

# From Petro to Agro: Seeds of a New Economy

Robert E. Armstrong\*

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## Introduction

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Nevertheless, new international relationships will be based upon the increasing interaction and interconnectivity between the gene-rich/technology-poor countries of the developing world [the source of raw renewable materials for global bioeconomic development] and the gene-poor/technology-rich countries of the developed world.

Agriculture, the new foundation stone of the bioindustrial, energy, and health sectors, offers the most economical and environmentally friendly methods to produce large quantities of biorenewable biomaterials.

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## The Age of Geology

For much of the last century, and particularly since the end of World War II, petroleum has been the primary raw material for the world's economy. In 2004—the last year for which data are available—crude oil and NGPL (natural gas plant liquids which are hydrocarbon liquids obtained when extracting natural gas that are combined with petroleum) accounted for 38 per cent of the world's energy supply. Coal stood at 26 per cent, while natural gas accounted for 23 per cent. Hydropower and nuclear power each accounted for 6 per cent, and a variety of other sources combined accounted for just 1 per cent.<sup>1</sup>

The US consumption of petroleum is typical of worldwide trends. The bulk of US petroleum use goes to meet energy demands, with approximately 90 per cent of a barrel of crude oil going to gasoline, diesel, and other fuels. Since 1949, however, the industrial consumption of petroleum for nonfuel use in the US has increased nearly seven-fold.<sup>2</sup> The chemical industry, for example, relies on petroleum for more than 90 per cent of its raw materials to manufacture its myriad of products, ranging from plastics, refrigerants, and fertilizers to detergents, explosives, and medicines. Virtually everything requires petroleum or petroleum derivatives for its manufacture.

As the twentieth century was ending, Michael Bowlin, then the president of the American Petroleum Institute, and chief executive officer of Arco, told industry executives that the world was entering "*the last days of the Age of Oil*".<sup>3</sup>

Estimates of the remaining life of the reserves vary widely, but many experts agree that worldwide oil production will peak between 2010 and 2020. Even if there is agreement with those who hold that the petroleum supply may be renewable, environmental pressures and economic incentives will remain that will move us to newer technologies. Far from repeating the apocalyptic warnings of the 1960s and 1970s about the end of oil, however, there is no doubt that the new technologies will replace petroleum.

## The Age of Biology

Prominent among the replacements for petroleum are products developed from biological sources. Using biomaterials obtained from plants and animals as raw materials for industrial and consumer products is not new. Before the rise of cheap oil, agriculture was the dominant source of raw materials. Indeed, when the US Department of Agriculture

was established in 1862, its motto proclaimed, "*Agriculture is the Foundation of Manufacture and Commerce.*"

Even today, agriculture supplies raw materials for industry; for example, as recently as 2002, about 8 per cent of the US corn crop went to industrial uses rather than directly towards meeting food or feed requirements.<sup>4</sup> Some US government estimates suggest that if current trends continue, within the next five years, nearly one-third of the US corn crop will be used solely for ethanol production. While that seems unlikely, as alternative feedstocks will no doubt be developed, it still illustrates the growing demand for industrial uses of crops. Agriculture offers the most cost-effective way to manufacture large volumes of biologically based raw materials.

In its vision statement for the twenty first century, the National Agricultural Biotechnology Council—a consortium of leading agricultural research universities in the United States—forecasts agriculture to be the source of not only our food, feed, and fibre, but also our energy, materials, and chemicals.<sup>5</sup> In a 1999 report on biobased industrial products, the National Research Council noted that US farmers already generate annually about 280 million tons of waste biomass—leaves, stalks, and partially used plant portions. That is more than sufficient material to serve as feedstock for all of the domestic industrial chemicals that can be readily manufactured from agricultural sources.<sup>6</sup>

One argument that is often posed against the move to a biobased economy relying on agricultural production is that it will take land and crops away from food and feed production. In the United States, for example, resources needed for food and feed production will not compete with resources required to grow industrial raw materials. The United States has the largest arable land per capita of any country in the world (1.73 acres for the United States versus 0.99 for other developed countries; the developing world average is only 0.49 acres).<sup>7</sup> Additionally, through the US Department of Agriculture's Conservation Reserve Programme, 35 million acres are left fallow each year, some of which could be used to grow crops specifically for biomass. Even in those countries with less available arable land, the use of intensive agricultural techniques could provide adequate yields and biomass to sustain both food/feed and industrial demands.

