EMERGING IMPORTANCE OF BIO-BASSED PRODUCTS AND BIO-ENERGY IN THE U.S. ECONOMY: INFORMATION DISSEMINATION AND TRAINING OF STUDENTS

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Abstract

Bio-based products are non-food, non-feed agricultural products that are used in a variety of commercial/ industrial applications, thereby harnessing the energy of sun to provide raw materials for industry and transportation fuels. The importance of bio-based products in the U.S. and the global economy is expected to increase tremendously. The objectives of this paper are to: (1) Identify various bio-based products and energy sources and their applications, (2) Examine emerging importance of bio-based products in the U.S. and discuss technical and marketing barriers and need for market development and maintenance of information resources, and (3) discuss a plan to prepare students to work in the bio-based product economy. Results of a survey of employers about training needs will be reported and discussed.

Introduction

Most people see agriculture as a source of "food and fiber". Taken in a broad sense it includes crop production, range and pasture lands. The output materials from these land areas, and forestry, are "bio-based" and are renewable through primary production from solar energy, atmospheric carbon-dioxide, and terrestrial nutrients. A much broader role for agriculture is emerging as new markets develop for renewable energy and other industrial products from bio-based feedstocks. Any organic material that is produced by the process of photosynthesis and is available on a renewable basis, including crops and their residues, wood and its residues, animal and municipal wastes, and aquatic plants are biomass feedstock (Figure 1). A wide variety of biomass resources are available for conversion into bio-products. Bio-products are defined as non-food, non-feed agricultural products that are used in a variety of commercial/industrial applications there by harnessing the energy of the sun to provide raw materials for the industry and transportation fuels known as bio-fuels such as ethanol and methane (figure 1). Forestry contributes a significant portion of materials via lumber and pulp, while agriculture is primarily focused on feed and food provision. Scientific developments are allowing changes in the relative contributions of these two industries and the chemical industry leading to increased use of renewable inputs.

As the world human population grows and with changing consumer demands, sustained economic development will depend upon a secure supply of raw-materials as inputs for

manufacturing needs. The majority of consumer goods are currently made from hydrocarbons produced by petrochemical industry. Continued depletion of limited global natural resources supports the concept of supplying industrial production and energy needs through the use of renewable or bio-based resources. The United States has highly productive agricultural system, the opportunity exists for agriculture to become a major source for production of energy, chemicals, and materials in the 21st century.

The importance of bio-based products in the U.S. and the global economy is expected to increase tremendously. The U.S. federal government has set the goal of tripling U.S. use of bio-energy and bio-based products by the year 2010. Meeting this goal could create $15-20 billion a year in new income for farmers and rural America, and reduce annual greenhouse gas emissions. Increasingly agricultural research and development (AR&D) will take the lead in providing the technology for a bio-based economy in the 21st century. The USDA has projected that the number of bio-based startups will go from 200 companies in 2000 to over 600 companies by the year 2003.

Bio-based products will change the economics, policy and trade of agricultural commodities around the world. This revolution in the use of agricultural raw materials in the manufacture of chemicals, bio-energy, plastics, and other new products, is being fueled by a wealth of knowledge about novel conversion processes, new technologies, and innovative product applications. The Task Force on Building a Science Roadmap in its report "A Science Roadmap for Agriculture" (Nov. 2001), prepared by the National Association of State Universities and Land-Grant Colleges (NASULGC) and Experiment Station committee on Organization and Policy (ESCOP), also emphasized the development of a "significant technical information base for use by producers, shippers, exporters, rural communities, government agencies, and universities for informed decision-making and termed to be crucial to their success. Creation and maintenance of such an information resource is appropriately within the domain of universities and government agencies, and it will require state and federal investments."

The bio-based industrial products will be a major U.S. economic growth area in the 21st century. The need in this area is not only for investment in AR&D to develop the bio-based industry of the 21st century but also to gather, sort and disseminate information/knowledge concerning the scope and potential of bio-based products to targeted audience is great. At the

same time agriculture graduates will require knowledge and training in bio-based products processing and marketing.

