Current and Next Generation Agricultural Biotechnology Products and Processes Considered from a Public Good Perspective

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I appreciate the opportunity to provide my perspective on three interrelated topics relevant to the NABC 6 open forum on agricultural biotechnology and public good. These interrelated topics are 1. a self-generated hierarchical structure of public good; 2. selected examples of the status of current and next-generation agricultural biotechnology products and processes in the areas of food, crop production, energy, materials and human health with a listing of their public good; and 3. the need for initiatives such as the Alternative Agricultural Research and Commercialization Agency (AARC) to facilitate technology development and commercialization so that agricultural biotechnology products and processes will be available in the marketplace and thereby provide public good. Public good is the common denominator of these products. It is not only important but imperative in today's post-cold war, tight budget environment that the public good of new products and processes be communicated to the public. The public is more interested in the public good of products and processes than they are in the sophisticated tools and intellectual approaches that are used to generate the products and processes.

The public good story for those agricultural products and processes that are approved and marketed and the projection of the public good for next generation products and processes is a very positive one and, to date, has been inadequately communicated. The public good is a story of improved food safety and food quality, lower cost food, improved human health, new jobs, products made from materials produced (and in many cases also processed) in primarily rural communities, decreased subsidies, decreased environmental problems, and increased sustainability. As change occurs due to new agricultural biotechnology products and processes, society at large should benefit; at the same time, certain subsets of society that fail to or are unable to take advantage of the new opportunities will be disadvantaged. This will be no different for agricultural biotechnology than for any other technological change or change in governmental policy, trade or finance. In fact, the extensive discussion of these products and processes prior to their market introduction is providing more advance information than has occurred for almost any other technological change. Without question, there are more advance indications of the impact of biotechnology products or processes than there are for government policy, trade and financial change, to list a few that can also have major impacts on producers. It is hoped that the following perspective will help to stimulate productive discussion on agricultural biotechnology and public good.

WHAT IS PUBLIC GOOD?

If we are to address the impact of current and next generation agricultural biotechnology products and processes on public good, we need a description of public good. There is no broadly accepted description of public good. Any description is influenced by the viewpoint of the individual or the organization that produces it. The structure I will provide is based on a hierarchy of relative importance based on my personal viewpoint. This viewpoint has evolved from a career in science that has been almost exclusively in the private sector and, until the last few years, in the for-profit private sector. I also recognize the importance of the viewpoints of others, including consumers. Robert Nicholas' and my recognition of the need for a vehicle through which all viewpoints could be expressed in an open forum led us in 1987 to found the National Agricultural Biotechnology Council (NABC). I have had the benefit of participating in the open discussion at all five previous NABC annual meetings. These and other dialogues have sensitized me to a diversity of issues and viewpoints regarding agricultural biotechnology. Based on these inputs and some recent conversations with individuals outside the science community, I have generated a hierarchical structure of public good (Figure 1). My prioritization of the structure is based mainly on a U.S. national perspective.

FIGURE 1

HIERARCHICAL STRUCTURE OF PUBLIC GOOD

LEVEL OF IMPORTANCE	ISSUES
Greatest ↑	Freedom of Choice
	Knowledge
	Human Health
	Economics
	Environment
	Sustainability
↓	Global Interdependence
Least	Other

Freedom of Choice

In my list, freedom of choice is the most important public good. Let me relate freedom of choice to agricultural biotechnology. One should have the opportunity to choose, if one wishes to do so. If one wishes to choose, one has a responsibility to become informed so that a decision is an informed one. Useful information must be provided so that one can make such an informed choice. Words like "transgenic" or "genetically engineered" may be useful, at best, to a scientist. In my view, such words are of no use for decision-making by a consumer. On the other hand, highly information-rich designations such as Flavr Savr™ tomatoes are very useful to me as a consumer wishing to make an informed choice.