Water does present some local and regional challenges to the potential expansion of agriculture. As the need for affordable water

increases, however, improvements in irrigation technology and the development of new water resources are likely to follow. One estimate suggests that improvements in irrigation technology alone can reduce the anticipated worldwide demand for additional water resources by one-half during the next 25 years.<sup>8</sup> Thus, concern about water availability is not likely to present a barrier to expanded agricultural production.

Technological innovations in agricultural production undoubtedly will continue to increase yields. Corn yields in the US, for example, gained an average of 1.0 bushel per acre per year during the last century. In the last half of the century, the average increase was 1.8 bushels per acre per year. Depending on soil characteristics and water availability, even something as simple as the spacing between corn rows can be used to maximize yields. Corn yields in the United States averaged 138 bushels per acre for the decade of 1996–2005, vs. 115 bushels per acre for the previous decade. Some researchers believe that within the next 20 years technology and cultural practices can increase yield averages to nearly 260 bushels per acre.<sup>9</sup>

While the production capacity to produce and process the raw materials for a biobased economy are available, for most current industrial practices, the cost of the conversion process—turning biomass into energy, materials, and chemicals—is not competitive with petroleum. Of course, making such cost comparisons varies, based in large measure on the price of oil. However, even with the recent rise in oil prices, it is still fair to say that petroleum-based products are generally less expensive than biobased products.

One key problem with making cost comparisons is that the production costs are based on existing facilities designed for petroleum feedstocks. When using biomass, some of the end products can be made through direct physical or chemical processing; others can be produced indirectly through fermentation (using microbial agents) or by enzymatic processing. What is needed is “biorefineries”.<sup>10</sup> Like an oil refinery, a biorefinery would take carbon and hydrogen and produce desired products. The biorefinery’s economic advantage will emerge from its dual capability. Along with the desired end products, foods, feeds, and biochemicals could be produced.

Prototypes of the biorefinery already exist in our industrial base in the form of corn wet mills, soybean processing facilities, and pulp and paper mills. While the prototypes of full-scale biorefineries are

mostly in the planning stage at the moment, two facilities designed for specific biobased end products have been operating in the United States for the past few years.

One of the largest biomaterials facilities in the world has been built in the US state of Tennessee and is operated under a joint venture between DuPont and Tate & Lyle BioProducts.<sup>11</sup> In mid-2001, DuPont announced that it had successfully manufactured a key ingredient in a new clothing polymer (now known as Sorona™) from corn sugars instead of petrochemicals—previously the only source for the polymer.

The biobased version of the key polymer used in Sorona™—1, 3 propanediol, or PDO—is marketed as Bio-PDO™. At the end of November 2006, DuPont announced the first commercial shipments of Bio-PDO™ from the \$100 million Tennessee plant. Products incorporating Sorona™ are expected to be available by early 2008 and used in a wide variety of applications, including cosmetics, liquid detergents and anti-freeze.

For the last four years, NatureWorks, LLC—a wholly owned subsidiary of Cargill—has been manufacturing a biodegradable plastic made from sugars derived from cornstarch. (The manufacturing takes place in a \$300 million plant in the US state of Nebraska, specifically built for the production of biobased products.) The plastic—known as PLA, or polylactide acid—has already been incorporated into products for large food sellers, including Coca-Cola and McDonalds. The corn-based PLA can be incorporated into a number of products that replace current petroleum-based polyesters, polyolefins, polystyrenes and cellulotics; for example, fibres, non-wovens, films, extruded and thermoformed containers and emulsion coatings.

NatureWorks is also currently manufacturing the world's first artificial fibre, named Ingeo™, completely constructed from renewable resources. The fibre is stain-resistant and is being used for many items ranging from pillows to carpeting to padded outerwear. A most interesting recent application of Ingeo™ was revealed at the first European Bioplastics conference, held in Brussels in November, 2006: a biopolymer-based wedding dress created by a famous fashion designer and sponsored by a major European agricultural organization!<sup>12</sup>

The biobased economy is growing at a rapid pace and is much more than just two biorefineries. A simple Internet search of the words “biobased plastics” yielded nearly a quarter of a million entries, for example. Many new partnerships are being forged.