The objectives of this paper are to: (1) Identify various bio-based products and energy sources and their applications, (2) Examine emerging importance of bio-based products in the U.S. and discuss technical and marketing barriers, and need for market development, creation and maintenance of information resources to be used by various stakeholders for informed decision making, and (3) discuss a plan (being developed at Tennessee State University) to prepare students to work in the bio-based product economy.

Bio-based Products and Energy Sources

A wide variety of industrial products, including biomaterials, fuels and bio-chemicals are already manufactured from bio-based raw materials, divided into three broad groups – Biomaterials, Energy Fuels and Bio-chemicals. (Figure 2).

Bio-materials

A wide variety of bio-mass resources are available for conversion into bio-materials. These may include whole plants, plant parts (e.g., seeds, stalks), plant constituents (e.g., starch, lipids, protein, fiber), processing byproducts (distillers' grains, corn solubles), materials of marine origin (e.g., chitin, sea weed, etc), and animal byproducts (e.g., gelatin, albumen, etc). These resources may be used "as is" to create new bio-materials, but more typically they will be processed for use in bio-material manufacture. This will require an intimate understanding of the composition of raw materials – whether it is whole plant, constituent, or byproduct – so that desired functional elements can be obtained for bio-material production. Equally important, however, is the fact that this fundamental understanding will afford the opportunity to recover other potentially valuable components (bio-fuels, bio-chemicals) from these raw materials.

Conversion of raw materials (or their constituents) into bio-materials will entail three steps: process design, system optimization, and model development. Processing will take the form of various biological, thermochemical, and/or physical methods designed to synthesize or bio-convert new materials, recover/purify such products, and subsequently perform any needed downstream modifications. In some cases, the desired product may already exist within the raw material, thus requiring only extraction, recovery, purification, and modification steps. Once individual methods have been developed, linking them into an integrated processing system will be the next challenge. The goal will be to optimize this system in terms of yield, efficiency,

productivity, energy balance, and cost. As part of this optimization work, a system model will be developed to permit sensitivity analyses of process variables. Products derived from this process may be finished products or may be incorporated into multi-component products. Examples might include biopolymers, biopolyols, adhesives, resins, food/feed ingredients, etc.

Energy Fuels

Biomass is an attractive energy source for a number of reasons. First, it is renewable as long as it is properly managed. It is also more evenly distributed over the Earth's surface than are finite energy sources, and may be exploited using more environmentally friendly technologies. Biomass provides the opportunity for increased local, regional, and national energy self-sufficiency across the globe.

The energy in biomass can be accessed by turning the raw materials, or feed stocks, into a usable form. Transportation fuels are made from biomass through biochemical or thermochemical processes. Known as biofuels, these include ethanol, methanol, biodiesel, biocrude, and methane.

Biochemicals and Materials

Biobased chemicals are biobased commercial industrial products derived from biomass feed stocks. Commodity chemicals include solvent additives, lubricants, adhesives, and inks. Major five chemicals include enzymes, pharmaceuticals, plastics produced from biomass. Resources show great promise for replacement derived from petrochemicals. Many building products, such as engineered lumber and structured panel are made primarily from wood.

A report prepared by NRC targets for increasing biobased industrial products manufactured in the U.S. over current levels for liquid fuels, organic chemicals and materials are 50 percent, 90 percent and 99 percent respectively, of total industrial production by 2090 (Table 1). A report "Biobased Products and Bioenergy Road Map – Framework for a Vital new U.S. Industry" envisions a tenfold increase in the use of biobased products and bioenergy. The 2020 estimates in Table 2 are illustrated only and will very on the actual magnitude of contribution from different biomass sources. In Table 1. targets developed by NRC for bio products are presented.

Perhaps the most important issue surrounding the status of our transportation fuel is that no one knows how long the world's petroleum resources will last. The limited U.S. domestic petroleum resources do not meet its energy needs. The Persian Gulf region holds nearly two-

thirds of the world's known oil reserves, and the United States imports more than 53% of its petroleum – much of it from the Persian Gulf. The U.S. Department of Energy estimates that this will increase to 75% by the year 2010.

