.**

National Research Council (NRC) Report on Biobased Products

"Biological Sciences are likely to make the same impact on the formation of new industries in the next century as the physical and chemical sciences had on industrial development throughout the century now coming to a close"

BioProducts and BioEnergy: Drivers

- Energy Security
- Climate Change
- Other Environmental Issues
- Rural Development
- Biotechnology Revolution

U.S Department of Energy

DOE Spends over $145 million on Biobased Products & Bioenergy

- Basic science - plant genetics and processes
- Applied R&D - biomass for fuels, power & industrial products

Agriculture and More

Feedstock
- Trees
- Grasses
- Agricultural Crops
- Agricultural Residues
- Animal Wastes
- Municipal Solid Waste

Conversion Processes
- Acid/enzymatic hydrolysis
- Fermentation
- Bioconversion
- Chemical Conversion
- Gasification or Pyrolysis
- Combustion
- Co-firing

USES

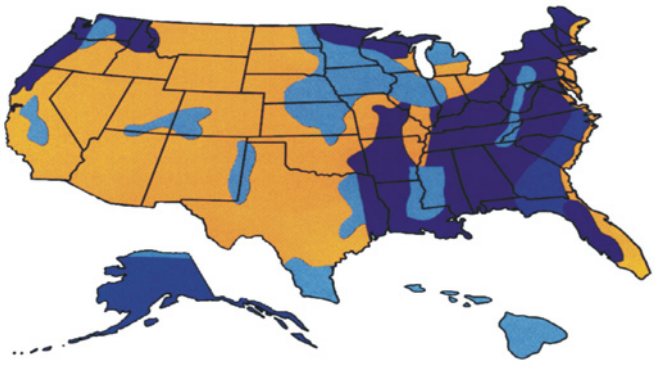
Fuels:
- Ethanol
- Renewable Diesel

Electricity
Heat

Chemicals
- Plastics
- Functional Monomers
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Hydraulic Fluids
- Fatty acids
- Carbon black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

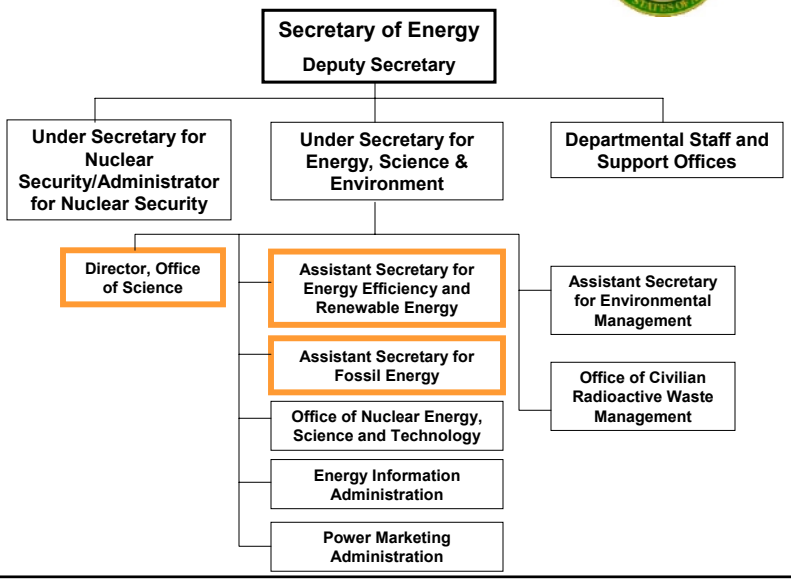
U.S. Biomass Resources



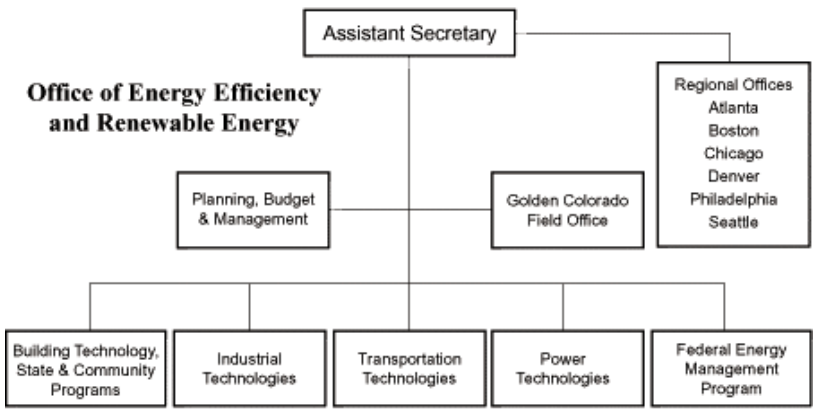
- Low Inventory
- Agricultural Resources
- Agricultural and Wood Resources
- Wood Resources

Source: U.S. DOE

U.S. Department of Energy



Office of Energy Efficiency & Renewable Energy



Biopower Program Overview

DOE National Bioenergy Center

Strategic Partnership Workshop

Golden, Colorado

Biopower Mission

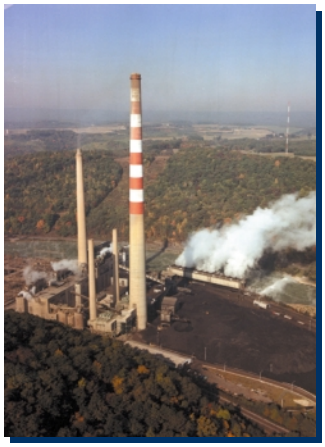
- **Mission – In partnership with industry, the Biopower Program will encourage the development and utilization of biopower technologies that are competitive with conventional power systems**

Biopower Program

- **Near Term**
  - Co-firing (Rural Development)
- **Mid Term**
  - Modular Systems
- **Long Term**
  - Integrated Gasification Combined Cycle

Status of Biopower in U.S.

- **Currently Installed:**
  - U.S. Biomass Power: 7,000 MW (or about 8% of all non-utility generating capacity)
  - Over 500 facilities in U.S. generate electricity from wood or wood waste



FY 2001 Funding

Program Element	FY01 Enacted ($k)
Thermochemical Conversion	3,400
Systems Development	25,965
Feedstock Production	3,300
Regional Biomass Energy Program	1,335
Bioenergy Initiative	6,000
Total	**40,000**



Co-Firing

- **Commercialize and promote biomass co-firing using the least cost approach**
- **Broaden the base of utilities employing co-firing in existing generating units**
- **Increase the number and type of technologies used in co-firing**

Co-firing (cont'd)

- **New York Salix (Willow)**
  - Dunkirk Power Plant
    - 10-15 MWe from biomass
- **Iowa Switchgrass**
  - Ottumwa Generating Station
    - Up to 35 MWe from biomass
- **Hawaiian Energy Cane**
  - HC&S Sugar Mill, Puunene , Maui
  - Alternate feedstock processing

Gasification

Develop gasification technologies for the conversion of biomass into clean, sustainable energy and other products

Elements:

- **Build on successful and existing technology platforms**
- **Plan and implement a robust R&D program**
- **Establish supportive infrastructure**

Gasification

Objectives

- Initiate development of low-BTU fuel gas to demonstrate high thermal efficiencies
- Examine integrated systems fueled with medium-BTU gas to evaluate advanced power cycles
- Evaluate synthesis gas production for evaluating chemical and liquid fuels production
- Test and validate integrated gasifier systems for producing power, chemicals and liquid fuels

Gasification Project

- Co-funded demonstration of gasification of renewable biomass for electricity production
- Vermont Gasifier Highlights

- Project being undertaken at the existing 50 MW wood-fired McNeil Power Generation Station in Burlington, Vermont
- Gasifier integration with a gas turbine
- "Development and Applications Test Platform" will allow for testing of turbines, fuel cells, other feedstocks and synthetic fuels production, methanol, gasoline, diesel (2001 estimated completion date)

Small Modular Systems

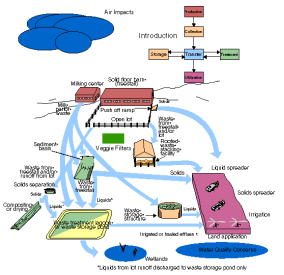
- Working with industry to develop small, modular biopower systems
- Power range from 5 kW to 5 MW
- Cost-shared contracts awarded in gasification and combustion technologies

Small Modular Biopower Phase 2 Projects

Carbona Corporation boiler/	Atlanta, Georgia	Up-draft gasification with steam turbine
Community Power Corporation	Aurora, Colorado	Gasification with spark ignition engine/generator
External Power fueled	Indianapolis, Indiana	Residential-scale biomass-system using stirling engine developed by Sun Power
Flex Energies Inc.	Mission Viejo California	Microturbine for biogas applications

Anaerobic Digestion

- Reduce air & water emissions
- Improved economics/Increased energy self-sufficiency
- Contributes to grid stability, reliabilty, efficiency
- Leverages small system improvements



Anaerobic Digestion Projects (FY2001)

- **MEAD – Tillamook Bay, OR $1000 K**
  - Cow manure methane/IC engine electricity generator
  - Approximately 350 kw production capacity
- **EERF – Michigan State University $500 K**
  - Bioreactor landfill project
- **Vermont Agriculture Methane Project $395 K**
  - Cow manure methane/IC engine electricity generator
  - For onsite use at Foster Brothers farm

SBIR — Role of Biopower Program

- **Biopower Program has been participant in 4 consecutive years (first 2 years under biopower, last 2 years under bioenergy and bioproducts topic heading)**
- **Current Subtopics:**
  - Animal Waste Modular Power System
  - Biomass Material Handling
  - Clean-up of Gases from Gasification Processes
  - Production of Energy Efficient Low-Cost Sugar

Small Business Innovation Research Program (SBIR): Biopower

FY 2000 Phase I:

- **Advanced Fuel Research, Hartford, CT $100 K**
  - Feasibility of two-stage pyrolysis processing
- **Barham Farms, Zebulon, NC $100 K**
  - Industry waste treatment solutions
- **Physical Sciences, Andover, MA $100 K**
  - Alkali control system for gasification

Small Business Innovation Research Program (SBIR): Biopower

FY 2000 Phase II:

- **Spinheat Ltd., Fairfield, CT** **$750 K**
  - Modular system to burn animal waste
- **Altex Technologies, Santa Clara, CA** **$712 K**
  - CHP plant using dairy farm waste

Regional Biomass Energy Program

Technology Transfer Network

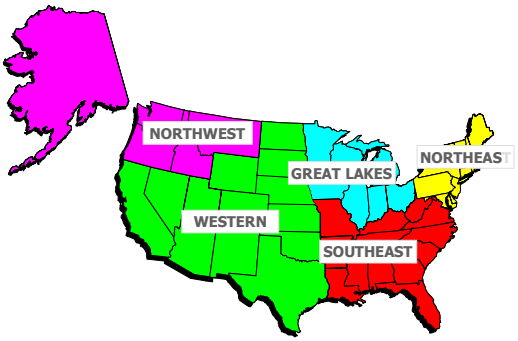
Northeast - 11 States

Southeast – 13 States

Great Lakes – 7 States

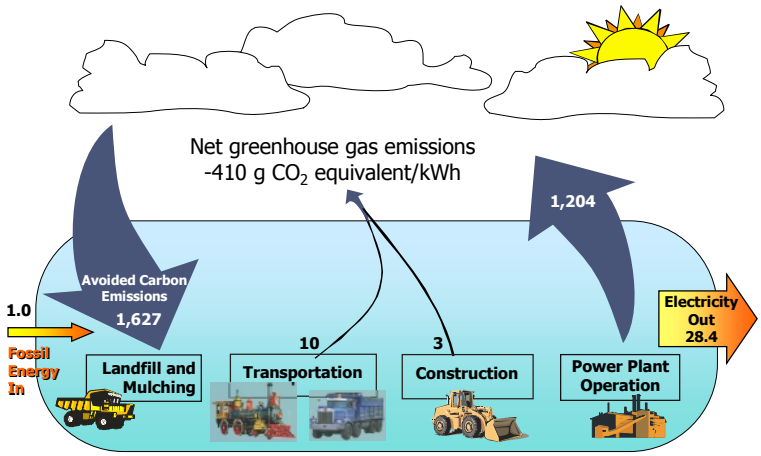
Western – 13 States

Northwest – 5 States



Life Cycle CO_2 and Energy Balance for a Direct-Fired Biomass System

Current biomass power industry



Direct-Fired Biomass Residue System

134% carbon closure

Biomass Feedstocks

Wood Residues

- Sawdust
- Wood chips
- Wood waste
  - pallets
  - crate discards
  - wood yard trimmings