One good illustration is the partnership announced between DuPont and British Petroleum (BP) to manufacture biofuels. By the

end of 2007 they anticipate marketing biobutanol made from agricultural materials. Many new products are being introduced to the marketplace. BiOH™, for example, is a new biobased foam product introduced by Cargill that is a replacement for previously petroleum-based foam and has gained wide acceptance in the furniture industry.

In November 2001, the Organization for Economic Cooperation and Development (OECD) published *The Application of Biotechnology to Industrial Sustainability*—one of the first studies to demonstrate the ecological and economic advantages of using biotechnology, biobased feedstocks and bioprocesses on an industrial scale. The European Union is also investing in the biobased future and examining the role of biorefineries. The EU has established EPOBIO, which is an international effort with the objective “to design new generations of bio-based products derived from plant raw materials that will reach the market place 10-15 years from now”. The initial areas of study are plant cell walls, plant oils and biopolymers. In May 2006, EPOBIO held a workshop specifically focused on the future of biorefineries.<sup>13</sup>

Similarly, Canada is also preparing for the biobased future with the formulation of the Strategic Plan for the Canadian Biomass Innovation Network (CBIN) that will serve as a guide, specifically “to improve the availability of biomass feedstocks for energy and industrial uses, and develop technologies, processes and systems that convert biomass into energy, biofuels, materials, chemicals and other industrial bioproducts”.

Biobased materials will only be successful if they are competitively priced with their petroleum counterparts. As much as individuals and corporations like to talk about being ‘green’, experience has demonstrated that they are seldom prepared to pay any sort of premium price. With the recent increases in world oil prices, the biobased materials have gained some advantage. However, oil prices are volatile, and can just as easily fall again. The important point is that the first steps have been taken to construct true biorefineries. Just as petroleum refineries have improved their efficiencies and profit margins over the last century, biorefineries will do likewise. Moreover, as we learn to derive sugars from the cellulose in the plant matter—as opposed to the starch in the grain—the base of source materials will significantly increase (e.g., we could use agricultural waste, or biomass) and the costs will decline.

Is this biobased economy just a vision with a few immediate examples, or is there a long-term probability for its success? In its 1999 report on biobased industrial products, the National Research Council—an agency of the United States' National Academies—argued that a competitively priced, biobased products industry eventually would replace much of the petrochemical industry. As an intermediate goal, the report suggested that by 2020, a biobased economy could provide 25 per cent of the 1994 levels of the United States' organic carbon-based industrial feedstock chemicals and 10 per cent of liquid fuels. The report suggested that, ultimately, 90 per cent of the US organic chemical consumption and 50 per cent of our liquid fuel needs could be met by a domestic biobased economy.

In this new economy, plants and animals will be specifically bred and farmed to produce desired raw materials. For example, if an industrial process requires a chemical to have certain tolerances to heat, a protein may be available to provide that tolerance. The protein, which would be the product of a gene, could be derived from plants. If the protein occurs naturally in animals or in plant species that are not easily farmed, genetic engineering offers the ability to transfer the gene to a plant species more suited to agricultural production. Once introduced into an agriculturally desirable plant, the protein can then be produced more cost-effectively and made available on a commercial scale.

### **Fueling the Biobased Economy**

As the biobased economy matures and issues of production and processing are improved, the demand for new products will grow. New products will require new raw materials. In a biobased economy, the basic raw material will be genes, and novel genes will be the source of novel products. Thus, as we shift from an economy based on geology to one based on biology, the basic unit of commerce will shift from the hydrocarbon molecule to the gene. Just as we currently demand assured access to sources of hydrocarbons, in the near future we will demand assured access to a broad-based, diverse supply of genes.

As with any resource vital to our economy, the location of large supplies of genes will become important to a country's national security concerns. In our petroleum-based world, the resource is concentrated in various pockets distributed worldwide in nearly all climate regions. Obviously, genes are distributed worldwide, as there is life in every nook



and cranny of this planet. However, the overwhelming majority of genes are concentrated in the equatorial regions.