Oil imports account for almost half the U.S. trade deficit, which has an enormous impact on our economy and the creation of new jobs. A high trade imbalance from dependence on foreign oil also leaves our economy vulnerable to price hikes from supply disruptions. Developing a stronger market for domestically produced biofuels in the United States will help alleviate the negative implications of our trade deficit and contribute to positive economic trends in the U.S. transportation sector.

Currently, the ethanol industry is responsible for approximately 20,000 jobs. Between 1996 and 2000, the ethanol industry added approximately $51 billion to the U.S. economy. Ethanol production creates domestic jobs in plant construction, operation, maintenance, and support in the surrounding communities. This can have a profound impact on rural America, where a decline in employment has placed increasing burdens on cities, infrastructure, and tax base.

Biobased Products

The USDA projects that the number of bio-based startup companies will go from 200 companies in 2000 to over 600 companies by 2003. Bio-based products and companies span a broad range of industries including:

- Absorbents/adsorbents
- Activated carbon
- Adhesives
- Agricultural chemicals
- Alternative fibers/bonded fabrics/textiles
- Bio-based fuels such as ethanol and bio-diesel
- Bio-energy
- Bio-plastics/polymers/films
- Construction and composite materials
  (Panels, Laminates, Hardware)
- Cleaning chemicals, surfactants, soaps, detergents
- Foods, beverages, nutrients

- Fuel additives
- Fertilizers
- Gases and vapor technology
- Inks, dyes, pigments
- Landscaping materials/ soil amenders
- Lubricants/rust inhibitors/functional fluids
- Oils, waxes, binders
- Packaging
- Paints/coatings
- Personal consumer items/cosmetics
- Pharmacology & neutracuticals
- Soil remediation
- Solvents & co-solvents
- Specialty chemicals, fatty and acetic acid
- Paper & paper products
- Water & wastewater treatment

Benefits to the Nation

- Enhanced National energy security.
- Improved Environmental protection.
- Rural Economic growth.
- U.S. leadership in global market.

Drivers of Bio-based Products and Various Products and Energy Sources

A number of economic changes in consumer attributes, technological development and environmental concerns make it almost necessary for development of bio-products and bio-fuel. Some of these factors are as follows:

- Agriculture in the United States has produced industrial products from food stocks even before 1940 including medicines, inks etc.
- New techniques/tools of genetic and bio-process engineering now enable economic improvements in feedstock utility and manufacturing systems.

- Increasing environmental problems, including air and water pollution and global warning are associated with industrial processing of fossil fuels.
- Reducing our dependence on non-relevant source of energy (on foreign oil).
- Impact on environment quality, climate change, and economic competitiveness.
- Genetically engineered crops currently meeting disapproval by foreign markets and by the public. This false perception is not a problem in the market place for bio-based industrial products. (Zeikus, 2000).
- Needs for food, shelter, and health.
- Demographic changes in developing countries.
- Technology, information/bio-technology.
- Environmental necessities: Local/global
- Business competitiveness
- Sustainability

In summary, several key trends support the emergence of an integrated bio-based products and bio-energy industry:

- Rapid progress in bio-technology.
- Increasing potential of bio-based products and bio-energy.
- Growing interest in distributed production.
- Emerging technologies for bio-refineries.

Key Challenges

- Creating market demand and preference for bio-based products and bio-energy, based on superior life-cycle value.
- Establishing market qualifications and standards for bio-energy and bio-based products.
- Identifying customer needs to drive the design of bio-products.
- Jump-starting the market for bio-mass by providing incentives for producers.