Agricultural Residues

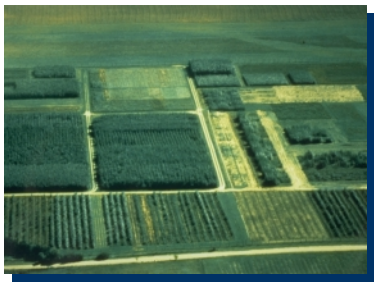
- Corn stover
- Rice hulls
- Sugarcane bagasse
- Animal waste

Energy Crops

- Hybrid poplar
- Switchgrass
- Willow

Feedstock Development Program

Collaboration between Oak Ridge National Laboratory and USDA



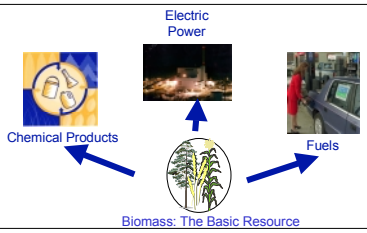
- Screened over 150 woody and herbaceous species as potential energy crops
- Validating the technical and economic viability of integrated supply systems
- More than 100,000 acres of short-rotation woody crops established by industry to date

Office of Fuels Development
Energy Efficiency and Renewable Energy

Strategic Partnership Meeting
NREL
April 11-12, 2000

Mission

Perform R&D to enable and support the establishment of a large integrated biomass-based bioenergy industry that supplies fuels, chemicals, and electricity



Foster new domestic jobs, reduce carbon emissions, and reliance on imported fuels

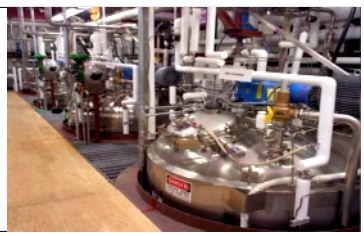
Scope

- Program Areas
  - Biomass Feedstock Development
  - Biomass Conversion Technology R&D
  - Renewable Diesel Alternatives R&D
  - Regional Biomass Energy Program
  - Bioenergy Initiative

Objectives

Feedstock Production
Develop cost competitive feedstock supply systems to support large-scale wide-spread production of fuels, chemicals, and power

Biomass Conversion
Develop integrated bioengineering systems to increase conversion yields and reduce ethanol and chemicals production cost



Objectives (continued)

Renewable Diesel Alternatives
Support the development, testing, and deployment of diesel alternatives.

Regional Program
Foster the use of bioenergy alternatives through technology transfer and industry support at regional and state levels.

Government Role

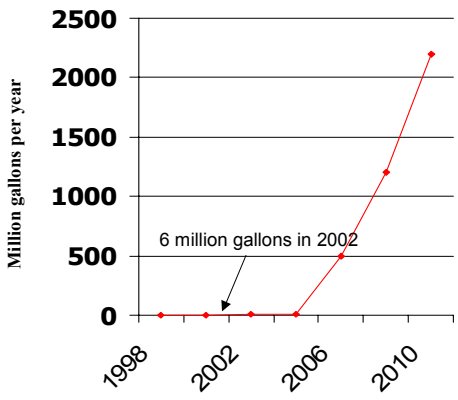
- **Overall**–The Biofuels program is a mid to long term high risk R&D effort to lower our nation's dependency on foreign oil, promote domestic economic growth, and lower carbon emissions.
- **Feedstock Production and Conversion Technology**– High-risk R&D required to achieve cost reduction goals, significant market penetration and realization of national benefits.

Strategic Approach

- Focus on ethanol production research, development and deployment as most promising option
- Highly leveraged partnerships to build first commercial demonstration facilities
- Core research and development to reach program cost goals and proceed beyond first demonstration facilities

Cellulosic Ethanol Production Goals

- demonstrate costs competitive in the oxygenate market using low cost biomass by 2002
- develop and demonstrate technologies capable of producing ethanol with an average production cost of $1.02/gallon at the ethanol plant gate
- Increase cellulosic ethanol production to 2.2 billion gallons by 2010



Projected Cellulosic Ethanol Production Rates

"The Future Is Bright For Ethanol"

Ethanol market share should more than triple by 2010!

- Oil supply and demand imbalances drive the price of oil to its highest level in years.
- MTBE will be phased out.
  - RFG requirement vs. Renewable requirement
- Cost effective cellulosic technologies are being demonstrated in the near future.
- Bioenergy Initiative provides additional focus

Sugar Platform

- Has been initiated and integrated into Bioenergy Initiative
- Genencor Contract in FY 2000

  - 3 year project, Total DOE Cost: $13.55 million; Cost Share: $3.4 million
- Second Contract in Negotiation

  -2 year project, Total DOE Cost: $11.8 million; Cost Share: $2.4 million

Sugar Platform – A Research Strategy

- Natural intermediate of ethanol production is production of pentose and hexose sugars and relatively pure lignin
- Sugars and lignin can be converted to higher value products that may help jump start biomass conversion
- Decoupling of hydrolysis and fermentation offers various processing advantages and opportunities
- Can serve existing sugar markets, as well as supply sugars for fermentations

Projected Cost of Sugar Production

Near term	6.4 cents to 5.7 cents per lb.
2005	4.4 cents per lb.
2010	3.9 cents to 3.0 cents per lb

This compares favorably with current costs of glucose:

6 cents per lb (estimated corn wet mill)

Higher Value Products from Sugar Stream

	Market	Price	Yield	Fraction of	Revenue***
	MM lb/yr	$/lb	lb/ton	Market**	MM $/yr
Ethanol*	93,600	$ 0.15	593	0.5%	$ 68
Acetic Acid	3,400	$ 0.33	574	13%	$ 146
Butyraldehyde	2,100	$ 0.43	287	11%	$ 95
Adipic Acid	1,600	$ 0.65	860	41%	$ 431
Butanol	1,000	$ 0.41	287	22%	$ 91
Acrylic Acid	1,000	$ 0.69	918	71%	$ 488
Succinic Acid	600	$ 0.35	998	128%	$ 210
Propylene Glycol	600	$ 0.58	310	40%	$ 138
Glycerol	350	$ 0.58	574	126%	$ 203
Citric Acid	350	$ 0.82	998	220%	$ 287
Propionic Acid	100	$ 0.41	528	406%	$ 41
Butyric Acid	30	$ 0.48	436	1119%	$ 14
Malic acid	15	$ 0.81	642	3297%	$ 12
2,3-butanediol		$ 0.90	379		
* Assuming 10% of Gasoline Market					
** Based on one 2000 T biomass/day plant					
** Based on one 2000 T biomass/day plant or 100% of Market					

BCI Jennings Project

- BCI Jennings Ethanol Plant - Jennings, LA
  - Total estimated cost $119 million
  - Ethanol Capacity 21 million gallons/year

- State of Louisiana Tax Free Bond Financing
  - Underwriters - Goldman Sachs Group, Inc. and Lehman Brothers Holdings, Inc.
  - Equity partners - BCI, DOE, Marubeni America Corporation, and the Shaw Group, Inc.
  - Total Equity - $29 million

MASADA RESOURCE GROUP

Today's Solutions for Tomorrow's Environment

- City of Middletown, New York
  - Ten million gallons of ethanol
  - Total estimated cost, $250 million
  - Facility will process 230,000 tons/yr. of garbage
  - and 72,000 dry tons/yr. of sewage sludge
- Project financing tax free New York state bonds
  - Underwriters Merrill Lynch and J.P. Morgan Securities
- Total equity $60 million

BCI - Gridley Ethanol Project

- 20 million gallon/yr from rice straw and wood waste
- BCI-Gridley LLC is the owner/operator & BCI is the technology provider
- NREL/BCI CRADA - demonstrate BCI technology at the bench and pilot scale
- Co-located with biomass power plant

Southeast Alaska Project

- Sealaska and NREL have completed a preliminary feasibility study for a 6-8 million gallon/year
- 80 cents per gallon state tax credit
- NREL will test feedstocks
- Engineering and cost estimates by Merrick Engineers indicate $40 million investment
- Sealaska has procured engineering services for detailed siting and feasibility study

Collins Pine Project

- Collins Pine/BCI joint venture proposed
- $1.1 million award from CEC
- Convert softwood thinnings and mill residues at Chester, CA facility (lumber mill and 12 MW biomass power plant)
- Ethanol and biomass power integration issues will be investigated
- Evaluate higher value products from softwood extractives

Florida

- Working with University of Florida
- Bioengineering of e-coli to add enzyme production capability
- Optimization of strains to increase ethanol yield

Mississippi

- Partnership between DOE's Office of Science and Office of Fuels Development
- Develop biotechnologies for ethanol production including:
  - Process integration
  - Strain development
  - Fermentation organism to convert syngas to ethanol

Mississippi Ethanol Project

- Gasification to ethanol project
- Supported by Senator Thad Cochran
- DOE to provide support for validation and engineering assessment

Broad-based Solicitation

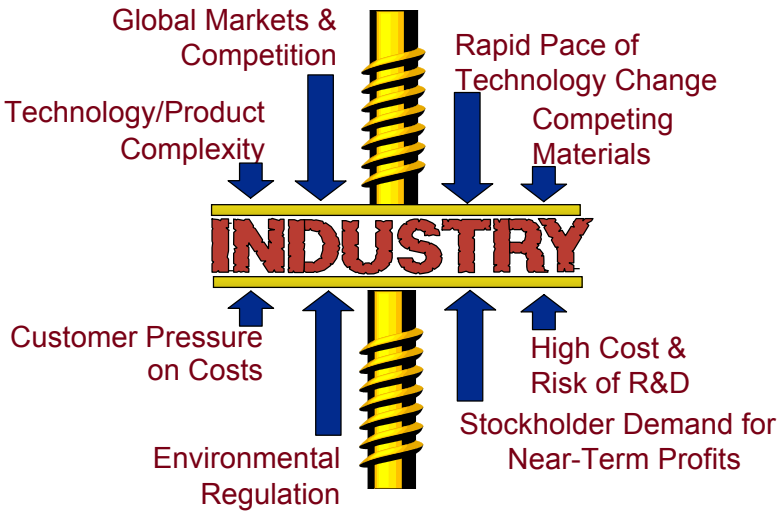
- **Managed through Golden Field Office**
- **OFD will provide approximately $2.0 million**
- **Innovative technologies for ethanol conversion (in line with Biomass R&D Act of 2000)**
  - **Pretreatment**
  - **Strain Development**
  - **Agricultural residue handling**
  - **Feasibility studies**
- **RFP out January, 2001…closing end of March, 2001**

Office of Industrial Technologies

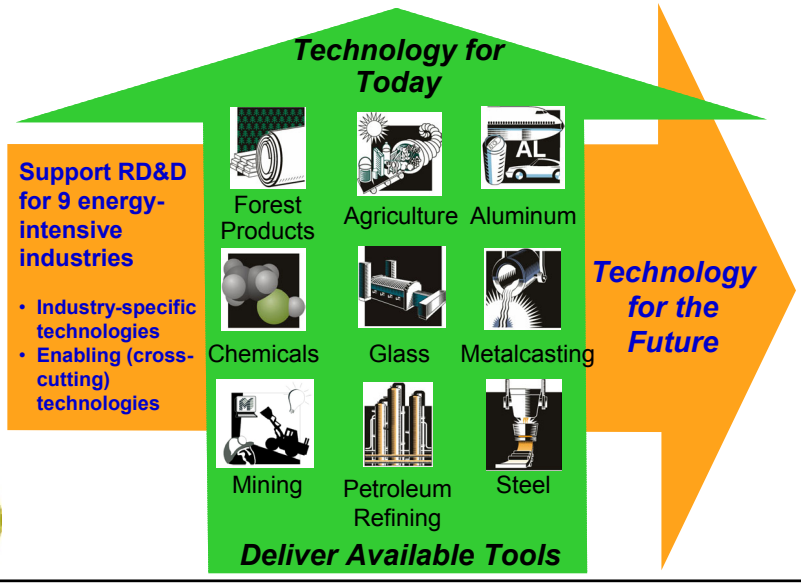
OIT Mission:

Develop and deploy advanced, energy-efficient, renewable, and pollution prevention technologies through partnerships with industry, government, and non-governmental organizations.