Biologists refer to a region's biodiversity when commenting on the range of life forms present. The more life forms present (that is, the more genes present), the greater the biodiversity. The general biological principle of the latitudinal diversity gradient contends the closer to the equator, the greater the biodiversity. The amount of solar energy present, the lack of seasonal climate fluctuations, and the expanse of land explain the gradient's existence. By way of illustration, consider the results of a study that used comparable sized plots of land at different latitudes to compare the number of different bird species found at each latitude: Greenland, 56 species; New York state, 195 species; Colombia, 1,525 species. Plants show a similar degree of biodiversity. For example, in all of Canada and the United States, there are only 700 native tree species. In one census involving about 25 acres in Borneo, more than 1,000 different tree species were cataloged.<sup>14</sup>

### **International Implications**

In a biobased world, international relations with Ecuador (to use a representative country that takes its very name from the equator) will be more important than those with Saudi Arabia. At this early stage in the biobased economy, it would be wise to consider what controversies could arise over another nation's genetic treasure and how best to secure access and provide compensation to the regional owners. These are not new issues.

A classic example that illustrates the potential issues is the rosy periwinkle plant of Madagascar. In the early 1950s, a plant biologist working for the US drug firm Eli Lilly extracted two cancer-fighting compounds from the flower. During the course of the patents on the two compounds, Lilly earned hundreds of millions of dollars from the sale of the drugs. Madagascar received no compensation whatsoever.

By the early 1990s, two documents were ready for international agreement that sought to address cases like that of the periwinkle, among other things. The Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement—part of the Final Act of the Uruguay Round of Multilateral Trade Negotiations—sought to strengthen international intellectual property protection in order to promote world trade. The United Nations Framework Convention on Biological Diversity, known

commonly as the Biodiversity Treaty, sought to preserve agrarian societies and promote sustainable development.

Emblematic of the problems associated with intellectual property rights were the 1993 riots in India directed against W.R. Grace, a US chemical firm. Indian farmers were protesting that Grace had a patent on an insecticide derived from the neem tree, even though the farmers had a traditional method to extract the compound from the leaves. Although Grace's process gave the compound a shelf life and allowed it to be transported to areas where neem trees were not available, the farmers accused Grace of 'gene piracy'.

The Biodiversity Treaty sought to address the issue of the biodiverse-rich underdeveloped countries seeking compensation for the resources taken and used by the technology-rich developed countries. Provisions of the treaty require biodiverse-rich countries to provide access to genetic material in return for the developing countries providing a fair and equitable share of the benefits. US pharmaceutical and biotechnology firms initially opposed the treaty. Eventually, however, they dropped their opposition, out of fear that it might ultimately preclude their exploration for genetic resources in underdeveloped countries. The treaty was signed by President William Clinton in 1993, but was never ratified by the US Senate.

Although the treaty was not ratified by the United States—meaning it is not a party to the treaty—the business sector moved forward with an agreement that serves as a model for such arrangements. In 1991, Merck and Company signed an agreement with the Costa Rican Instituto Nacional de Biodiversidad (INBio) for a 2-year renewable contract, in which INBio supplied Merck with extracts from plants, insects, and microorganisms for its drug-screening programme. In exchange, Merck paid INBio \$1,135,000 and royalties on any resulting commercial products.

Thus, even more than a decade ago, the business sector was quite aware of the potential for genes as raw materials. This is especially true in the pharmaceutical industry at the moment, as about one-fourth of all prescription drugs contain an active ingredient derived from plants.

In a biobased economy, with many players seeking access to the biodiversity treasures of developing countries, the possible international scenarios that might arise are limitless: conflicts between developed countries over who had access to what gene at what time; conflicts between developing and developed countries over access to genes and

compensation; conflicts between developing countries over territory, and thus ownership, of particular stores of genes.

In this context, a serious dilemma could surface if a state set out to destroy large amounts of diverse genetic material. This is not a hypothetical situation. It is estimated that some 31 million hectares of rainforest are destroyed annually. Article 3 of the Biodiversity Treaty states that countries have the "*sovereign right to exploit their own resources pursuant to their own environmental policies.*" If genes were the basic unit of commerce, would the international community tolerate another state's environmental policies that allowed for the continued destruction of the rainforest?

Another likely point of international friction will be the use of transgenics. Moving genes from one species to another provides for tremendous diversity and the opportunity to create new products. It also raises safety and ethical concerns about introducing such genetically modified organisms (GMOs) into the environment.