Barriers in the Use of Biobased Products and Bioenergy – Technical and Market Barriers

In order to increase the use of renewable resources, it is useful to identify areas where progress is slow or limiting. The Technology Road Map for Renewable Resources identified four key barrier areas that influence (factors affecting) these barriers (Figure 3). These are:

- Plant Science – altering plant metabolic pathways to produce certain carbon molecules with valuable functional properties.
- Production – lowering unit production costs for consistent quality raw materials.
- Processing – more economically separating diverse materials.
- Utilization – improving material performance through better understanding for plant constitution – Markets and Market Development.

Market Development

A key barrier to the use of plant-derived materials is the high cost of developing the market, even when unique new products have been created. As in many emerging product markets, research in new products begins in small companies that are under-capitalized and lack the resources needed to go beyond the laboratory scale. The success rate for commercialization is low and promising products often languish through lack of volume generation. A major effort is needed to examine improved approaches for product development, support mechanisms, and market development in relation to products that utilize renewable resources.

Like other emerging technologies, biobased products and bioenergy must navigate a development curve, reaching a point at which their demonstrated value makes them successful and competitive in marketplace. Yet these products face an unusually high hurdle in becoming a viable supplement to fossil fuels. Throughout the last century, a sophisticated infrastructure for researching, producing, processing, securing, distributing, and utilizing fossil energy has been developed. As a sunk cost, this infrastructure currently favors the continued use of fossil energy and petrochemicals in cost comparisons with bioenergy and biobased products.

At some future point, when crude oil prices increase due to declining supply, and when environmental results of increased use of fossil sources are factored into their costs, comparative-cost equations can be expected to favor bioenergy and biobased products. Long before this point, however, there is need to increase a ramp investments in bioenergy and biobased products infrastructure, if these renewable resources are to be a significant part of our future economy. (Bioenergy Vision, 2001).

Strategic market development efforts must be made in the near future to achieve the visionary goals. There is need for priority actions for building significant markets for bio-based products and bio-energy. In particular, the need to develop market preference for bio-based

products and bio-energy and to attract substantial infrastructure investments is of great importance. The following actions need to be undertaken.

- Defining market requirements that will drive design of plant- based feed stock- plants, trees, and other biomass sources.
- Promoting market demand for feedstocks production and delivery.
- Attracting investment in integrated facilities, including bio-refineries.
- Progressively increasing market share as well as the size of overall markets for bio-based products and bio-energy.

Information Resources and Training of Students

Biotechnology, agribusiness, power and electric companies, automotive, aerospace, information technology, chemical and many other interrelated businesses all will have a major stake in the biobased product economy. All of these companies will need a new kind of personnel, one that understands the complexities and variability of agricultural production, and yet can recognize and help advance promising new technologies utilizing agricultural materials as a biomass feedstock. Thus, workforce development and creative linkages with new sources of human and technological capital are essential to the success of the biobased economy.

The need in this area is not only for investment in AR&D to develop the biobased industry of the 21st century but also to gather, sort and disseminate information to appropriate and interested audience concerning biobased products and related technology innovations. At the same time the agribusiness graduates will require knowledge of and training in biobased products processing and marketing.

In the development of these opportunities students and faculty at Tennessee State University will work directly with the Biobased Information System®. The Biobased Information System® is an internet-based system of categorized information and data quantifying tools used to gather, sort, exchange, and disseminate biobased information to a highly targeted, specialized audience who access the system through the affiliated website of their choice. It is important that graduates in Agribusiness and Agriculture in general be knowledgeable in this newly developing system to advance knowledge and marketing of biobased products in the global economy.

The transition to a biobased economy will be technology – and market –driven, and the educational skill needs of farmers will change. Traditional attitudes and expertise may no longer serve farmers well. In short, the attitudes, skills and knowledge of farmers and other agricultural professionals must change to take full advantage of biobased economy. (Swisher and Fields, 2000). These changes make it necessary to re-evaluate educational programs in agriculture to specifically address the question: What are the competencies required of graduates of schools/colleges of agriculture as perceived by employers?