We need to provide information-rich designations throughout the production and distribution system. As, for example, Monsanto's proposed designation of "Roundup Ready™" to grain farmers for crops tolerant to the herbicide Roundup®. The name Prosilac™, used by Monsanto for their bovine somatotropin (bST) product, is information-rich for dairy farmers. However, there has been a failure to provide information to the consumers of milk that will enable them to make an informed choice to purchase, or not to purchase, milk produced from cows treated with bST. I appreciate that there is no chemically analyzable difference between milk from cows treated with bST and those not treated with bST. Some consumers, though, are understandably expressing concern because they have been denied this right to choose. Personally, I would appreciate the ability to exercise the right to choose in this case. I would like to be able to choose milk from bST-treated cows because it is my understanding that average or above average dairy farm management is required for successful use of bST. As someone who grew up on a dairy farm, I would like my milk to come from the best managed dairy farms. In the same way product identification for marketing provides information for choice by the producer/user, such as the dairy or grain farmer in the above examples, there should be information for choice by the ultimate consumer, especially when a significant proportion of consumers indicate the desire to have such information.

Knowledge

Knowledge is probably the second most important public good. To exercise freedom of choice, one must be informed, i.e., have knowledge about, the object of that choice. Many organizations are involved in the knowledge area. The public trust varies with respect to information provided by different organizations (i.e., perceived acceptable knowledge provided). In January of 1994 Thomas J. Hoban IV conducted a survey for the Grocery Manufacturers of America to assess the amount of trust that individuals had in sources of information on the safety of bST. This survey was conducted in the month preceding the first commercial sale of bST in the U.S. Trust was highest (80+ percent) for information provided by organizations such as the American

Medical Association (AMA), the National Institutes of Health (NIH), the Food and Drug Administration (FDA) and the American Dietetic Association (ADA). Trust was lowest for grocery stores, activist groups and chefs.

Human Health

In my list, human health is the third most important public good. Within the human health area I include food and medical aspects of human health such as food adequacy and security, food safety, nutritional quality, food preference characteristics, food variety, food cost, wellness, diagnostics, therapeutics, vaccines and prostheses. Current and next generation agricultural biotechnology products from new foods to food-vaccines are expected to impact broadly on human health.

Economics

The next public good is the economic area. There are several economic factors from the public good perspective. A major one is new jobs in both urban and rural locations. In addition, there are issues of production, productivity, value-added, proprietariness, competitiveness, community development, imports, exports, subsidies and taxes. Agricultural biotechnology products and processes can have significant impacts on many of these economic factors. For example, it is critical that the U.S. reduce its need for agricultural subsidies and that we create jobs in rural locations. Agricultural biotechnology products, in the longer term, have major potential in both these areas.

Many of the public good issues of economics are first and foremost national issues. In the U.S. there are about 90 million acres of excess or unused agricultural land that could be used for production. Our productivity is increasing two to two and a half percent annually. There is also a continuing decline in grain exports from 150 million tons exported in the late 1970s to only 90 million tons in the early 1990s, and this continuing decline in exports will expand substantially the number of excess arable acres. The availability of this excess acreage capacity and the power of agricultural biotechnology provide the potential for major economic public good, especially in rural communities.

Most people agree that a product or process should be economically competitive to remain in the market. A growing segment of our society is sympathetic to so-called "green" products and processes. However, "green" product or process alternatives that involve a significant additional cost over traditional products without other advantages probably will not survive in the marketplace, or if they do, will only have a very small market share. There may be indirect production costs for which we need to develop systems to incorporate these costs in the selling price of a product. These indirect costs are most relevant to the next public good areas of environment and sustainability.

Environment

As the more primary and traditional public good needs of human health and economics are met, society begins to address additional public good issues. Environment, in my view, is the next public good issue. The environmentally related actions of many developed countries in the last quarter of the 20th century document the public good acceptance of environment as a timely concern. There are many environmental issues including erosion, salinization, desertification, soil and water contamination, air quality (ozone [OJ, nitrogen oxides [NOJ, sulfur dioxide [$S0_2$], volatile organic chemicals [VOC]), stratospheric ozone/UVB, wetland preservation, greenhouse gases, forestry, etc. There are existing or projected examples where agricultural biotechnology products or processes favorably impact the environment.