A distinction is drawn between GMOs that are nonliving end products that would have no effect on the environment—for example, the heat tolerance protein theorized above—and living modified organisms [LMOs], such as seeds, that may have some environmental consequences.

The use of GMOs has steadily increased since their introduction in 1996. In late 2005—the last year for which data are available—BIO, the biotechnology trade organization, reported the following:

Global biotech crop acreage grew to 222 million acres in 2005, according to the International Service for the Acquisition of Agri-biotech Applications (ISAAA). In 1996, when the first biotech crops were commercially grown, 7 million acres of biotech crops were grown worldwide. In 2004, a total of 222 million acres of biotech crops were planted in 21 countries by 8.5 million farmers. Of the 8.5 million farmers, 90 per cent are resource-poor farmers in developing countries; developing countries account for more than one-third of the global biotech crop acreage. Of the 21 countries growing biotech crops, five are in the European Union. Additionally, the one billionth cumulative acre of biotech crops was planted in 2005.

The use of GMOs will increase as the biobased economy matures, and, likewise, the potential for disputes will increase. These are not hypothetical issues for the distant future but are present day concerns. The European Union (EU), for example, had a long-time moratorium

on approving the importation of GM crops. It resulted in the US, Canada and Argentina filing a complaint in 2003 with the WTO against the EU. In February 2006, the WTO ruled that the EU had indeed broken international rules. The issue is further clouded, though, by the fact that the EU has already allowed some 30 GM food and feed products to be sold in the EU, thus bolstering their likely counter-claim that the moratorium was already lifted. The point is, we are in the very early stages of the biobased economy, and we can already see protectionism and non-scientific claims being used for the preservation of national markets—things that can thwart the growth of this new industry. Environmental activists in Europe will no doubt continue to encourage EU governments to take anti-GM positions. In Australia, the Insurance Council of Australia even stated its reluctance to insure farmers, biotechnology companies, or food companies in cases involving GMOs.

Significant multilateral international efforts have been made to address specific concerns surrounding LMOs. In January 2000, the Biosafety Protocol to the Biodiversity Treaty was signed. Known as the Cartagena Protocol on Biosafety, it is the first protocol to the Biodiversity Treaty. Its intent is to provide countries the chance to obtain information about LMOs before they are imported. Moreover, it acknowledges each country's right to regulate bioengineered organisms and provides a framework to help the developing world to protect its biodiversity further. Although the United States is not a party to the Biodiversity Treaty and thus cannot be a party to the Protocol, it participated in the negotiations as a member of the so-called Miami Group, a coalition of leading agricultural exporters that included Argentina, Australia, Canada, Chile, and Uruguay.

While the various treaties and scenarios described above depict potential conflicts, not all international implications of a biobased economy will be filled with peril. For example, consider the implications for job creation. As a raw material, petroleum has considerably more energy per unit volume than biological materials. Thus, it is economical to transport petroleum from its source to distant refineries for processing and then further to ship the refinery products for use as end products or industrial intermediates. With biological materials, however, the economics will not support shipping the raw materials much farther than 250 to 300 miles from their point of origin. Biorefineries will have to be built close to the source of their raw materials. A regionalized

agriculture will likely develop, with certain areas growing specific crops to supply regional biorefineries. Additional processing and manufacturing of value-added biologically based products can economically take place farther from a biorefinery, but there will be limits to the distances involved. The significance is the likely creation of nonfarming jobs in rural areas.

Urbanization in the developing world is often noted as a major issue of strategic concern for the twenty first century. Currently, there are approximately 40 cities in the world with populations of 5 million or more. By 2015, it is anticipated that nearly 25 more will join the ranks. Only 11 of these 65 will be in the developed world. Moreover, the demographic structure of societies in developing countries is heavily weighted toward people 25 years of age and younger. Unemployment among large numbers of young urban males in developing countries is frequently cited as a root cause of the terrorism that we are fighting today. A biobased economy ultimately could help stem the flow of urbanization and provide rural employment opportunities.