To accomplish this a survey was designed by the project staff to gauge employers (industry and government) needs for training concerning biobased products, bio-energy and knowledge; skills employers look for in their employees. The survey is being administered on-line to industry, government and research stakeholders via the Biobased Information System® providing a database for survey recipients to answer questions. The results of the survey and comments provided by stakeholders will guide in the selection of electives, development of course outlines and topics/areas to be included.

The proposed curriculum (electives) in bioproducts to be developed at Tennessee State University for agriculture graduates (in partnership with academia, industry and government) will focus on macro – examination of key drivers, macro perspective of conversion technologies, commercial applications and market development.

The biobased product curriculum is unique, it is designed to interface with an internet-based database thereby offering students real time data concerning outputs, business trends, statistics and other vital functions in understanding the complex and ever-expanding biobased products industry. In addition the curriculum will be designed to be complemented with a website offering students the ability to access the Biobased Information System®, global databases, links to valuable information and other features to enhance the value of the biobased products curriculum.

The proposed course development in the use of bio-information system to market bio-products and disseminate information/knowledge concerning the scope and potential of biobased products will be designed to serve junior/senior level undergraduates to graduate level students. It will provide cost-effective method of training students in the newly developing area of bio-products, the databases and courseware will be developed as part of this project, will help state

and regional agencies and the private sector in regard to availability of trained and knowledgeable employees in the area of bioproducts information systems.

Table 1 TARGETS FOR A NATIONAL BIOBASED INDUSTRY (NRC 2000)

	Biobased production level (percent derived form biobased feedstocks)		
Biobased product	Current level	Future target: intermediate (2020)	Future target: ultimate (2090)
Liquid fuels	1-2%	10%	Up to 50%
Organic chemicals	10%	255	90+%
Materials	90%	95%	99%

Table 2. Illustrative Levels of Use by 2020

Categories of biobased products and bioenergy	Current use in the U.S. (approximate)	Illustrative levels of use by 2020
Carbon-based chemicals and materials[2]	18 billion pounds = **0.2 quads**	180 billion pounds = **2 quads**
Fuels	Ethanol: about 1.7 billion gallons from corn = **0.2 quads** Biodiesel: about 2-3 million gallons = **0.0004 quads**	**2 quads**
Power and heat[3]	Total output (actual use) = **1.4 quads (400 million megawatt-hours)**	**14 quads (4 billion megawatt-hours)**
Total use (output)	**~ 1.8 quads**	**~ 18 quads**

[2] This figure excludes conventional forest products (lumber, pulp, and paper), which are not part of the Vision goals. Bioproducts account for about 3 percent of the more than 300 billion pounds of chemicals and materials – including about 90 billion pounds of plastics – currently produced. The energy value is expressed in terms of material use in the final product and does not include the process energy or material losses in the process.

[3] Although conventional forest products (lumber, pulp, and paper) are not included in the chemicals and materials category (above), the power and heat used to manufacture them is included in this figure.