Sustainability

The next emerging public good issue is sustainability. We are still in the process of defining sustainability. Almost all agree that use of renewable versus nonrenewable sources and resource conservation fall under sustainability. In addition, some believe that sustainability requires self-sufficiency at the local level. Agricultural biotechnology products and processes are clearly relevant to the use of renewable sources.

Global Interdependence

Increasingly, we recognize that there is, indeed, global interdependence, and it is in the national interest to address issues at a global level. These global public good issues include humanitarian ones, environmental ones such as global environmental change and pollution, and economic ones such as the global marketplace, proprietariness, sources and rights to genetic materials, technology access, trade and tariffs. It is clear that agricultural biotechnology products and processes will impact and be impacted by the above global public good issues.

Other Public Goods

There are many other public good issues that apply to limited areas or subsets of people in contrast to the above global and national ones. Some of these public good issues may be identified under the composite public good area of pride. Pride occurs at many levels: national, community, organizational, ethnic and cultural. There are religious beliefs—these are considered as a public good by those people who so believe. There are those who believe that "how things were" is a public good. I refer to these as the "way things were" myths. One of these is the family-farm myth. I grew up on a family farm. I often have fond recollections of that family farm, but then I recall only too clearly the reality of the family farm of the 1940s. The reality was that intellectually unchallenging, repetitive physical labor dominated the family farm of the 1940s. There were, though, significant opportunities for entrepreneurial family farmers in the 1940s as, I believe, there are in the 1990s.

The hierarchical structure of public good presented in Table 1 and described above is a self-generated list. You may strongly agree; you may strongly disagree. The list is a starting point that I will use in a summary of selected current and next generation agricultural biotechnology products and processes.

SELECTED EXAMPLES OF CURRENT AND NEXT GENERATION AGRICULTURAL BIOTECHNOLOGY PRODUCTS AND PROCESSES

The number of current agricultural biotechnology products and processes in the marketplace has doubled within the last year. The premier agricultural biotechnology product to date is chymosin for cheesemaking which was approved by the Food and Drug Administration (FDA) over four years ago and now has more than a 60 percent share of the market. If you have eaten cheese regularly during the last four years, it is almost certain that you have eaten cheese made with highly pure chymosin produced by transgenic microorganisms, rather than using the highly impure chymosin obtained traditionally from stomachs of slaughtered calves. The microbially produced chymosin product has been joined by microbially produced bST for enhanced milk productivity that was approved by FDA in November, 1993 and marketed in February, 1994, and by Flavr Savr™ tomatoes approved by FDA in May, 1994 which are now also in the market. Clearly, momentum is growing for agricultural biotechnology products and processes. Opponents of these products have had a losing year in their battle to keep agricultural biotechnology products either out of the marketplace or “dead on arrival” in the marketplace.

In this section I will provide synoptic tables of selected agricultural biotechnology products and processes for food, crop production, energy, materials, and health care. The tables include a general description of the product or process, its status, its advantages and a listing of public good.

Food Products and Processes

Four food or food safety products are summarized in Table 1: clotting enzyme for cheesemaking, bST for improved milk productivity, DNA-probe diagnostics for food-based microbial contaminants and improved consumer preference characteristics of fruits and vegetables, e.g., Flavr Savr™ tomato. All of the above products are already in the marketplace.

The public good benefits include the areas of economics, health and environment. The favorable public perception of high-purity chymosin produced by transgenic bacterial systems versus the unfavorable perception of low-purity chymosin from slaughtered calf stomachs probably caused the opponents of agricultural biotechnology not to express opposition to this biotechnology product in the manner they expressed concern about bST also produced