### **Domestic Implications**

Just as new international issues will surface as a result of our transition to a biobased economy, new domestic considerations will likewise arise. For example, in the United States, most homeland defense planning focuses on the protection of urban populations and infrastructure, while the safeguarding of agricultural areas does not receive much consideration. Agriculture simply does not enter into the thinking of most people in the developed world. Throughout most of the last century (from about 1930 to 1999), agriculture as a per cent of US employment declined nearly 90 per cent—from 23 per cent to 2.6 per cent. The number of farms declined from 6.3 million to 2.2 million. Agriculture was not even included among the eight critical national infrastructures in Presidential Decision Directive (PDD) 63, “Critical Infrastructure Protection.” Interestingly, however, agriculture is included as a subgroup of the Weapons of Mass Destruction Preparedness Group resulting from PDD 62, “Combating Terrorism.”

In fairness, it has not seemed particularly necessary to include agriculture as critical infrastructure, since croplands have not surfaced as likely terrorist targets. Terrorists usually aim to score immediate to near-term effects by striking high-profile targets. While a present-day attack on field crops could have a large economic price tag, it certainly

would not affect our ability to feed ourselves. Food is plentiful worldwide, and the marketplace easily could meet any immediate or near-term demands. Even with the growing world population, per capita food production has actually increased during the last 30 years from 2,360 calories per day to 2,740 calories per day.

In addition to field crops, farm animals, food in the processing or distribution chain, food at wholesale or retail establishments, and agricultural facilities are all potential targets. Presently, an attack on any link in the chain would result in large economic losses, as well as likely loss of human and animal life. It is estimated that a natural outbreak of foot and mouth disease on just 10 farms would result in a \$2 billion loss.<sup>15</sup> Losses from the 2001 outbreak of foot and mouth disease in the United Kingdom were estimated at \$30 billion. However, if we relied upon agriculture to provide the raw materials for our economy, the potential disruption could be of greater magnitude.

Consider this hypothetical scenario. What if, as the National Research Council report suggests, the US did derive 50 per cent of its liquid fuels from agriculture? As new biotechnologies improve the processing of biomass, ethanol will become an economically viable option, and it will become a larger source of our liquid fuel supply. At that point, destruction of a large portion of US farmlands would be tantamount to an invasion of Kuwait.

The issue of agricultural bioterrorism is complex, but for the purpose of this argument, let us focus solely on croplands. How vulnerable are our croplands? In 1970, without planning or assistance from any organized terrorist group, a naturally occurring epiphytotic, an epidemic in the plant world, destroyed 15 per cent of the US corn crop with an estimated value of \$1 billion. Although we have diversified the genetic base of corn in an effort to avoid another such disaster, crops are still vulnerable to disease. Any number of organisms, including various molds, fungi, viruses, and bacteria, can cause epiphytotics. These organisms are easily grown in laboratories, at no threat to humans, and can be transported worldwide without detection.

At present, crops present a relatively simple target set for anyone wishing to do them harm. The US crop base is fairly uniform, with 8 of every 10 acres planted to just 3 crops: corn, wheat, or soybeans. There is genetic diversity within each crop, offering some disease resistance. Predicting the actual loss for any given attack would be based on several assumptions, as epiphytotics are dependent on multiple variables.

Moisture and temperature are the most complex variables involved and are extremely difficult to predict in any long-term fashion. Nonetheless, well-coordinated simultaneous attacks in many areas, using multiple pathogens, would no doubt result in significant losses.

From a plant protection perspective, the shift to a biobased economy will have some positive aspects, though. To provide new materials for industry, there will be a demand for new genes and their products. If novel genes are found in plants that can be easily grown then their direct cultivation would be the preferred method rather than creating a transgenic with corn, wheat, or soybeans. With direct cultivation, the overall crop base would be broadened and thus provide a more challenging target set for terrorists. Also, the construction of regional biorefineries would complicate targeting more than the current groupings of petroleum refineries.

While a biobased economy will no doubt bring the developed countries the same benefits of slowing urbanization and rural revitalization as anticipated for the developing world, the net effect most likely would be marginal. These will remain predominantly urban societies. As we consider the potential terrorist threat, however, it is important to note that agriculture will assume a greater significance as a potential target.

## **Challenges to the Elements of Power for International Relations**

Converting to a biobased economy will present new but not totally unfamiliar challenges on all fronts. This is not the first time we have developed and used new resources. Nor will it be the first time we have sought to obtain resources from other nations or wanted to trade finished products. None of these changes will happen quickly or without warning. Nonetheless, it is worth considering some possible effects on the so-called "elements of power" that nations have at their disposal when playing on the international stage. These include the diplomatic, informational, economic and military domains.