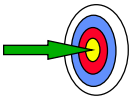
Competitive Pressures



Industries of the Future Strategy



An Industry-Driven Process



- Target Industries
- Let Industry Define R&D Needs and Priorities
- Foster Public-Private R&D Partnerships

RD&D: Industries of the Future Process

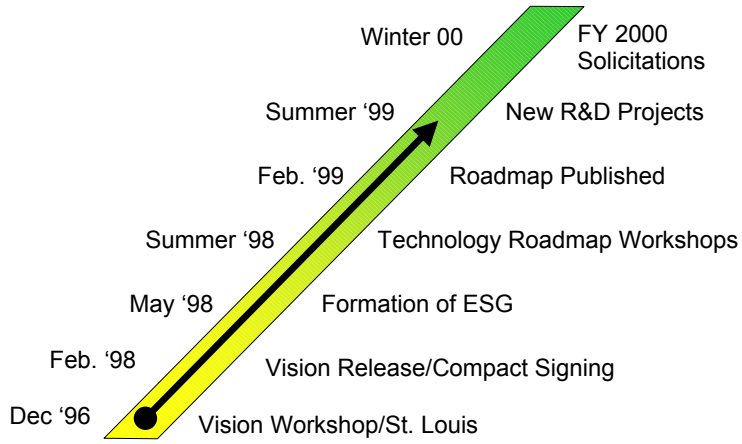
Agriculture

Industry of the Future

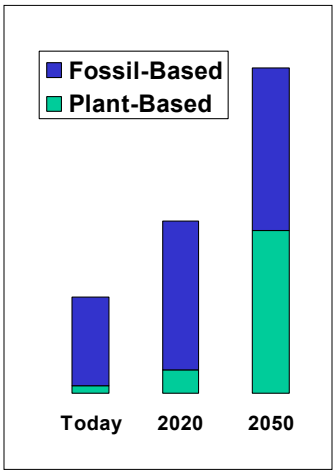
Office of Industrial Technologies
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Building the Renewable Bioproducts Partnership

DOE: OIT

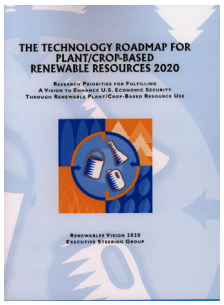


Renewable Bioproducts Vision



Vision Goals: Achieve 10% of basic chemical building blocks from plant-derived sources by 2020, with concepts in place to achieve 50% by 2050

Renewable Bioproducts Technology Roadmap



Roadmap Published
February 1999

Key Technology Areas

Plant Science
Altering plant metabolic pathways

Production
Consistent raw materials

Processing
Economic processing of diverse raw materials

Utilization
Plant structures designed to yield specific properties

Potential Biobased Product "Platforms

- Fermentation of Sugars
- Thermochemical Conversion of Sugars
- Oils/Lipids
- Proteins
- Lignin
- Gasification
- Pyrolysis
- Plants as Factories
- Aquatic Photosynthesis

Agriculture R&D Projects

Catalytic Upgrading of Glucose
Converts glucose into value-added chemicals (propylene glycol)

Partners: National Corn Growers Assoc.,Michigan State University, PNNL

Soy-Based 2-Cycle Engine Oils
Produces biodegradable engine oil from soybeans for recreational marine uses

Partners:Terresolve Technologies, Ltd., United Soybean Board, Smith, Bucklin & Associates, Omni Tech International

Agriculture R&D Projects

Utilization of Corn-Based Polymers
Improves properties of new plastics derived from corn, such as polylactic acid.

Partners: Cargill Dow Polymers, NREL, Colorado School of Mines

Improved Catalytic Enzymes
Improved catalysts for converting corn to industrial chemicals.

Partners: Altus Biologics, Genencor, Cargill, ORNL

Products from Wheat Milling

- Recovers starch-rich product from mill feed, a low-value by-product of wheat flour milling.
- Converts the starch into value added product via catalytic or fermentation process.

Partners:

- Pendleton Flour Mill, Inc.
- Mennel Milling Co.
- PNNL

High Value Products from Wheat

• Idaho is developing new process to separate low value and high value components from wheat

• Process will produce a better fuel to generate electricity and fiber for plastic composites

Partners:

- Idaho Department of Water Resources
- Idaho National Engineering & Environmental Lab
- Idaho Wheat Commission

Recent IOF Awards for Agriculture

- Clean Fractionation of Cellulose - Eastman Chemical and National Renewable Energy Lab
- Monomer (isosorbide) from Corn Glucose - Iowa Corn Promotion Board and Pacific Northwest National Lab
- Vegetable Oils to Polymers - Pittsburg State University and BF Goodrich
- New Polymers from Corn-Derived Malonic Acid - National Corn Growers Association and Pacific Northwest National Lab
- Separation Technologies for Bio-based Feedstocks - Amalgamated Research, Inc., Idaho National Engineering & Environmental Lab, Arkenol Inc., and Koch Membrane Systems
- Yeast for Fermentation of Bio-based Feedstocks - Cargill Dow Polymers, LLC and National Renewable Energy Lab

New Education Initiative

- Addresses concerns raised in technology roadmap workshops
- Promotes multi-disciplinary training and integrated research in renewable bioproducts
- Promotes academic and student interest with programmatic stipends
- Industry involvement

New Education Initiative

Recent awards

- Michigan State University
- Iowa State University
- University of Georgia Research Foundation
- Colorado School of Mines
- Oklahoma State University
- University of Nebraska - Lincoln

Integrated Vision and Roadmap

- **Bioproducts and Bioenergy Vision** (Draft stage)
- **Bioproducts and Bioenergy Roadmap** (in progress)
- **First Biorefinery Solicitation Awarded**

Biobased Products & Bioenergy

Goals:

- By 2010: Increase the use of biobased products and bioenergy by 3 fold
- By 2020: Increase the use of biobased products and bioenergy by 10 fold
- By 2050: Increase the use of biobased products and bioenergy buy another 2-3 fold over 2020

1.6 quads (2000) → **30-50 quads (2050)**

Biobased Products & Bioenergy Awards

Biobased Products Biorefinery FY 00 Solicitation Awards

- Separation of Corn Fiber & Conversion to Fuels & Chemicals, National Corn Growers Association ($1.7 million)
- Conversion of Corn Fiber and Stover to Polylactic Acid, Ethanol & Power, Cargill Dow Polymers ($1.1 million)
- Chemicals, Fuels & Power from Hog Manure, Institute of Gas Technology ($265,000)
- Bark-derived Oils for Use in Structural Adhesives, Louisiana Pacific Corporation ($1.2 million)

Partnership Opportunities

- Solicitations
- University Interdisciplinary Grants
- States IOF
- State University & Land Grant College Initiative
- Symposia and Conferences

How to Get More Information

- Office of Industrial Technologies Web Site: www.oit.doe.gov
- OIT Agriculture Team Leader, Mark Paster: mark.paster@ee.doe.gov voice: 202-586-2821
- Bioproducts Bioenergy Web Site: www.bioproducts-bioenergy.gov

Identified Biobased Product Opportunities

Sugars Fermentation
Sugars Thermochemical
Oils/Lipids
Protein
Gasification
Pyrolysis
Lignin
Plants as Factories
Photosynthetic Organisms
Anaerobic Digestion

Sugars Platform: Fermentation

Corn → Starch → Glucose —Fermentation→ Xantham Gums
beets
sugar cane
etc.

Lignocellulose → Glucose —Fermentation→ Fumaric Acid

Lignocellulose → C5 Sugars —Fermentation ??→ Butanol

Citric Acid
Acetic Acid
Propionic Acid
Butyric Acid
Gluconic acid
PHA Polymers

Sugars Platform: Fermentation

Sugars —Fermentation→

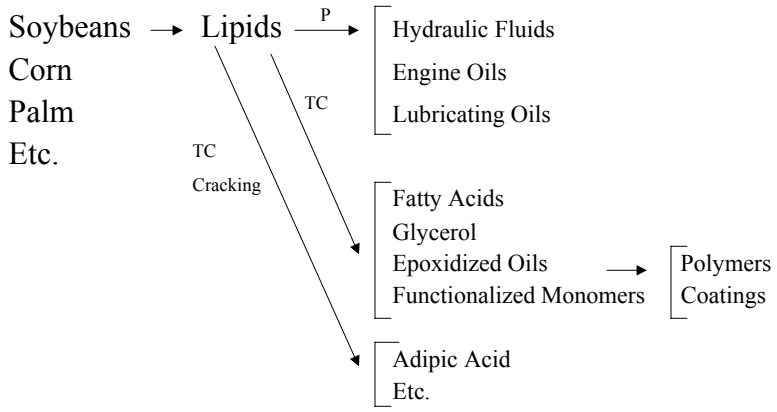
- Ethanol → Ethylene
- Lactic Acid →
  - PLA
  - Ethyl Lactate
  - PG, EG
  - Acrylic Acid
  - Acrylates
- Succinic Acid →
  - THF
  - 1,4-butanediol
  - NMP
  - Polymers
- Malonic Acid → 1,3-Propanediol

Sugars Platform: Thermochemical (TC)

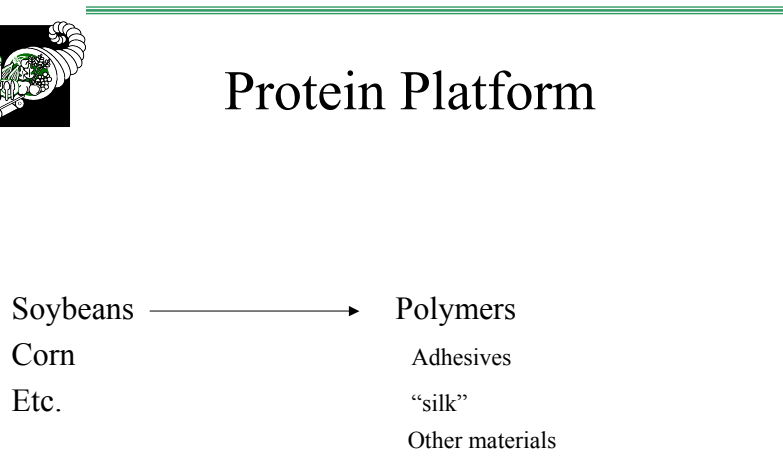
Glucose →
- Sorbitol →
  - PG, EG
  - Isosorbide
    (1,4-3,6 dianhydrosorbitol)
- Mannitol
- Gluconic Acid
- Formic Acid
- Levulinic Acid → Succinic Acid

C5 Sugars →
- PG, EG
- Furfural →
  - Furfural Alcohol
  - Furan → THF
- Xylitol

Oil/Lipids Platform



Protein Platform



Biomass Gasification Platform

Lignocellulose
MSW

Gasification

Pyrolysis
Partial Oxidation
Steam Gasification

CO, H_2

CO, H_2, CO_2

CO, H_2, CO_2, CH_4

Methanol → Acetic Acid

Paraffins, Olefins,
Alcohols (FT)
FT Gasoline
FT Diesel
DME
Dimethoxymethane

?????

Biomass Pyrolysis (Liquification)

Lignocellulose
MSW

Vapors →

Butadiene

Pentanes, Pentenes (e.g. Isoprene)
BTX

levoglucosan → resorcinol

Liquids →

esters

ketones, aldehydes

acids (acetic, formic, propionic, etc.)

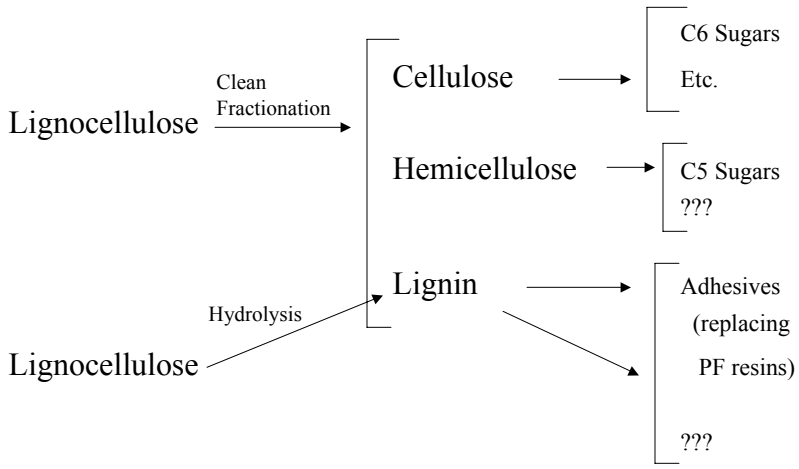
alcohols

phenolics (PF Resin replacement)

Solids →

char, ash

Lignin Platform



Plants as Factories Platform

Corn, Wheat → Starch Plastics

Rubber Plants → Polyisoprene

Plants → PHA Polymers

Seaweed → Alginates

Corn Cobs → Furfural →

Plants as Factories Platform

Trees →
- Pulp and Paper
- Lumber → Acetylated Lumber
- Wood/Wood Fiber/Sawdust Composites
  - OSB, Chip Board, Filled Plastics, Etc.
- Cellulose Acetate (Films, Tow, Flake)
- Rayon
- Rosins, Rosin Esters
- Terpenes

Fibers →
- Cotton Fiber
- Composites
- ???