TABLE 1: FOOD PRODUCTS AND PROCESSES

	Clotting Enzyme for Cheesemaking	bST for Improved Milk Productivity	DNA-Probe Diagnostics for Food-Based Microbial Contaminants	Improved Consumer Preference Characteristics of Fruits and Vegetables
Technology	Transgenic microbes produce identical enzyme	Transgenic microbes produce a product essentially identical to bovine bST	DNA probes for ***Listeria, E. Coli, L. monocytogenes, Salmonella, Staphlococcus aureus, Campylobacter*** and ***Yersinia enterocolitica***	Antisense technology used to extend tomato shelf-life
Status	FDA approved chymosin 3/90; 60% of market; Kosher, halal, vegetarian accepted	FDA approved Monsanto Prosilac™ 11/93; Marketed 2/94 following 90-day moratorium; Used on 10-15% of cows by 4/94	GENETRAK Systems, Inc. markets kits	FDA approved Calgene Flavr Savr™ tomato 5/94
Advantages	50% cost reduction Reliable, reproducible supply; High purity; High cheese yield	10-15% increased production	Speed: 24-48 hours; Equal or better than traditional culture methods sensitivity/specificity	Increased shelf life; Improved flavor
Public Good Economics	Reduced cost; Reliable supply	Decreased cost of milk production; Lower cost to consumer	$40 billion cost/year	Premium for value added
Environment	--------------	Fewer cows-less methane and manure	----------------	----------------
Health	High purity	Neutral overall: possibly increased milk consumption with lower cost; Requires above average farm management	Reduce the 80,000 illness (death in a few cases) per year	Increased fruit/vegetable consumption
Other	Perception-microbial vs. slaughtered calf stomachs	Concern about impact on less efficient (not necessarily smaller) dairy farms	----------------	----------------

microbiologically. I suggest that the concern about the impact of bST on dairy farmers really is a concern for the survivability of less efficient dairy farms whose survival may not be an overall public good. However, lower cost of milk to the consumer, that should result ultimately from use of bST, is a public good. In general, improvements in agriculture ultimately benefit the consumer. Such improvements are the basis of the very low cost of food in the U.S. and Canada. Overall, agricultural biotechnology products now in the marketplace will impact in a highly positive manner on the public good. Improvements in the methods to detect microbial contaminants in food should decrease illnesses and even deaths such as occurred in the recent case of microbially contaminated ground beef. Reduction in the major estimated annual cost of $40 billion for time lost due to these illnesses could be major. Increased consumption of fruits and vegetables is being recommended for improved health. Products such as the Flavr Savr™ tomato should promote this desired dietary change.

The progress in development and marketing of food products and processes is impressive. Chymosin, the first transgenic food product, was approved by the FDA in early 1990. Four years later it has captured a 60% market share. Furthermore, it is accepted as kosher, halal and vegetarian, thereby demonstrating the broad acceptability of a transgenic food material. It is expected that bST from transgenic organisms and Flavr Savr™ tomatoes, which were approved by FDA in 1994, will show similar acceptance within four years as that now achieved by chymosin. Within only two months of approval, bST was reported to be used on 10-15% of cows. All of the above food products and processes provide significant economic benefits and/or added value and health benefits to consumers. The above should be viewed as the earliest examples of food biotechnology products and processes with substantial overall public good.

Crop Production

Three examples of agricultural biotechnology products for crop production are summarized in Table 2. None is yet in the marketplace. Research and development for transgenic crops with enhanced or added herbicide tolerance is highly advanced, and products should be marketed within the next few years. Currently, crops with herbicide tolerance produced by traditional selection and cell culture methods are marketed. Transgenic plants with coat-protein genes or other viral genes to protect against viruses are in advanced field-testing. For example, the improvement in quality and yield of squash produced by Asgrow is dramatic. A more futuristic potential is self nitrogen-fertilizing cereal grains that contain the legume genes for symbiotic nitrogen fixation. The potential public good benefits for this product are outstanding in multiple areas: replacement of the $20+ billion annual cost for synthetic nitrogen fertilizer, decreased NOj(nitrates) in ground water and a sustainable method to replace fossil fuel based synthetic nitrogen fertilizer—all with applications in both developed and developing countries. Major research and development remains to be done. At the Boyce Thompson Institute, the biological materials to produce self nitrogen-fertilizing plants are in hand and the approach is defined. There is a reasonable chance of success within the next fifteen years if the needed investment is made now.