Source: Biobased Products and Bioenergy Roadmap

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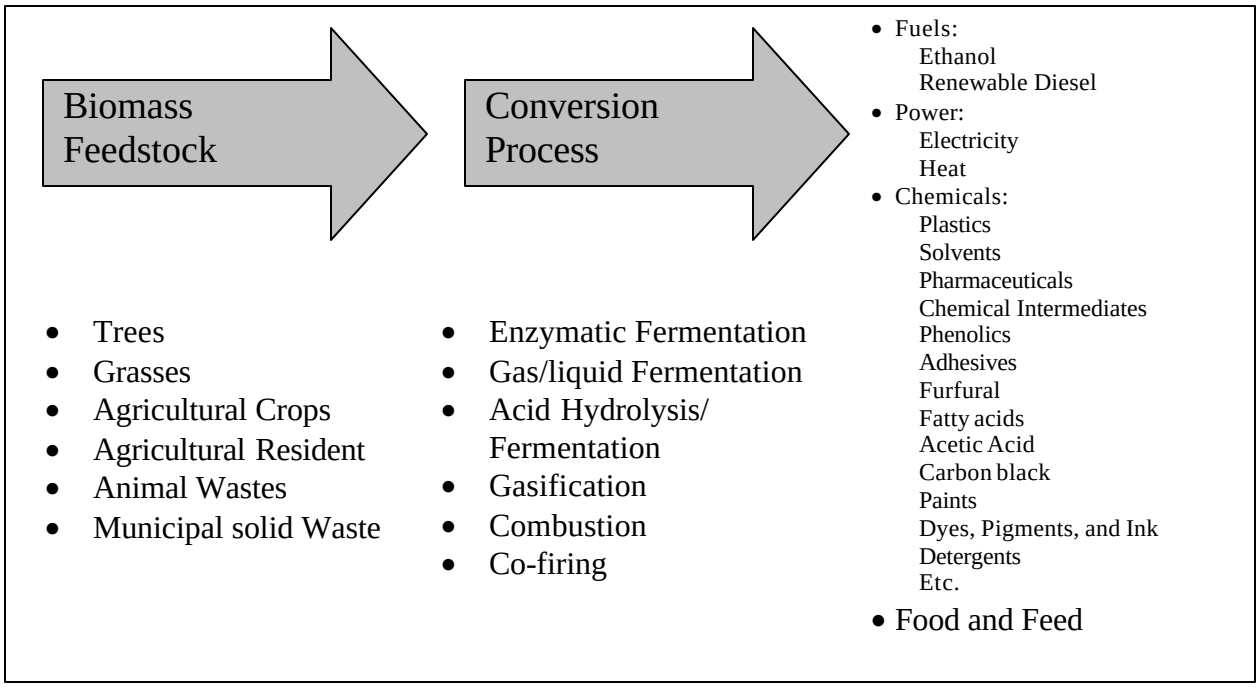
The Technology Road Map for Plant/ Crop-Based Renewable Resources 2020, Renewables Vision 2020

Biobased Products andBioenergy Roadmap. Framework for a Vital New U.S. Industry.

Figure 1. Conversion of Biobased Products from Biomass



Figur2: Biobased Products manufactured today(NRC 2000)