Photosynthetic Organisms

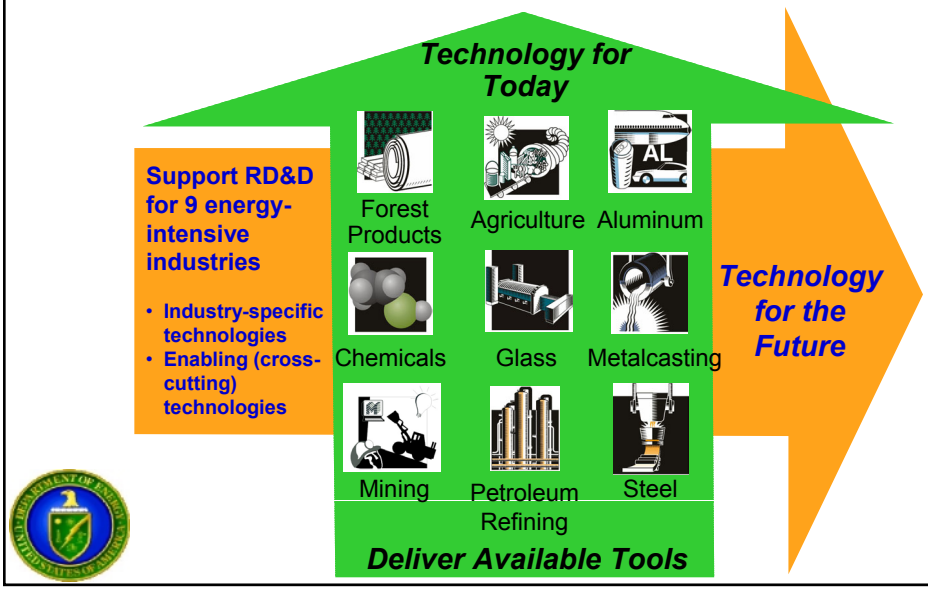
Organisms → H_2
???

Anaerobic Digestion

Lignocellulose → CH_4 → Syngas → Methanol
MSW

???

Industries of the Future Strategy



Forest Products

Industry of the Future

Office of Industrial Technologies
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Forest Products Industry

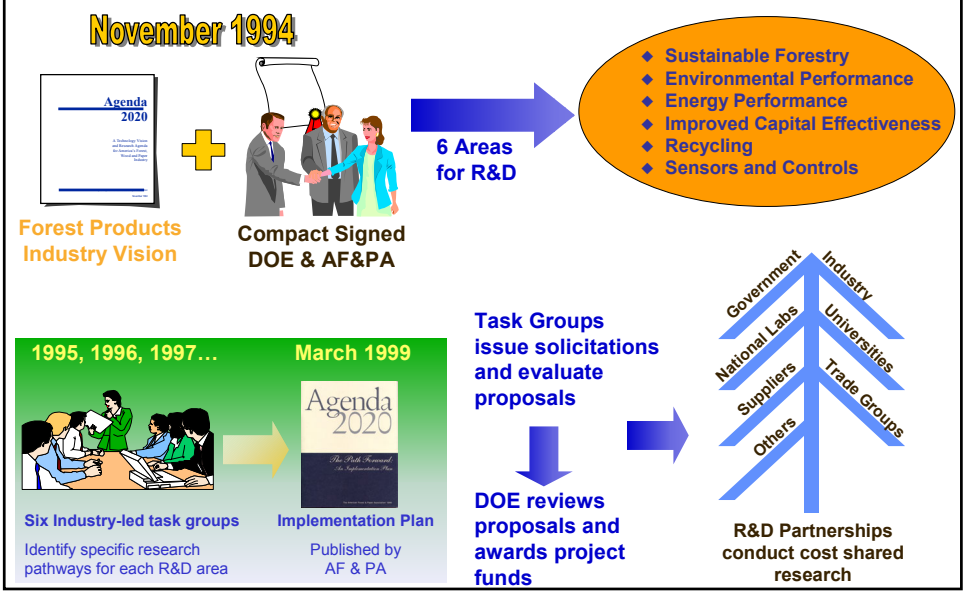
	SIC 26 Paper & Allied	SIC 24 Lumber & Wood
Major Products	paper, tissue, newsprint, packaging, corrugated, paperboard	lumber, veneer, plywood, particle board
Shipments ('96)	$160,661 million	$106,518 million
Employees ('96)	683,600	778,400
Total Energy Use ('94)	2.66 quad	0.49 quad
Purchased Energy Cost ('96)	$6,262 million	$1,846 million
Capital Costs ('96)	$9,543 million	$3,638 million
Pollution Control Costs ('94)	$2,515 million	$478 million

Energy Use: Forest Products Industry

- **Uses 3.1 Quads Annually**
  - **57% Self Sufficient**
- **Energy Intensive Processes**
  - **Papermaking**
  - **Pulping/Chemical Recovery**
  - **Pumping**
  - **Wood Drying**

2.7 Q Pulp & Paper
0.5 Q Wood Products

The Forest Products Partnership Experience



Program Goals

- Reduce net purchased electricity to zero by 2020
- Reduce average water effluent by 35% (to about 10,400 gallons per pound of product) by 2015
- Increase recovered paper utilization rate to 50% by 2010
- Reduce capital requirements
- Improve fiber yield and increase fiber growth in managed forests

Agenda 2020: Making Progress

- DOE has funded over 100 projects through Agenda 2020.
- Over 1600 proposals have been reviewed
- Partners include:
  - ★ 20 universities (8 PPERA)
  - ★ 11 National Laboratories
  - ★ 10 suppliers, engineering firms
  - ★ 2 research institutes
  - ★ about 30 forest products companies

Current Pathways

Sustainable Forestry
- Biotechnology
- Basic Physiology
- Sustainable Soils
- Remote Sensing

Environmental Performance
- Safety
- Pollution Prevention
- Treatment

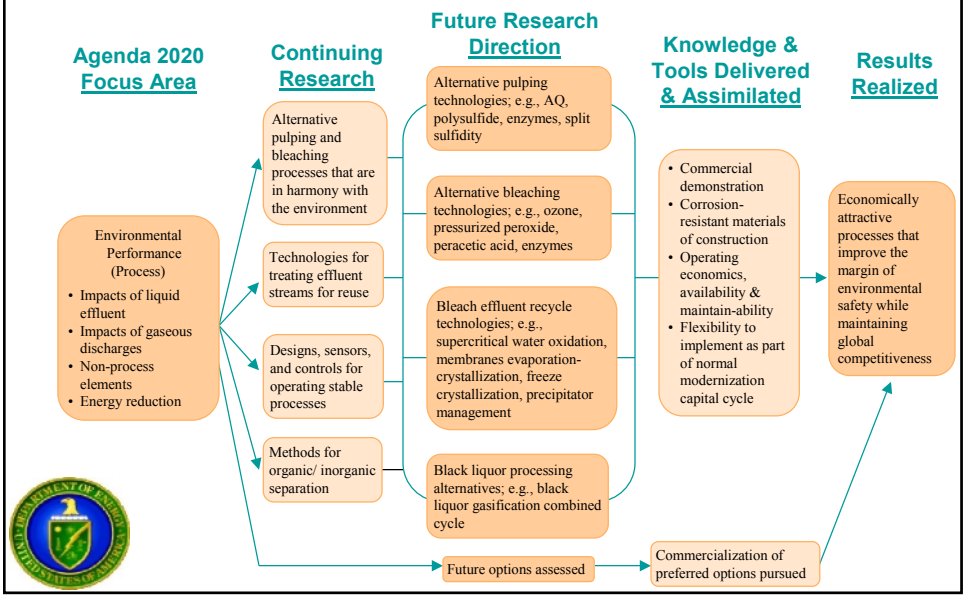
Energy Performance
- Fuel Production
- Fuel Conversion
- Process Efficiency & Heat Recovery
- Environmental Impacts
- Use of Renewables

Capital Effectiveness
- Systems & Process Technologies
- System Fabrication & Construction
- System Efficiency

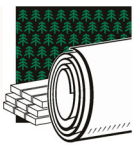
Recycling
- Sludge Use & Disposal
- Surface Chemistry & Fiber-Fiber Bonding
- Sorting & Collection
- Improved Separation
- Adhesives

Sensors & Control
- Actuators and Controls
- Process Measurement & Diagnostics
- Process & Product Models
- Data Presentation, Interpretation, and Interface

Research Pathway for Pollution Prevention

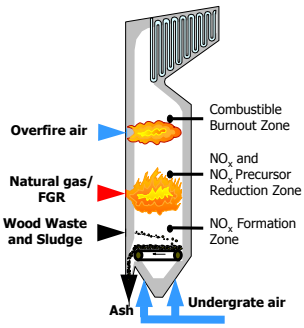


Methane de-NOX®



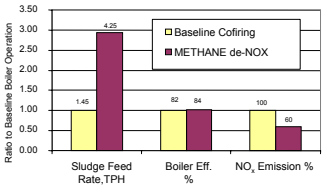
Key Features

- A reburn technology that uses natural gas injection above the stoker grate to improve combustion and reduce NOx in biomass and sludge-fired boilers
- Injects 5-25% natural gas heat input for 40-50% NOx reduction, improved thermal efficiency, and increased sludge feed rate
- Developed by Institute of Gas Technology and licensed by Detroit Stoker



Methane de-NOX®

Demonstrated Benefits at Boise Cascade

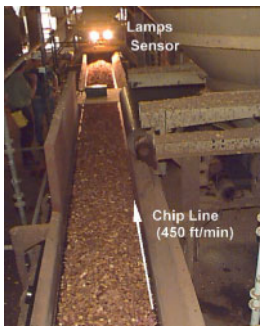


- Increased sludge firing rate by a factor of 3
- Reduced NOx emissions by 40-50%
- Increased boiler thermal efficiency by 1.5% over 60-100% of load
- Reduced overall natural gas use by 30%
- Combustion temperature increased 100ºF average while temperature in upper furnace was reduced

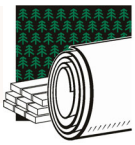
Near-Infrared Sensor

Key Features

- For on-line measurement of the physical and chemical properties of wood chips, pulp, and paper products
- Measures cellulose, hemicellulose, lignin, extractives, and moisture with precision and accuracy equivalent to laboratory chemical analyses



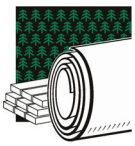
Near-Infrared Sensor



Applications

- Several manufacturers are designing systems for installation
- NIR technology has been used in feed and grain industry for on-line measurement of moisture and protein content
- Three-day field test has been conducted at Champion/Cantonment, Florida and similar field demonstrations have been performed in Sweden
- Phase III of the project will develop a hand-held NIR device for standing trees

Low VOC Drying of Lumber

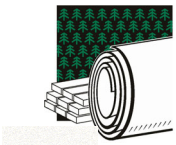


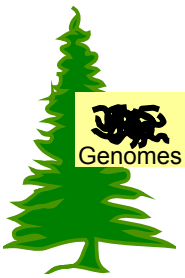
- Radiofrequency pretreatment of wood removes over 70% of VOCs prior to conventional drying
- Significantly lower VOC control costs
- Lower energy requirements and costs

Partners:

- IPST
- Georgia-Pacific Corp.
- Potlatch Corp.
- Georgia-Power
- American Kiln
- Electric Power Research Inst.

Pine Gene Discovery Project



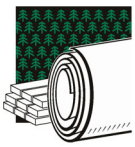


- Paves way for trees that are disease-resistant or have new fiber characteristics.
- Increases knowledge of the genetics of major plant groups.

Partners:

- CA State University
- NC State University
- University of MN
- Georgia-Pacific Corp.
- Rayonier Corp.
- Union Camp Corp.
- Westvaco Corp.

Genetic Engineering for Sterility



- Helps introduce commercially desirable traits into poplars.
- Eliminates uncontrolled dispersal of genetically altered plants.
- Eliminates many environmental, legal, and political concerns.

Partners:

- OR State University
- Tree Genetic Engineering Cooperative

Composite Tubes for Kraft Recovery Boilers (AIM)

Investigated cracking of floor tubes in the black liquor recovery boilers of pulp and paper mills and Identified alternative materials and procedures to reduce or eliminate cracking

Recommended alloy tubes installed in at least 8 boilers.