TABLE 2: CROP PRODUCTION PRODUCTS

	Transgenic Crops with Enhanced or Added Herbicide Tolerance	Trangenic Plants with Coat and Other Viral Genes	Self -Nitrogen Fertilizing Cereals
TECHNOLOGY	Tolerance genes for Bromoxynil, Glyphosate, Sulfonylureas, Imidazolinones and others	Virus-resistant fruit and vegetable crops: cucumber, squash, papaya, etc.	Transgenic cereals with legume genes for symbiotic nitrogen fixation
Status	Many successful field trials; Bromoxynil cotton (Calgene, Inc.) deregulated status by USDA/APHIS	Field trials by Asgrow show major improvement in quality and yield of squash	Early research, but approach is defined and doable; 30+ single gene pea mutants for *sytn* genes generated and being located, isolated and characterized
Advantages	Increased efficacy of and flexibility in weed control	Quality and productivity	---------------
Public Good Economics	Reduced cost of weed control	Reduced cost	Reduce $20 billion synethic nitrogen fertilizer cost with transgenic seed (corn, wheat, rice) and microbes
Environment	Enable use of more effective herbicides with less residue; Safer use of safer herbicides (see *NABC Report* 3); Reduce cultivation and soil erosion; Develop-ment of herbicide-tolerant weeds is often expressed as concern.	Concern regarding viruses with expanded host range	Decreases in: NOj ground water pollution; greenhouse gases (N$_2$0, C0$_2$) and impact on global N cycle
Health	Reduced soil/water residues of long-lived herbicides	Increased consumption of fruits and vegetables due to reduced cost	Improved drinking water quality
Global Interdependence	---------------	e.g., Papaya in Brazil	Applicable to both developed and developing countries
Sustainability	---------------	---------------	Replace fossil use

ENERGY PRODUCTS

Two examples in the energy area are summarized in Table 3. Biodiesel, which is the methyl esters of plant or animal oils or fats, is being proposed as a 20 percent component of diesel fuel. This 20 percent biodiesel fuel reduces substantially particulate emissions without the need for major capital costs in engine or vehicle modification. The Environmental Protection Agency (EPA) is reviewing information to determine if 20 percent biodiesel in diesel fuel can be designated as substantially similar to diesel. With such a designation, this 20 percent biodiesel product could be used without delay, which should enable public transport buses to reduce particulates in diesel exhaust for the January 1, 1995 requirements of the Clean Air Act. With required approvals, biodiesel could be a commercial product within the year providing multiple public good benefits. Another energy example is oxygenated gasoline. Lignocellulosics are an abundant part of agricultural wastes and forestry materials. Much research has focused on producing an economic process to produce ethanol for oxygenated fuels from these low-cost materials. About 30 percent of lignocellulosics is hemicellulose. A biotechnological process invented by the University of Florida is being developed by Bioenergy International for the highly efficient conversion of hemicellulosics to ethanol. Added value and reduced cost are the key benefits from this process. There are other energy products in the pipeline but space does not allow their review; the above examples should be viewed as illustrative.

TABLE 3: ENERGY PRODUCTS

	Biodiesel	Oxygenated Gasoline
Technology	Methyl esters of plant oils or animal fats, e.g., soydiesel	Hemicellulose to ethanol by transgenic microorganism
Status	20% biodiesel in diesel fuel reduces particulate emision without engine/vehicle modification; Many tests in process with city buses and other; EPA reviewing regarding substantially similar designation	Process being developed by Bioenergy International
Advantages	New use for plant oils with environmental and economic benefits	Value added to waste material
Public Good: Economics	Reduce capital costs for retrofit but increase operating cost; Expanded market for plants/oils	Added value/reduced cost
Environment	Reduce particulates in diesel exhaust to meet 1/1/95 requirement by Clean Air Act	Ethanol and clean air; Recycle carbon dioxide
Health	Cleaner air	Reduce air pollution
Sustainability	Renewable vs. fossil	Renewable vs. fossil