### ***Diplomatic and Informational Issues***

Already, diplomatic challenges are being presaged by topics such as the Biodiversity Treaty and WTO complaints. Such issues may well become the norm, requiring a diplomatic corps well trained in scientific and technical skills. Water warrants some extended discussion, as it will be

at the heart of diplomatic concerns in the twenty first century, regardless of the world's resource base. A biobased economy, though, may well intensify the issue.

Globally, the renewable fresh water supply has fallen by nearly two-thirds in the last 50 years. During that same period, the human population has increased nearly 250 per cent. Two-thirds of the world's water demands are for agricultural use, and while irrigated agriculture accounts for only 20 per cent of farmland, 45 per cent of the world's food supply is grown on irrigated land. By 2025, it is estimated that nearly 3 billion people—40 per cent of the projected world's population—will find it difficult or impossible to satisfy basic water needs.

The potential international points of conflict over water are also significant. Two or more countries share 261 of the world's rivers. Some 51 countries, within 17 international river basins, are at risk of water disputes during the next decade. An analysis of 1,831 international water-related disputes over the last 50 years revealed that about one-fourth resulted in violence.<sup>16</sup>

Although water will be a problem, it will not be an insurmountable one. In a US study published in 1999 by the National Academy of Science, it was noted that with respect to the future of water in the Middle East, additional supplies could be obtained by using a variety of techniques. Some involve improved management of watersheds and collection of water that now is lost as runoff. Other techniques use current technologies and include wastewater reclamation and desalination. Some of these can be made even more productive and economical with further improvement. Conservation still remains a significant factor in extending water supplies. Between 1985 and 1993, for example, Israel reduced its water consumption by more than 200 million cubic metres per year, almost entirely through improvements in irrigation and water delivery restrictions.

Former US Senator Paul Simon is a strong advocate of desalination. In his 1998 book on the world's coming water crisis, he noted the progress being made in desalination technologies and use. About 11,000 plants are in operation in more than 125 countries. Desalination is most widely used in the Middle East, which accounts for about 60 per cent of the world's plants. In fact, Saudi Arabia built the first modern desalination plant in the late 1930s. To be certain, the economics of desalination are still not competitive, especially for agriculture, but continued development will ultimately drive down the price. That will



be especially true as the price of water from other sources rises.<sup>17</sup>

The informational element of the biobased economy is of particular interest and is worthy of a separate study. It is probably unprecedented that both government and business sources are being required by the general population to provide such large amounts of detailed technical information on procedures and products. This issue will only become more complicated, as non-technical societies will demand data. Additionally, bioethics considerations will have to consider differing cultural views.

### ***Economic Issues***

The economic forces of globalization at work today will not be affected by the biobased economy with the possible exception of urbanization, as previously discussed. Thomas Friedman points out that the driving force of globalization is free market capitalism.<sup>18</sup>

A discussion of agricultural trade may well question how much it follows the rules of a truly free market. Indeed, the recent Doha Round of WTO trade negotiations faltered, in part, over the issue of farm subsidies. Nonetheless, it is anticipated that this contentious issue will ultimately be resolved, and the agricultural sector will represent a more level playing field for those involved in the biobased economy.

Friedman also notes that globalization has its own set of defining technologies, which includes computerization, miniaturization, digitization, satellite communications, fibre optics, and the Internet. Those are the same technologies farmers in developed nations use in a technique called precision agriculture, which enables them to integrate all available data and to make the most efficient and economical decisions concerning a crop. (For example, using data collected from field sensors, a farmer may detect a developing pest problem. Rather than treating an entire field, as would have been the solution in the past, very targeted treatments can be applied, saving time and money.) While over time there may be changes to the world's economic balance of power—as new players emerge as leaders in the biobased economy—it is unlikely that any new technology will create sudden and disruptive changes to the current order.

### ***Military Issues***

Of all the instruments of national power, the military is the one most likely to be affected by a shift in the world's resource base. The

instruments of diplomacy, information, and economics do not require long lead times to research, develop, and acquire the tools of their trade. Nor are the consequences potentially as serious if an initial misstep is made in exercising one of those instruments of power. The international consequences of launching military operations, however, can be long lasting and potentially fatal to those directly involved.