Benefits include:

- Decreased risk of tube failure and boiler explosion
- Enhanced safety
- Increased energy efficiency
  - Reduced downtime
  - Increased operating temperature/pressure

Partners:

- Oak Ridge National Lab
- 18 pulp and paper companies
- 6 equipment suppliers
- IPST
- Pulp & Paper Res. Inst. Canada

Perceptron, Inc

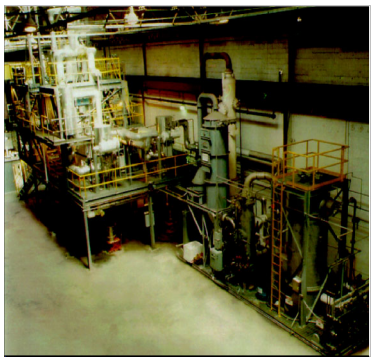
- Ultrasonic scanner detects defect conditions in southern pine
- Will replace manual grading
- Successfully demonstrated at East Alabama Lumber for optimal cutting
- Over 0.9 million board feet per week now being successfully scanned
- Received blanket purchase order from Barr-Mullin for 20 systems over the next two years

DOE Bio-Gasification Program

Phase I Awards

Preliminary engineering

– Georgia-Pacific, MTCI/ThermoChem
  - $1 million project
  - Big Island, VA pulping mill
  - 400,000 lbs/day black liquor solids



DOE Bio-Gasification Program

Phase II

– Solicitation in FY2000 for gasification
– NETL coordinating
– Three projects selected
  - Georgia-Pacific
  - Boise Cascade
  - Gaylord Container

– Congressional allocation for FY2000: $14 MM
– Total program is estimated at $100 million over eight years

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Energy Biosciences Program

Strategic Partnerships Workshop

April 11-12, 2001

Gregory L. Dilworth

Energy Biosciences Program

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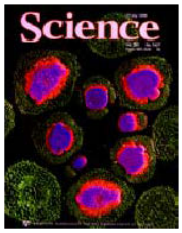
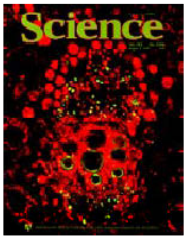
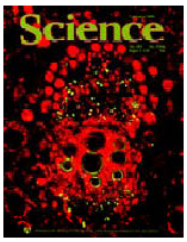
Mission and Goals





Obtain the fundamental knowledge necessary to develop future energy-related biotechnologies by supporting research in:

- **Plant Science**
  - — Structure and function of the plant cell wall (cellulose, lignin, hemicellulose, and protein)
  - — Biophysical and biochemical mechanisms of photosynthesis
  - — Plant primary and secondary metabolism
  - — Genetic and biochemical mechanisms of plant growth and development
  - — Bioenergetics, ion uptake, and other membrane-related phenomena
  - — Arabidopsis genome sequencing
  - — Functional plant genomics
- **Fermentation Microbiology**
  - — Bioenergetics and metabolic properties of anaerobic microbes
  - — Degradation of lignin, cellulose, and hemicellulose
  - — Biochemistry, genetics, and physiology of microbes that metabolize one and two carbon compounds
  - — Mechanisms of plant symbiotic and pathogenic interactions
  - — Functional microbial genomics
- **Extremophilic Organisms**
  - — Biochemistry, genetics and physiology of hyperthermophilic microbes
  - — Mechanisms of life under extreme conditions, temperature, salt, pH, etc.
  - — Metabolism of inorganic compounds
- **Biomaterials and Biocatalysis**
  - — Biosynthesis of novel materials
  - — Catalytic antibodies
  - — Structural and kinetic characterization of energy-related enzymes
  - — Bioadhesion



Long-term Accomplishments

Determination of the biosynthetic pathway for biological methane production from CO_2 and molecular hydrogen.

Elucidation of the biochemistry and genetic regulation of plant lipid synthesis.

Carbohydrate chemistry and the structure of plant cell walls.

Major role in developing *Arabidopsis thaliana* as a model plant experimental system.

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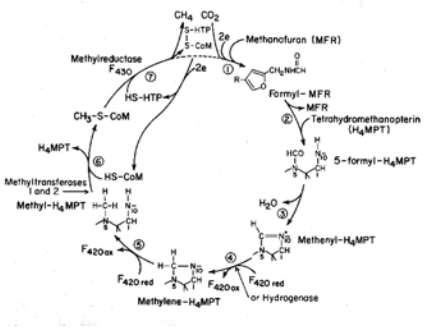
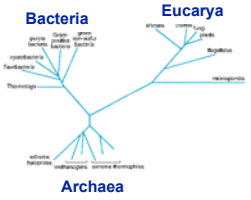
Biological Methane Production



Novel cofactors suggested that methanogenic bacteria are really quite different than the commonly studied studied bacteria. Sequence analysis indicates that they are part of a different biological kingdom, now called the *Archaea*.



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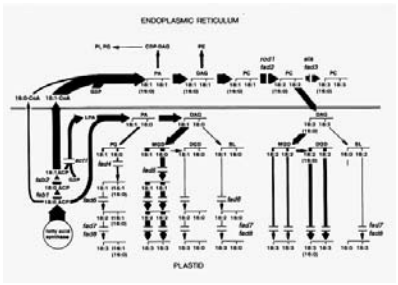
Plant Lipid Synthesis



The biochemistry and genes for plant fatty acid (lipid) biosynthesis have been characterized. Manipulation of these genes and biosynthetic pathways is leading to plants as a source of specific lipids and chemical feedstocks.

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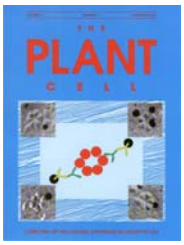
Energy Biosciences Program

Cell Walls

- **Cellulose, lignins, and other complex polymers**
- **Molecular genetic and biochemical studies**
- **Potential Applications: biomass energy, paper, lumber and chemicals**

Identified enzyme involved in stereoselective lignin polymer biosynthesis



Visualized cellulose synthase enzyme at site of growing cellulose fiber

Office of Science
Energy Biosciences Program

Arabidopsis thaliana

Arabidopsis thaliana

Selected for experimental properties rather than economic factors.

- Rapid growth cycle
- Small genome size
- Physically small
- Characteristic of typical flowering plants
- Numerous seeds
- Molecular and genetic tools available

Permits the ready accumulation and comparison of data from a large number of international researchers.

Office of Science
Energy Biosciences Program

Major Research Trends: *(Gene sequencing, genomic analysis and related technologies are providing the driving force for these progressions)*

Biochemistry
- Macromolecular Interactions
- Multicomponent/networked processes

Molecular Genetics
- Identify genes and gene products
- Regulatory genes
- Epigenetics
- Evolution (“DNA archeology”)

Functional Genomics
- Gene families
- Developmentally related gene groups
- Response related gene groups

Office of Science
Energy Biosciences Program

Linkages With Other Research Programs

Interagency:

- Three Agency Plant Science Activities (NSF/DOE/USDA)
  - Research Training Group Awards
  - Multi-institutional Research Coordinating Group Awards
  - Arabidopsis Sequencing Activities (International)
- National Plant Genome Initiative (NSF/DOE/USDA/NIH)
  - Accelerated Arabidopsis Sequencing (International)
  - Rice Genome Sequencing (International)
- Interagency Plant Science Coordination Group(NSF/NIH/ONR/USDA/DOE/NASA)
- Semiannual Microbiology meetings (NSF/NIH/ONR/USDA/DOE/NASA)
- National Bioenergy Initiative (DOE/USDA/NSF/EPA)
- National Science and Technology Council subcommittees

Within DOE:

- BioEnergy Coordinating Committee(BECC)
- Bioenergy Initiative Team and other joint activities with the applied technology programs
- Microbial Genome Program

Office of Science
Energy Biosciences Program

Microbial Cell Project

An effort to build on information from completely sequenced microbial genomes to achieve a more comprehensive understanding of the functioning of a prokaryotic microbial cell.

- functional analysis of the microbial proteome
- biochemical and physiological characterization
- intracellular localization
- cell modeling

Office of Science
Energy Biosciences Program

The National Plant Genome Initiative:

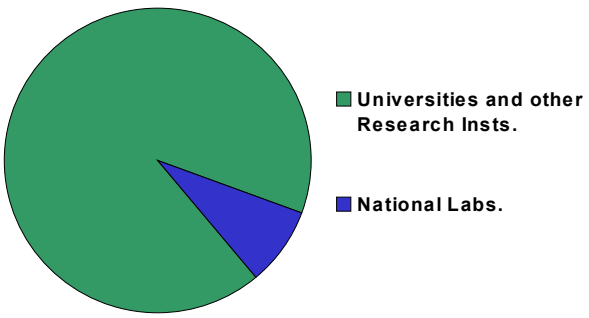
A Major White House Science/Budget Priority

Promote the coordinated development of plant genome information, new technologies and resources that will improve our understanding of plant biology and be applied to the enhancement of economically important plants.

Energy Biosciences Role: Full partner with responsibilities for genomic research related to bioenergetics and biomass production.

Office of Science
Energy Biosciences Program

Performer Demographics (By Expenditure)



Budget (In thousands)

FY1999	FY2000	FY2001
$29,078	$30,713	$33,714

EPA Identified Programs

and

Presentation by Donn Viviani
on

Pollution into Products:

Demand-Based Climate Mitigation

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)

Pollution into Products:

Demand-Based Climate Mitigation

abstract

-Current strategy to address rising CO_2 focuses on controlling emissions.

-Emissions are driven by energy use.

-Energy use increases as population and economies grow.

-Controlling emissions implies limiting growth.

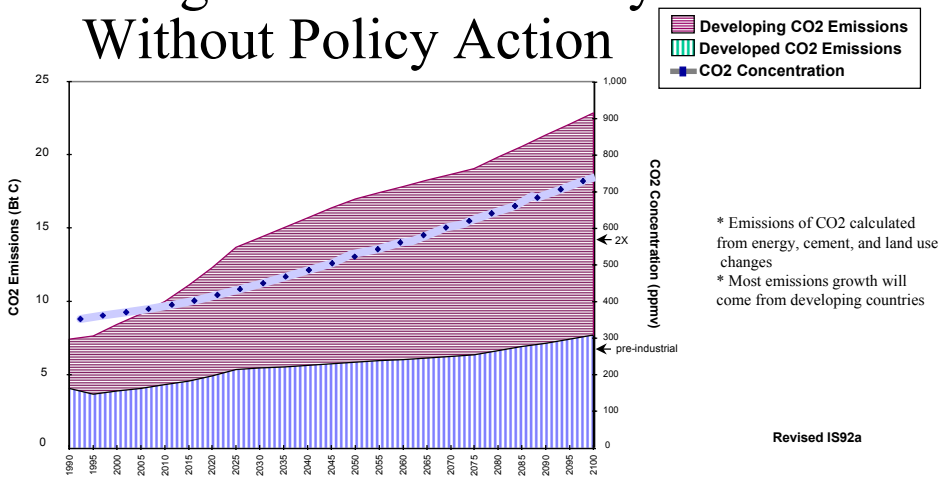
-Linking growth (that produces CO_2) to sequestering (e.g., biomass products) benefits growth and controls net emissions

-CO_2 becomes a resource rather than a waste and growth is sustainable.

-Proposed is a closed-carbon, economic cycle, with product-sinks in Gigatons and non-emitting production mechanisms.