HUMAN HEALTH CARE PRODUCTS

Therapeutics and vaccines are major human healthcare products. Transgenic animals with human genes are being developed to produce human therapeutic proteins in milk or blood. Table 4 lists several that are in the experimental stage. The value-in-use per animal is very high, but the number of animals needed will be limited. Such therapeutic-manufacturing animals, though, may be very relevant for the production of drugs in developing countries since it is the transgen ic an imal itself that is the production facility. A longer-term agricultural biotechnology effort is the production of edible vaccines by transgenic fruits and vegetables. This program at Texas A&M University is in the early research stage. It is suggested that the cost of such edible vaccines could be as low as six cents per "vaccine" food. The public good to developed as well as developing countries would be major, to say nothing of the benefit to the vaccine consumer who no longer must endure an injection.

Materials

Materials, both organic and inorganic, are huge total-volume markets. Prior to the era of cheap and consistently available fossil materials, agricultural and forestry materials were the primary source of most of the carbon-based

TABLE 4: HEALTH CARE PRODUCTS

	Human Proteins	Oral Vaccines
Technology	Transgenic animalswith human genes produce human proteins in milk/blood	Edible vaccines produced by transgenic fruits (bananas) or vegetables
Status	All are experimental; tx-l-anti-trypsin to treat emphysema by sheep; tPA for early treatment of heart attack by goats; Protein C to keep blood from clotting by pigs; Hemoglobin as a substitute for red blood cells; Lactoferin, a mother's milk protein for baby formulas by cows	Early research; Transgenic plants produced Hepatitis B vaccine
Advantages	Milk in most cases as the starting material for purification	Low cost and delivery in a normally consumed food
Public Good Economics	Very high value-in use animal products, e.g., $ 100,000/yr. animal	Low cost; 6 cents per "vaccine" fruit
Health	Therapeutic or beneficial	Immunization, especially for chi Idhood diarrheal diseases in developing countris
Global Interdependence	May be very relevant to developing countries	Especially appropriate to children in developing countries but could also be used in developed countries

materials. New technology and increasing concerns about the negative environmental impacts of fossil-based materials is generating a reemphasis on materials from agricultural and forestry products (see Table 5). A high-value polyester called Biopol™, produced by bacteria, is being marketed by ZENECA, Inc. as a non-wettable paper coating and moldings for bottles. Transgenic plants are also being developed to produce this and other polymers; the potential is large, but the research is at an early stage.

Nature already provides large quantities of materials that are used extensively. For example, worldwide cotton production in 1992 was about 19 billion kilograms (kg) out of a total worldwide fiber production of both synthetics and naturals of about 42 billion kilograms. An exciting example of a relatively undeveloped natural fiber is milkweed floss (Table 5). Natural Fibers in Nebraska has commercialized milkweed floss for the pillow and comforter market. They see potential for milkweed floss in nonwoven yarn and other markets. Successful utilization of milkweed floss fiber in these markets could lead to the domesticated production of millions of acres of milkweed The possible economic benefits in the materials area are huge.

The above examples illustrate the major public good that exists or is expected to flow from agricultural biotechnology products and processes. The breadth of the products and processes—from food to energy to materials to human health—is enormous. The potential is well beyond that recognized by the informed public, and even many scientists who probably think of agricultural biotechnology as being relevant only to crop and animal production, or possibly to food. The diversity and strength of the public good for these agricultural products and processes needs to be communicated. The next section discusses a government initiative to improve our success in delivering these products and processes to the public.

COMMERCIALIZATION OF AGRICULTURAL BIOTECHNOLOGY PRODUCTS AND PROCESSES

For public good to occur, the products and processes generated by research and development, for the most part, must be commercialized. This critical step is the limiting factor for most areas of technology, and biotechnology is no exception. Some describe this limiting factor as the "valley of death" which dramatically communicates our failure, in too many cases, to convert science and technology to successful commercial products and processes. In recent years the U.S. government increasingly has recognized the importance of improving our success in crossing the "valley of death" and has generated some initiatives to facilitate technology development and precommercialization activities. Two government initiatives have been established recently: one is the Alternative Agricultural Research and Commercialization (AARC) agency in the U.S. Department of Agriculture (USDA) and the other is the Advanced Technology Program (ATP) in the National Institute of Standards and Technology (NIST) in the Department of Commerce.