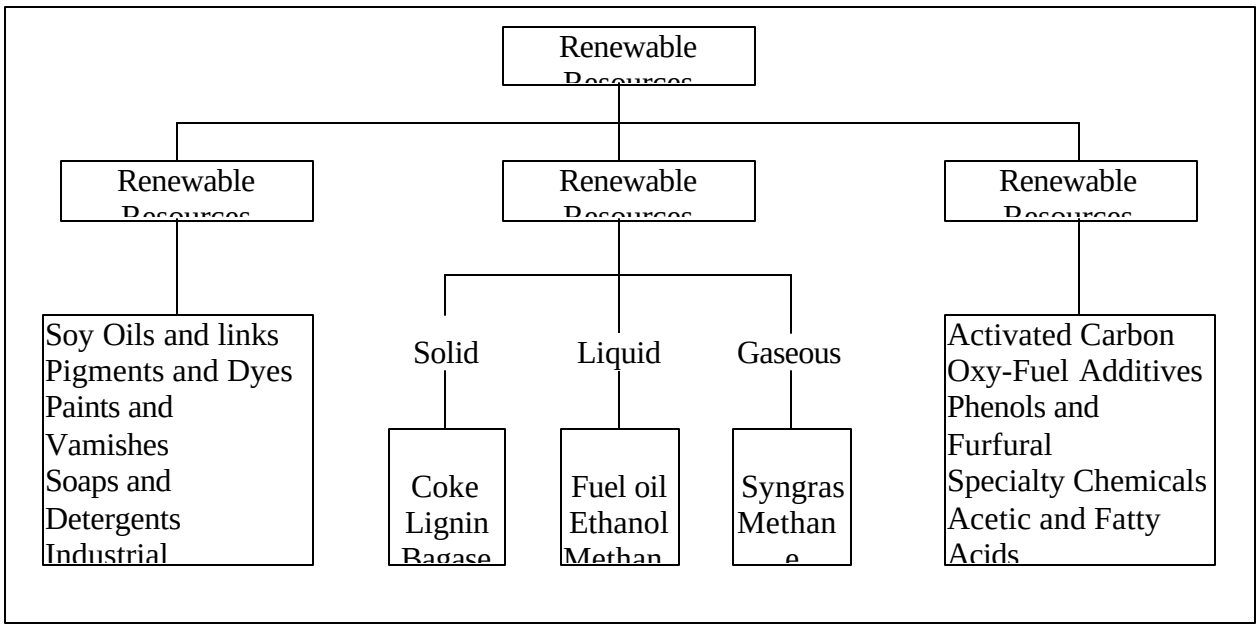
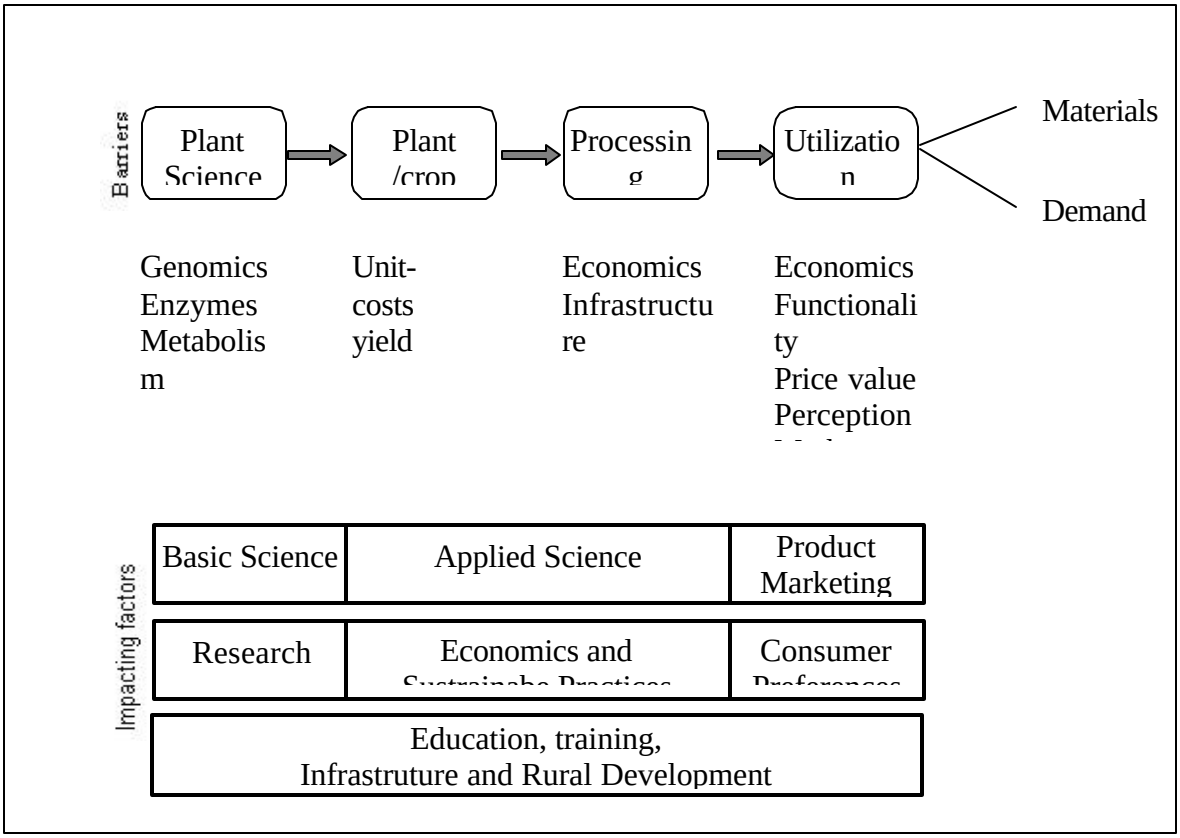


Figure 3: Key Barriers and Factors Impacting Barriers for Biobased Products



Source: Zeikus, 2000