It can be argued that there is less likelihood of exercising the military instrument of power in a biobased economy than in our current petroleum-based economy. That may be true, especially in terms of needing to ensure a daily supply of new raw material—genes rather than oil. Nonetheless, demand for new raw material will remain considerable. Novel genes will be the source of novel products in the biobased economy. While the other instruments of power may play a greater role in securing access to novel genes, national militaries must still be prepared to operate in areas of enduring interest. An important question to ask is whether an army will have the necessary equipment to conduct a forcible entry into an equatorial region to secure the genetic resources contained in a given 5,000-square-mile patch of rainforest. The significance of the question lies in the long lead-time needed for research, development, and acquisition of weapons systems.

Despite the war on terrorism, we are at one of those periods in history in which we are not burdened by pressures of such imminent danger that our very existence is threatened. We have time to ponder the distant future. We have an opportunity to shape our relationships with those countries that will be strategically important in a biobased economy. We have an opportunity to invest in those technologies that will be important to the development of the new economy. Winston Churchill is said to have stopped predicting future events because the future was just “one damned thing after another.” However, as we contemplate the future and the ultimate transition from a geologically based economy, pausing to take stock of the next damned thing—the biobased economy—may prove to be a damned smart thing.

## Endnotes

- <sup>1</sup> Energy INFOcard, accessed at <http://www.eia.doe.gov/neic/brochure/infocard01.htm>.
- <sup>2</sup> Energy Information Administration/Annual Energy Review 2000, “Table 5.12b Petroleum Consumption by the Industrial Sector, 1949-2000,” accessed at [http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5\\_29.pdf](http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5_29.pdf)

- <sup>3</sup> DIGEST, compiled from reports by the Associated Press, Bloomberg News, Dow Jones Service, Reuters, and Washington Post staff writers, accessed at <http://search.washingtonpost.com/wp-srv/wplate/1999-02/10/1741-021099-idx.html>
- <sup>4</sup> Sam Willet, National Corn Growers Association, personal communication, 2002.
- <sup>5</sup> National Agricultural Biotechnology Council, Vision for Agricultural Research and Development in the 21st Century, December 14, 1998.
- <sup>6</sup> National Research Council, Biobased Industrial Products: Priorities for Research and Commercialization (Washington, DC: National Academy Press, 1999).
- <sup>7</sup> Margot Anderson and Richard Magleby, Agricultural Resources and Environmental Indicators, 1996-1997, Agricultural Handbook no. 712, July 1997, US Department of Agriculture, Economic Research Service, chapter 7.1, 7.
- <sup>8</sup> *ibid*
- <sup>9</sup> W.E. Larson and V.B. Cardwell, "Corn Production: A Guide to Profitable and Environmentally Sound Management. Future Expectations," accessed at <http://citv.unl.edu/cornpro/html/future/future.html>
- <sup>10</sup> Section 9003, Biorefinery Development Grants of the Farm Security and Rural Investment Act of 2002, authorizes development grants to build biorefineries to "develop transportation and other fuels, chemicals, and energy from renewable sources."
- <sup>11</sup> "Renewable Resources & Sorona™", accessed at [http://www2.dupont.com/Sorona/en\\_US/home/bio\\_pdo\\_home.html](http://www2.dupont.com/Sorona/en_US/home/bio_pdo_home.html)
- <sup>12</sup> A New Reality for Bioplastics, Nature Works Press Release Nov 21, 2006.
- <sup>13</sup> Products From Plants – The Biorefinery Future, Outputs from the EPOBIO Workshop, Wageningen, and 22-24 May 2006 accessed at [http://www.epobio.net/workshop0605/0605ws\\_finalreport\\_v3.pdf](http://www.epobio.net/workshop0605/0605ws_finalreport_v3.pdf)
- <sup>14</sup> Edward O. Wilson, (1992).
- <sup>15</sup> Floyd and Breeze (1999).
- <sup>16</sup> Robert Toguchi, remarks made at seminar entitled The Role of American Military Power, held by the Association of the US Army, April 2002.
- <sup>17</sup> Paul Simon (1998).
- <sup>18</sup> Daniel L. Friedman (2000).

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