TABLE 5: MATERIALS

	Biopolymers by Microbes	Phytopolymers by Transgenic Plants	Natural Phytopolymers /Fibers
Technology	---------------	Transgenic plants to produce polymers/fibers with functionality that meets or exceeds that produced by synthetic chemistry; Opportunities for polyesters, cellulosics and amides	Milkweed floss for down, non-woven yarn and other markets
Status	Biopol™[1] is produced and marketed by ZENECA, Inc. as non-wettable paper coating ($15/lb) and molding for bottles for high value products (cosmetics and shampoos) ($8/lb); ProNectin™byProteinPolymerTechnologies; Cellulon™ by Weyerhauser Company	Early research; Polyester synthesis by transgenic *Arabidopsis* and Canola (0.1%)	Methods and equipment developed by Natural Fibers to grow, harvest and process milkweed with production of comfortors and pillows marketed as Ogalala Down™; Cultivar improvement
Advantages	Biodegradable but processing cost high	Yet to be demonstrated; Infinite variations with designed genetic template; Solar energy	Opportunity for major new crop with substantial value-in-use
Public Good Economics	Reduces disposal cost of non-biodegradable polymers	High performance?; Lower cost?; Domestic production	Major potential for agriculture; Very high to good value-in-use; Potential major new crop: reduces need for subsidies and offers rural opportunties; Jobs; Domestic vs. imported materials
Environment	Biodegradable	Renewable vs. fossil; Biodegradable; Decentralized manufacture	Perennial crop; Low water and nitrogen use; Opportunity for additional crop rotation
Health	---------------	---------------	Hypoallergenic vs. goose down
Sustainability	Renewable source	Renewable	Renewable

[1] Biopol™ polyester copolymer of (3-Hydroxy Valerate and Butyrate

AARC was created in the 1990 Farm Bill. Its two major proponents were the former Secretary of Agriculture and the New Uses Council. The role of AARC is to provide risk investment to the private sector for support of pre-commercialization activities for new added-value, non-food and non-feed uses of agricultural and forestry materials. The private sector must provide at least a 1:1 dollar match for the funds provided by AARC. AARC's primary objective is to utilize the excess U.S. agricultural production capacity or U.S. surpluses of agricultural and forestry materials for industrial products for domestic and international markets and to reduce simultaneously and substantially the need for agricultural subsidies. There are other expected benefits from AARC investments of public funds. Overall economic development should occur within the agricultural and forestry sectors. Production, processing and distribution of these added-value industrial products will create, for the most part, jobs in rural areas since the bulky raw materials are located in rural areas and are expected to be processed near their origin.

I am one of the nine members of the original AARC Board appointed in 1992. Based on my experience on other national committees, boards and commissions, the commitment and enthusiasm of the AARC Board members to the AARC mission is unprecedented. The Board believes that AARC is the right thing to do and that government has set it up the right way. These industrial products from agricultural and forestry materials should expand the use of renewables and reduce fossil use. The environmental impact from the bio-based industrial products should be reduced relative to those based on fossil sources. Also, the bio-based system should be more sustainable.

The operation of AARC is unique and may represent a model for management of future government investments in development. The AARC board is appointed by the Secretary of Agriculture with input from the National Science Foundation (NSF) and the Department of Commerce. The Board is composed of nine members with eight from outside of government representing technical, business and entrepreneurial expertise. This Board is not an advisory committee but rather an operating board that has total responsibility for the operation of AARC and reports directly to the Secretary of Agriculture. The Board operates AARC as a business, not as a government grant program. The Secretary of Agriculture can override decisions of the Board but must do this in writing. To manage investments in development, AARC utilizes the experience mainly of entrepreneurs from the private sector rather than government bureaucrats. There are five presidents or vice presidents of private corporations on the original Board.