CURRENT PROJECTIONS:

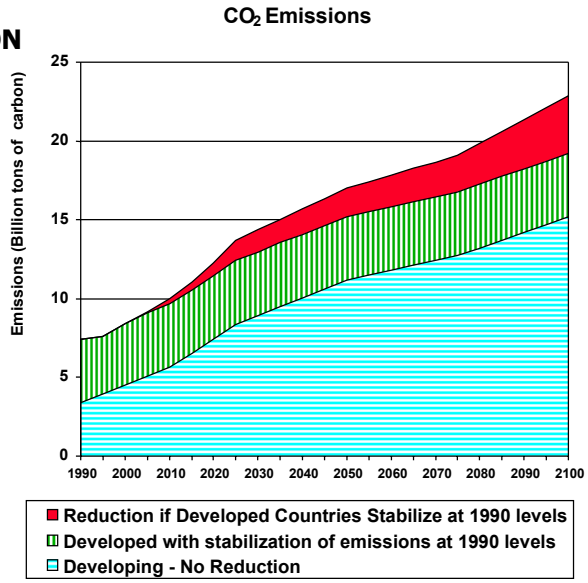
CO_2 Emissions and Concentrations Rise Through the Next Century Without Policy Action



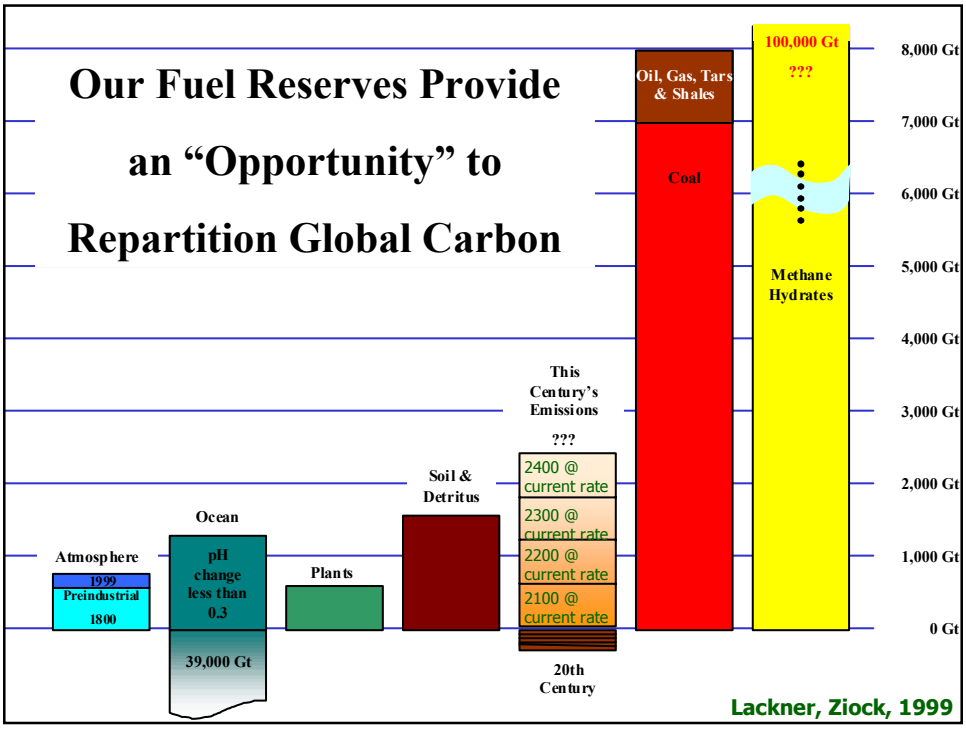
* Emissions of CO2 calculated from energy, cement, and land use changes
* Most emissions growth will come from developing countries

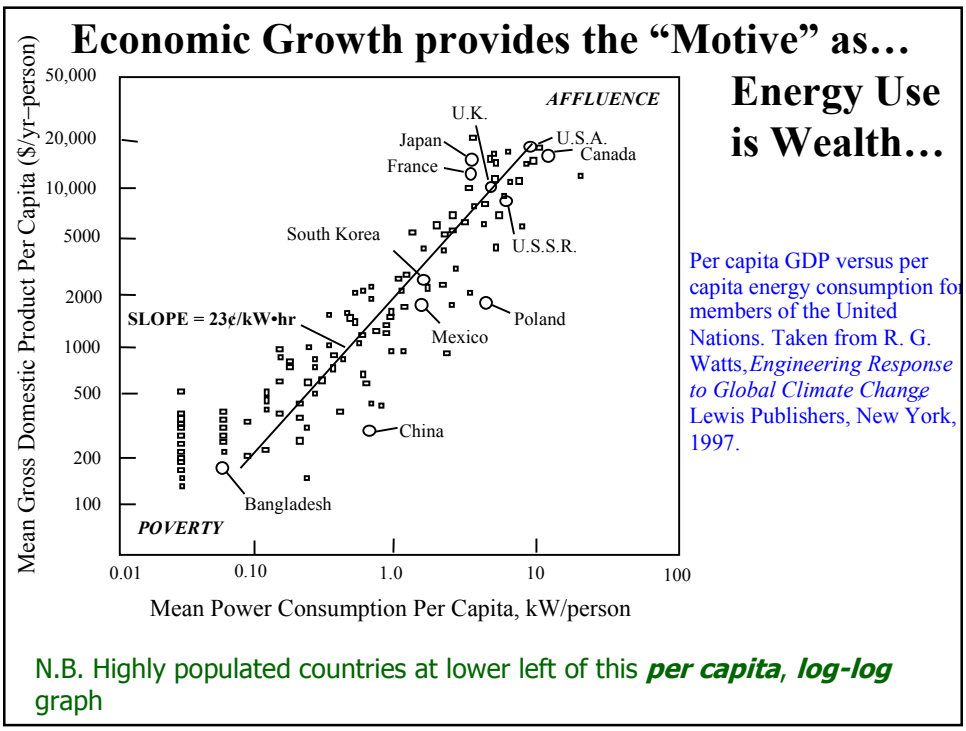
Revised IS92a

WHILE ALMOST ALL OF THE "HISTORICAL" ATMOSPHERIC CARBON IS FROM DEVELOPED COUNTRIES, MOST OF THE GROWTH, OR "FUTURE" CARBON, WILL BE ADDED BY DEVELOPING COUNTRIES



5


Our Fuel Reserves Provide an "Opportunity" to Repartition Global Carbon
Oil, Gas, Tars & Shales
Coal
100,000 Gt
???
Methane Hydrates
8,000 Gt
7,000 Gt
6,000 Gt
5,000 Gt
4,000 Gt
3,000 Gt
2,000 Gt
1,000 Gt
0 Gt
This Century's Emissions
???
2400 @ current rate
2300 @ current rate
2200 @ current rate
2100 @ current rate
20th Century
Soil & Detritus
Plants
Ocean
pH change less than 0.3
39,000 Gt
Atmosphere
1999
Preindustrial 1800
Lackner, Ziock, 1999


Economic Growth provides the "Motive" as…
Energy Use is Wealth…
Mean Gross Domestic Product Per Capita ($/yr–person)
50,000
20,000
10,000
5000
2000
1000
500
200
100
AFFLUENCE
U.K.
Japan
U.S.A.
Canada
France
South Korea
U.S.S.R.
SLOPE = 23¢/kW•hr
Poland
Mexico
China
Bangladesh
POVERTY
0.01
0.10
1.0
10
100
Mean Power Consumption Per Capita, kW/person
Per capita GDP versus per capita energy consumption for members of the United Nations. Taken from R. G. Watts, Engineering Response to Global Climate Change Lewis Publishers, New York, 1997.
N.B. Highly populated countries at lower left of this per capita, log-log graph

Stabilizing Concentrations?

To stabilize concentrations today, would require a 75% cut in emissions

To stabilize in 20 years, would require a 88% cut in emissions

To stabilize at double pre-industrialized concentrations, would require a 66% cut in emissions

CURRENT CLIMATE STRATEGY

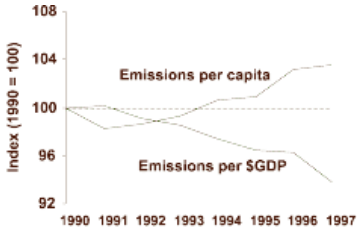
- **EMISSION REDUCTION***
  - **ENERGY EFFICIENCY**
  - **RENEWABLES ESPECIALLY BIOMASS**
  - **FUEL DECARBONIZATION**
- **SEQUESTRATION IN "PASSIVE" SINKS**
  - **OCEANS**
  - **UNDERGROUND**
  - **BIOMASS**

* Most Resources and Efforts Focus on Emission Control

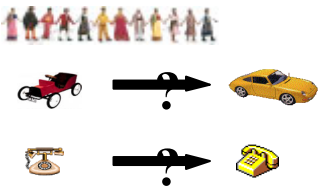
EMISSION REDUCTION THRU ENERGY EFFICIENCY?

1) HISTORICALLY, ENERGY DEMAND HAS GROWN AT A RATE OF ~2.8%, EFFICIENCY AT A RATE OF ~1%

2) AS EFFICIENCY INCREASES AND EMISSIONS/$GDP DROPS PER CAPITA ENERGY USE GROWS AND EMISSIONS INCREASE



3.) EFFICIENCY REDUCES EMISSIONS BY REPLACING LESS EFFICIENT UNITS WITH MORE EFFICIENT ONES, ENERGY GROWTH IS IN DEVELOPING WORLD… ALMOST ALL NEW UNITS…NOT REPLACEMENTS, EACH ADDS NEW EMISSIONS

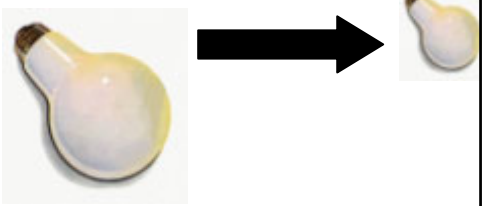


CUTTING EMISSIONS?

WAYS TO CUT EMISSIONS 75%

1) COOK TURKEYS 5 MINUTES A POUND INSTEAD OF 20, AND

2) REPLACE ALL 100W BULBS WITH 25W BULBS, AND



3) BATHE WITH "FRIENDS" (AT LEAST THREE) AND...

BESIDES DEVELOPING A TASTE FOR RARE POULTRY, OTHER ENERGY USES WOULD HAVE TO BE CUT BY 75%...

US Energy Consumption and Global Warming

Average carbon dioxide emissions in pounds/year

Automobile	11,400
Central air conditioner	4,800
Electric water heater	4,700
Lighting	2,500
Refrigerator	2,100
Room air conditioner	1,900
Clothes washer	1,800
Clothes dryer	1,700
Dishwasher	1,500
Electric cooking range	1,400
Dehumidifier	700

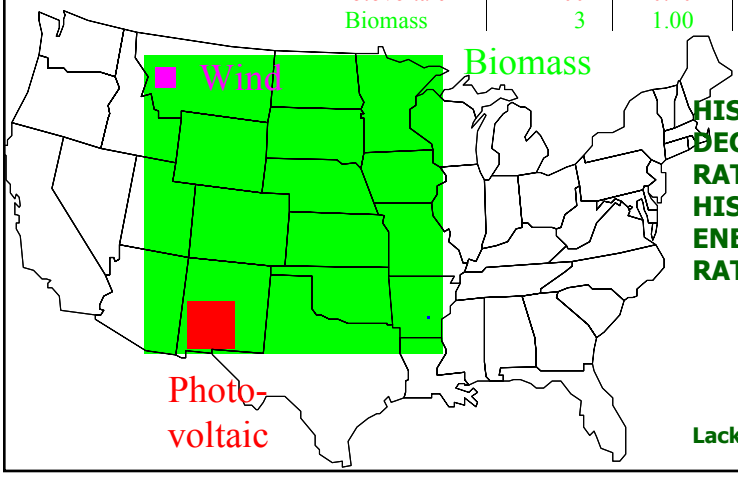
Source: Rocky Mountain Institute, courtesy of National Wildlife magazine (NWF) Oct/Nov 2000

DECARBONIZATION?

Area Required to Meet 1996 World Energy Demand

12,500 GW Raw Power

Source	Power/m^2 (Watts)	Collection Efficiency	Area (km^2)
Wind	600	0.33	20,898
Photovoltaic	200	0.20	104,491
Biomass	3	1.00	4,179,659



HISTORICAL US DECARBONIZATION RATE ~0.8%, HISTORIC US ENERGY GROWTH RATE ~ 2.8%

Lackner, Ziock, 1999

CURRENT CLIMATE STRATEGY

- **EMISSION REDUCTION**
  - **ENERGY EFFICIENCY**
  - **RENEWABLES ESPECIALLY BIOMASS**
  - **FUEL DECARBONIZATION**
- **SEQUESTRATION IN "SINKS"**
  - **OCEANS**
  - **UNDERGROUND**
  - **BIOMASS**

SEQUESTRATION IN "PASSIVE" SINKS

OCEANS

**OCEAN INJECTION ALTERS pH, WHICH…
HARMS BIOTA (e.g. CORAL), CHANGES SOLUTION/ CIRCULATION/VENTING RATES, AFFECTS CURRENTS, and REQUIRES A CONDENSED STREAM**

UNDERGROUND

ALTERS GROUNDWATER pH, BIOTA EFFECTS, SMALL LEAKAGE CAN NEGATE BENEFIT, and REQUIRES A CONDENSED STREAM

BIOMASS

COMPETES FOR LAND WITH FOOD, FIBER, BIOFUEL, HABITAT, and OTHER NEEDS

A JOINT ACCOUNT: NATURE AND MAN

NATURE

~160GT

DEPOSITS:
OCEAN VENTING
PLANT AND SOIL
RESPIRATION

MAN

~ 7GT

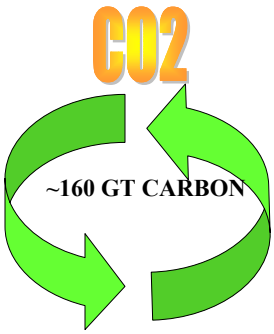
DEPOSITS:
FOSSIL FUEL
COMBUSTION

~160GT

WITHDRAWALS:
BIOMASS
GROWTH
OCEAN SOLUTION
ROCK AND SEDIMENT
FORMATION

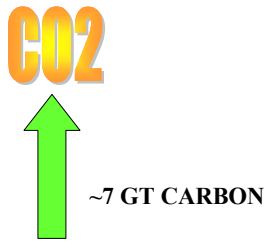
WITHDRAWALS ~0

BIOLOGICAL & GEOCHEMICAL CARBON CYCLE:
DRIVEN BY THERMODYNAMICS, SELF-REGULATED IN DYNAMIC EQUILIBRIUM, SUSTAINABLE



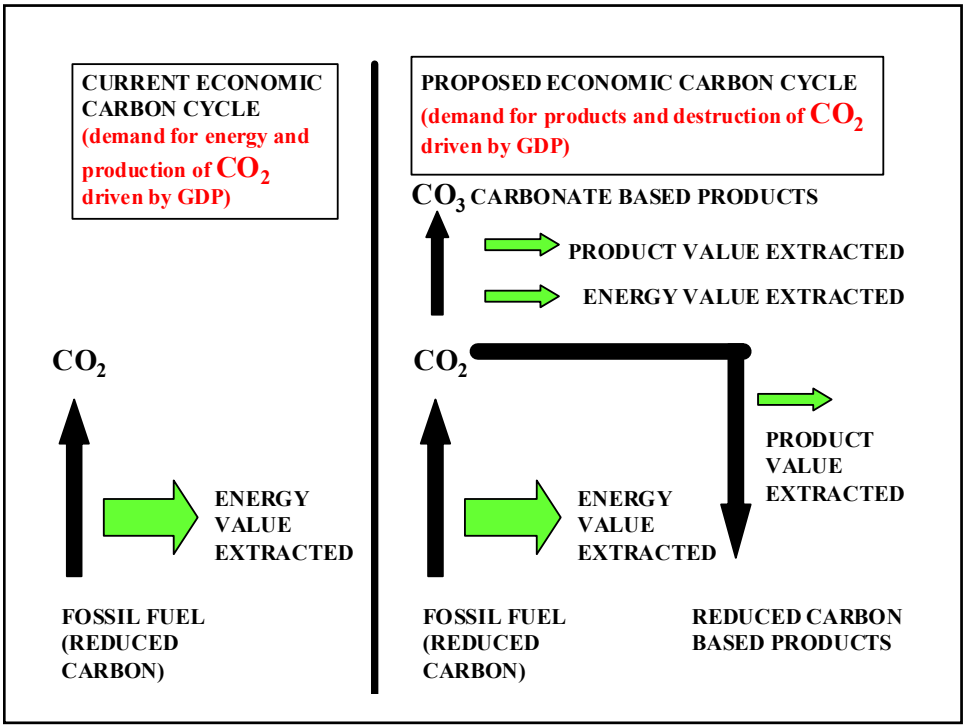
OCEANS, ROCKS, BIOMASS

ECONOMIC CARBON CYCLE:
DRIVEN BY COST OF ENERGY, UNBALANCED TOWARD CO2 PRODUCTION, UNSUSTAINABLE



FOSSIL FUEL

Need to develop a dynamic which takes carbon from the air at the same rate as fossil fuel use emits it to the air, i.e., at a rate that grows with GDP



TO SUCCEED...

1) PRODUCTS MUST SEQUESTER CARBON IN THE GT's

2) DEMAND FOR PRODUCTS MUST ~ MATCH GROWTH OF FOSSIL ENERGY DEMAND

3) TECHNOLOGY MUST BE AVAILABLE, AFFORDABLE, AND NOT A NET EMITTER

4) PRODUCTS MUST COMPETE ON PRICE AND PERFORMANCE WITH ALTERNATIVES

1) PRODUCTS MUST SEQUESTER CARBON IN THE GT's

PRODUCTS WITH SUFFICIENT CAPACITY:

- INFRA STRUCTURE: ROADBED, STRUCTURE AND OTHER CONSTRUCTION MATERIAL
- SEA-LEVEL RISE MITIGATION MATERIAL: BEACH ENRICHMENT, LAND ELEVATION
- ARTIFICIAL SOILS

2) DEMAND FOR PRODUCTS MUST ~ MATCH GROWTH OF FOSSIL ENERGY DEMAND...

PRODUCTS (CARBON CONSUMED)- ENERGY (CARBON EMITTED) COMPARISON...NORMALIZED BY GDP:

OECD	US
PRODUCTS: 6.6 LBS NATURAL RESOURCES/ $GDP[1]	**PRODUCTS:** 16 LBS NATURAL RESOURCES/ $GDP[2]
ENERGY: 4 KWH/$GDP[3]	**ENERGY:** 4 KWH/$GDP[3]
CARBON EMISSIONS: 2/3 LBS/$GDP	**CARBON EMISSIONS:** 2/3 LBS/$GDP
~ 9 to 1 (product/energy)	**~ 11 to 1 (product/energy)**

[1] WRI, [2] USGS, [3] RG Watts

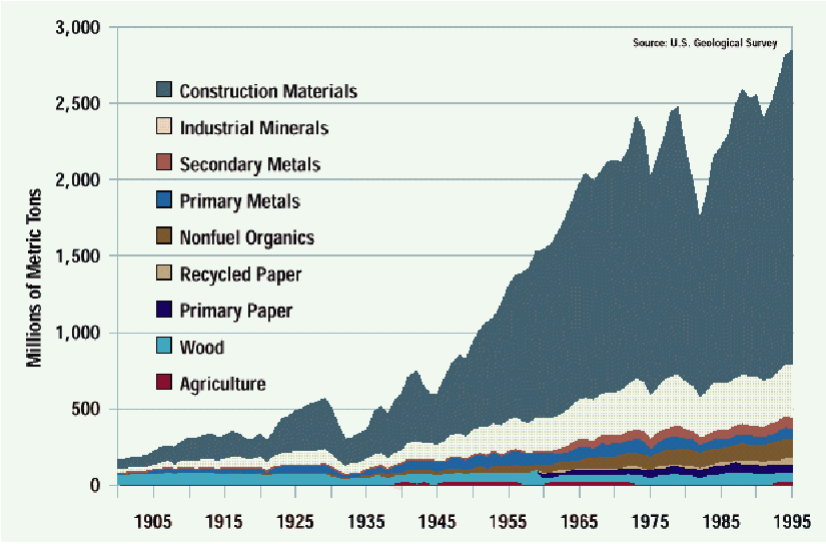
PRODUCTS - ENERGY COMPARISON BY SECTORS

Total Domestic Output 1996 (metric tons per capita)

Sector	Austria	Germany	Japan	Netherlands	US
Agriculture	1.66	2.17	0.51	4.25	16.53
Construction	6.83	4.02	9.73	6.84	13.82
Industry	6.37	25.05	3.43	3.70	38.52
Household	2.40	2.00	0.73	3.03	2.46
Transport	2.33	2.53	2.27	3.94	6.52
Other	0.41	0.98	0.82	1.23	n/a
Total	**20.00**	**36.75**	**17.49**	**22.96**	**77.85**
Energy	**1.27**	**5.92**	**3.43**	**2.93**	**8.48**

WRI, 2000

U.S. Consumption of (NON-FUEL) Raw Materials*



*** NOT INCLUDING 600 MMT ERODED SOILFROM AGRICULTURE**

PRODUCT-ENERGY COMPARISON, ON A SMALLER SCALE...

WHAT DOES LONDON CONSUME?

	Tons per year
Total fuel, (oil equivalent)	~ **20,000,000**
Timber	1,200,000
Paper	2,200,000
Plastics	2,100,000
Glass	360,000
Cement	1,940,000
Bricks, blocks, sand & tarmac	6,000,000
Metals (total)	1,200,000
	~15,000,000

NB: London is essentially "built" and requires little new infrastructure, less urban and less developed areas would have a larger product/energy ratio

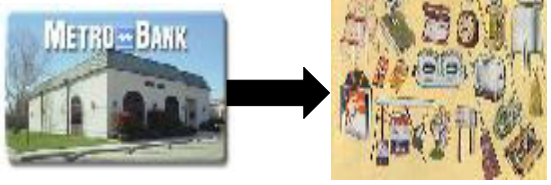
***LONDON FOOTPRINT 125X LONDON PROPER**

One World, Herbert Girardet

PASSIVE SEQUESTRATION REQUIRES MORE AND MORE LAND, AS NEED FOR MORE CARBON CAPACITY GROWS...

…AND, THIS LAND REQUIREMENT COMPETES WITH THE NEED FOR MORE LAND TO PRODUCE FOOD, FIBER, AND RENEWABLE ENERGY AS POPULATION AND ECONOMIES GROW

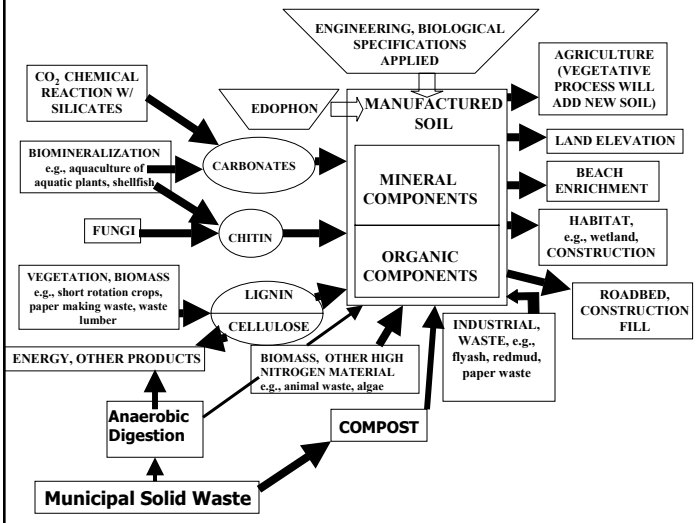
"PRODUCTS"



NO COMPETITION HERE, AND IF ONE OF THE PRODUCTS IS ARTIFICIAL SOIL…THIS ROUTE ADDS TO LAND CAPACITY

ACTIVE SEQUESTRATION IN PRODUCTS USES SAME LAND AND MOVES CARBON OUT...

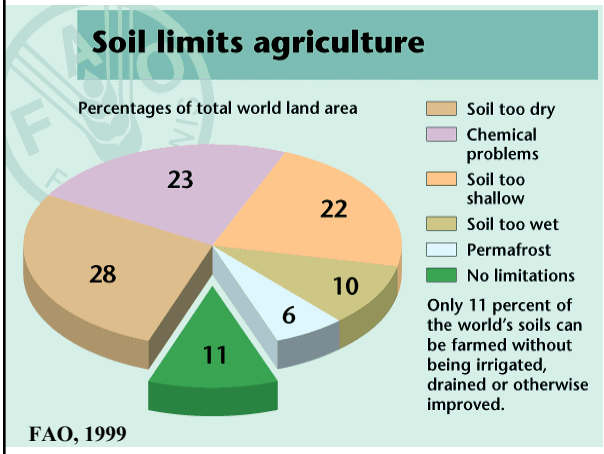
ARTIFICIAL SOILS:



BENEFITS:

-SEQUESTRATION
-NEW LAND FOOD/ FIBER/FUEL
-SLR MITIGATION
-SECONDARY SEQUESTRATION
BIOMASS
NEW SOIL
-WASTE UTILIZATION
-ALBEDO EFFECTS?

MARKETS FOR MANUFACTURED SOIL?



WORLD WIDE, THERE ARE ABOUT 19,000 MILES OF COASTAL DESERT[1]...READY MARKETS FOR MANUFACTURED SOIL... WITH ACCESS TO WATER (DESALINIZED) ALGAEL AND OTHER MARINE BIOMASS, TRANSPORTED LIGNIN, etc.