The composition and experience of the AARC Board is one of the keys to the novel operating structure of AARC. The other major key is the financial management of AARC investments. The government funds allocated to AARC are placed in a revolving fund. AARC investments are made so that the AARC revolving fund will receive a return on its investment based on the financial success of the products or businesses. This return may come from equity, royalties or other appropriate methods negotiated at the time of the AARC investment. It is the goal of AARC that the revolving fund will become financially self-sustaining, maybe within ten years. Society talks about sustainability in many areas. Why should government programs not be set up to be sustainable? The taxpayer provides the key start-up funds, but the activity must become self-sustaining if it is to continue. Thus the taxpayer will not need to provide continuous financial input. AARC aims to bring self-sustainability to a government program.

AARC seeks and evaluates proposals through broad solicitation and in-depth competitive reviews. There is external review by technical and business experts. The Board uses these external reviews and its own evaluation to select the most promising preproposals to be submitted as full proposals. Prior to funding, at least one Board member visits the site to meet with management, review the plan and facilities, and negotiate the basis for financial return to the AARC revolving fund. Board members and staff monitor the businesses on a regular basis. AARC has made investments in at least three of the examples described above.

The major limitation of AARC at this stage is the level of funding. Annual funding of less than $10 million enables AARC to invest in only a fraction of the promising opportunities. The U.S. must continue to fund and substantially expand our funding of research for new uses of agricultural and forestry materials. Even more importantly, the U.S. must increase substantially the investment in precommercialization activities. Such investments will serve the public good through new jobs, rural development, reduced subsidies and a self-sustaining investment fund for businesses based on agricultural and forestry materials.

Another government initiative to facilitate technology transfer across the "valley of death" is the Advanced Technology Program (ATP). Its objective is economic development by improving the competitiveness of U.S. industry with new high-value products/processes/services for domestic and international markets. It, like AARC, also hopes to create jobs. ATP focuses mainly on the urban non-agricultural area with investments in, for example, the electronics industry. The goals of AARC and ATP are similar, although the former is focused, for the most part, on rural communities and expanding the opportunities for agricultural and forestry materials. The operation of the AARC and ATP are very different. ATP operates as a traditional government program with management by government bureaucrats and no requirement for a return to the program from successful investments. ATP identifies technology or product deliverables, as does AARC, but does not seek a financial return so as to become self-sustaining. I believe that the AARC style of operation with decisions made by experienced, private-sector entrepreneurs and with a financial return to enable sustainability is a step in the right direction and consistent with the proposal of the current administration to reinvent government. ATP is growing at 80+ percent per year based on government funding and will shortly have 50+ times the annual funding provided to AARC. Both are excellent, timely programs. AARC needs to grow in the way ATP is growing so that AARC has funding consistent with the level of biobased opportunities, estimated to be at least ten percent as compared to ATP, not one to two percent as reflected in current funding. Both ATP and AARC can be important to the public good.

IN SUMMARY

A hierarchical structure of public good based on relative importance is presented. The issues, arranged starting with the greatest to level of importance, are: freedom of choice, knowledge, human health, economics, environment, sustainability, global interdependence and other. The other public good category includes issues that apply only to limited subsets of people. Fourteen selected examples of current and next generation agricultural biotechnology products and processes, crop production products, energy products, healthcare products, and materials were presented. A brief statement of technology status and advantages for each example is presented as well as the identification of public good for the relevant issues such as economics, health, environment and sustainability. The selected examples range from a transgenic product for cheese making, initially marketed in 1990 and presently with a dominant market share, to now marketed and much debated bST and Flavr Savr™ tomato products and processes in development such as biopolymers and a process for ethanol production for oxygenated fuels to products in the very early research stages such as self nitrogen-fertilizing cereals and edible plant vaccines for humans. Major public good exists or is expected for the above products or processes that are in the market, in the development stage, or in the research stage.

Public good requires the transfer of technology from the research and development arena to products and processes in the marketplace. Without commercialization or equivalent delivery to the users, there is no public good. A new federal program, the Alternative Agricultural Research and Commercialization Center, located within USDA, is described. Its mission is to invest in commercialization by the private sector so as to facilitate the marketing of new industrial (non-food or non-feed) value-added products from agricultural and forestry materials.