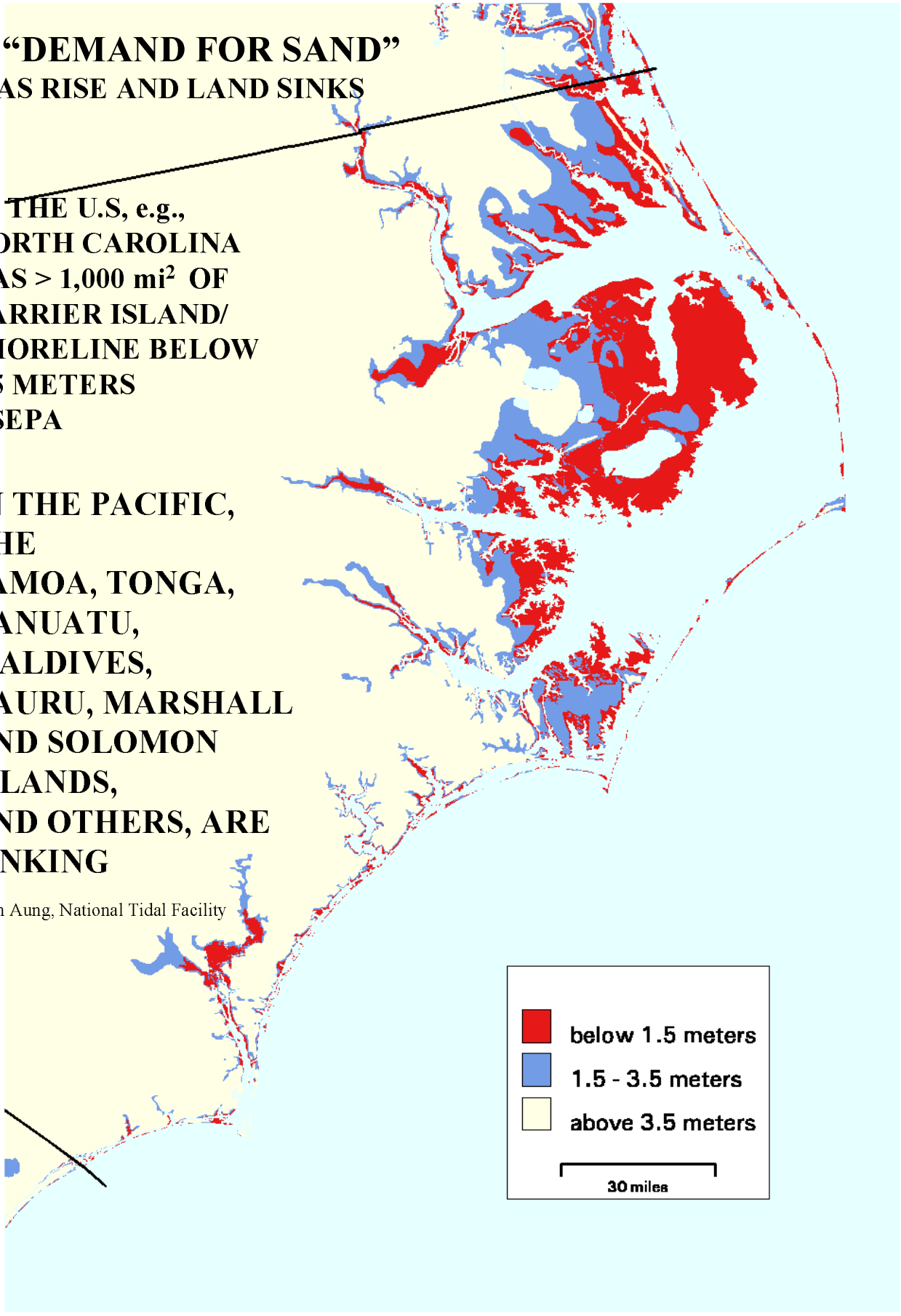
[1]Hans-Ernst Weitzel

THE "DEMAND FOR SAND"
AS SEAS RISE AND LAND SINKS

**IN THE U.S, e.g.,
NORTH CAROLINA
HAS > 1,000 mi^2 OF
BARRIER ISLAND/
SHORELINE BELOW
1.5 METERS
USEPA**

**IN THE PACIFIC,
THE
SAMOA, TONGA,
VANUATU,
MALDIVES,
NAURU, MARSHALL
AND SOLOMON
ISLANDS,
AND OTHERS, ARE
SINKING**

Than Aung, National Tidal Facility

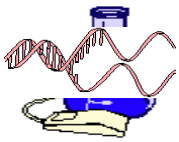


3) TECHNOLOGY…AVAILABLE? AFFORDABLE?

TURN CO2 INTO PRODUCTS,USING CHEMICAL-BIOTECH- AND BIOLOGICAL- METHODS

CHEMISTRY: e.g., REDOX, PHOTOREDUCTION

BIOLOGY: PHOTOSYNTHESIS



BIOTECHNOLOGY: PHOTOSYNTHETIC GMOs

COUPLED: e.g., CHEMOAUTOTROPIC AND BIOMINERALIZING ORGANISMS

STRUCTURES

BEACH NOURISHMENT

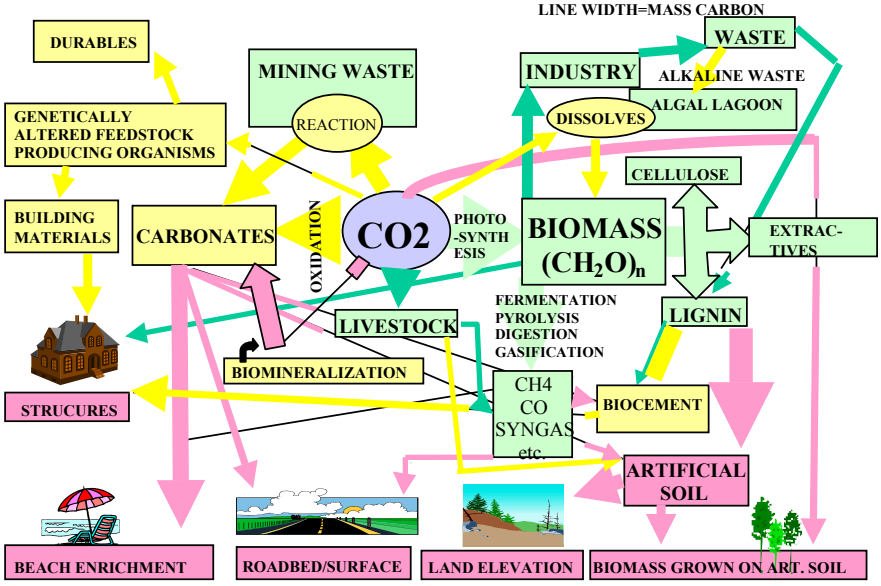
ROADS

CONSUMER GOODS

NEW, FERTILE LAND

THE "BIG" PICTURE

KEY: GREEN=CURRENT TECHNOLOGY
YELLOW=DEVELOPING TECHNOLOGY
RED=TECHNOLOGY OPPORTUNITY
LINE WIDTH=MASS CARBON



POLICY OPTION DRAWBACKS/LIMITS

OPTION	LIMITATION(S)
NATURAL GAS SUBSTITUTION FOR OIL/COAL	BENEFIT LIMITED TO 30%, GAS HAS 5% TO 70% CO_2 CONTAMINATION
MARINE/TERRESTRIAL SEQUESTRATION OF CO_2	ALTERS OCEAN pH (MARINE) UNKNOWN BIOTA EFFECT REQUIRES CONDENSED STREAM
ENERGY EFFICIENCY	LIMITED BY THERMODYNAMICS/ ENERGETICS
RENEWABLES	COMPETE FOR LAND WITH FOOD/ FIBER INFRASTRUCTURE LIMITS
FUEL DECARBONIZATION	TECHNOLOGY LIMITED
SEQUESTRATION IN PRODUCTS	TECHNOLOGY LIMITED PRICING BARRIERS

WHY SEQUESTRATION IN PRODUCTS?

BECAUSE IT:

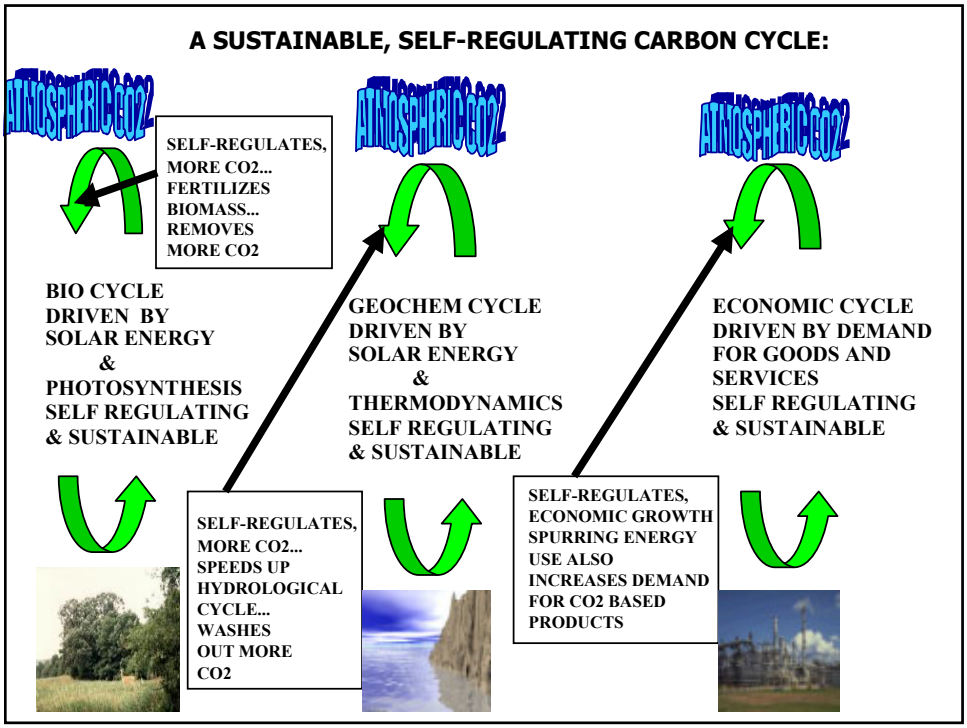
GROWS WITH POPULATION AND ECONOMIC GROWTH

HAS BENEFITS OUTSIDE OF CARBON STORAGE

RELIEVES PRESSURE ON OTHER NATURAL RESOURCES

HAS ENVIRONMENTAL DOWNSTREAM AND UPSTREAM BENEFITS, INCLUDING ENERGY SAVINGS, WASTE REDUCTION, AIR AND WATER POLLUTION REDUCTIONS.

IS SUSTAINABLE


A SUSTAINABLE, SELF-REGULATING CARBON CYCLE:
ATMOSPHERIC CO2
SELF-REGULATES, MORE CO2... FERTILIZES BIOMASS... REMOVES MORE CO2
ATMOSPHERIC CO2
ATMOSPHERIC CO2
BIO CYCLE DRIVEN BY SOLAR ENERGY & PHOTOSYNTHESIS SELF REGULATING & SUSTAINABLE
GEOCHEM CYCLE DRIVEN BY SOLAR ENERGY & THERMODYNAMICS SELF REGULATING & SUSTAINABLE
ECONOMIC CYCLE DRIVEN BY DEMAND FOR GOODS AND SERVICES SELF REGULATING & SUSTAINABLE
SELF-REGULATES, MORE CO2... SPEEDS UP HYDROLOGICAL CYCLE... WASHES OUT MORE CO2
SELF-REGULATES, ECONOMIC GROWTH SPURRING ENERGY USE ALSO INCREASES DEMAND FOR CO2 BASED PRODUCTS

Other Government Programs Identified in the Inventory but not Participating in the Workshop

Departments, Agencies, Offices, Programs	Web Site
National Science Foundation	**http://www.nsf.gov/**
Biological Sciences	***http://www.nsf.gov/home/bio/***
Biological Infrastructure	http://www.nsf.gov/bio/dbi/
Environmental Biology	http://www.nsf.gov/bio/deb/
Integrative Biology and Neuroscience	http://www.nsf.gov/bio/ibn/
Molecular and Cellular Biosciences	http://www.nsf.gov/bio/mcb/
Engineering	***http://www.nsf.gov/home/eng/***
Bioengineering and Environmental Systems	http://www.eng.nsf.gov/bes/
Chemical and Transport Systems	http://www.eng.nsf.gov/cts/
Design, Manufacture, and Industrial Innovation	http://www.eng.nsf.gov/dmii/
Mathematical and Physical Sciences	***http://www.nsf.gov/home/mps/***
Chemistry	http://www.nsf.gov/mps/chem/
Materials Research	http://www.nsf.gov/mps/dmr/
Mathematical Sciences	http://www.nsf.gov/mps/dms/

Grants address bioenergy and biobased products activities in various programs sponsored by NSF

Not highlighted at Workshop

Department of Commerce	http://www.doc.gov
Advanced Technology	http://www.atp.nist.gov/

Tennessee Valley Authority	http://www.tva.gov/
Renewables and Biomass	
Public Power Institute	http://www.publicpowerinstitute.org

ATP/NIST grants projects - specific companies have applied and obtained grants that are related to biobased products and bioenergy

TVA/Public Power Institute
Recently formed by TVA. Has specific funding for a while for cost-sharing with government and private sector

Not highlighted at workshop