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Biofuel and Biotech: A Sustainable Energy Solution

by

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A commitment to renewable energy production can reduce human causes of climate change and provide a stable energy supply if it is matched with a commitment to innovation in biofuel production and agricultural biotechnology. Agriculture will be challenged to meet increasing food demand and free land for energy production.

Just 150 years ago, 90 percent of U.S. energy was supplied by renewable sources. Today, renewables constitute a mere six percent of energy consumption in a U.S. economy that is heavily dependent on a finite supply of fossil fuels. To address this unsustainable situation, science and society are challenged to develop a long-term strategy to return to renewable sources of energy. Such a strategy should also address fuel price instability and contribute to containing climate change.

Because agriculture is a key source of renewable energy, it has a role to play in the development of a sustainable energy supply. A transition to sustainable energy sources can be expected to withdraw resources from the production of foods, and increase food prices. In the short run, it may end chronic oversupply of some commodities. In the longer run, it may impose pressure on agriculture which must not just feed a world population that is expected to grow by three billion people in the next half-century, but also meet some of their energy needs.

In this article, we demonstrate that while current biofuel production and agricultural biotechnology may not be sufficient to replace fossil fuels with renewable energy, they come close, and subsequent generations of these technologies offer greater promise. We make the case that California should invest in research that will improve these technologies and enable agriculture to meet world food demand and provide renewable energy within the next fifty years.

This is a considerable challenge that requires a serious commitment from the research community. World agricultural productivity will have to more than double in the next 50 years, much as it did in the preceding 50 years. We will not be able to capitalize on the same increases in inputs and factor productivity, however. We will rely, in part, on advances in agricultural biotechnology, which promise to increase crop yield and produce staple crops that can grow on marginal land.

The agricultural community has overcome significant challenges in the past. Agriculture met a six-fold increase in the world population from 1800-2000, with a ten-fold increase in agricultural production. Whereas extensive growth—increases in inputs—made possible such significant productivity gains in the past, growth today will be intensive, relying on total factor productivity rather than increases in land and water, two resources in low supply. Biotechnology offers new opportunities for productivity growth that can delay the onset of decreasing marginal returns.

But the growth of agricultural biotechnology is constrained by regulation and bans that may be politically motivated. These constraints reduce productivity and diminish opportunities to develop

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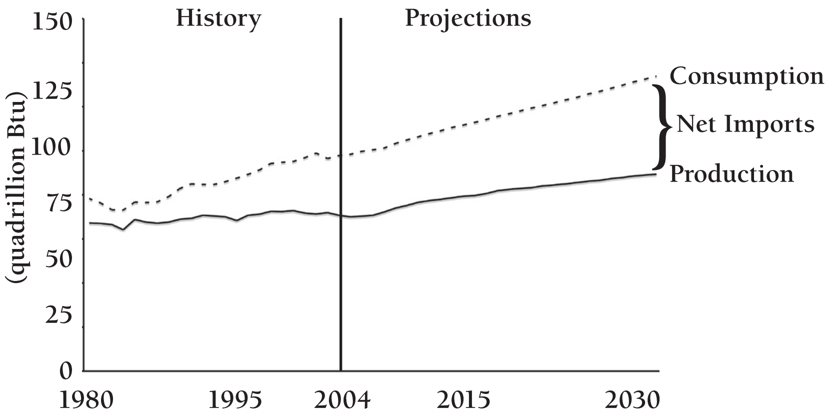
Immigration Reform: What Does it Mean for California Agriculture?

Figure 1: Total U.S. Energy Production and Consumption, 1980-2030



Source: Energy Information Administration

technology. There is evidence that these barriers slow the growth of agricultural biotechnology relative to its potential. They constrain agriculture's ability to address climate change and energy shortages.

In the United States, for instance, the Department of Energy forecasts a growing gap between domestic energy production and consumption, as domestic production lags and demand increases due to a populous that is driving farther and more frequently in bigger cars (See Figure 1). The gap between domestic production and consumption must, of course, be made up by imports. But U.S. oil imports, particularly from the oil-rich Middle East, are becoming increasingly untenable.

Biofuel Offers Hope for Replacing Fossil Fuel

In the field, we see technologies that have the potential to make biofuels a viable replacement of fossil fuels with further refinement of the production process and continued adoption and improvement of agricultural biotechnology. First-generation biofuel technologies can turn corn, sugar cane, and soy into fuel capable of powering cars and trucks. The next generation of these technologies—already being developed in laboratories—are expected to be more efficient.

Already, the technology exists to convert a 56-pound bushel of corn into 2.5-2.8 gallons of ethanol. Sugar is extracted from starchy crops like corn, sugar cane, and sugar beets with enzymes, and then converted into ethanol by yeasts. The ethanol can then be used to power cars that can run on 100 percent ethanol, or a mixture of ethanol and gasoline, or cars that can switch between gasoline and ethanol. Even adding just 15 percent ethanol to gasoline can reduce greenhouse gas emissions by 40 percent. This technology has been widely adopted in Brazil, where 40 percent of automobiles operate on 100 percent ethanol. Not only does ethanol burn cleaner, but it has a higher octane that improves engine performance.

Under current production methods, ethanol costs roughly $0.50 per gallon more than gasoline. The technology is viable when gasoline prices exceed $60 per barrel. There is an element of learning by doing that will improve the profitability of ethanol relative to other fuels. Furthermore, under more aggressive tax regimes, such as a carbon tax, the technology will become profitable. California, for instance, is considering increasing the gasoline tax consumers pay at the pump, moving the effective price of gasoline closer to ethanol.

It has been estimated that if the world community began today to increase ethanol production each year to 34 million barrels in 2056, greenhouse gas emissions could be reduced by one gigaton of carbon. This would require the commitment of one-sixth of the world's farmland to high-yield crops and ethanol production 50 times higher than it is today. In the United States, if all corn crops were devoted to ethanol production, ethanol could replace 20 percent of petroleum consumption. Minnesota, a Corn Belt state, could fully replace fossil fuels with ethanol if it devoted its entire corn production to the effort.

The current biofuel capabilities are encouraging, but they are not good enough. Such crop and land commitments are not feasible. In addition, as demand for biofuel feedstocks grows, food prices are expected to increase, hurting consumers while benefiting producers and reducing farmer subsidies. Agriculture, therefore, has two challenges: develop high-yield feedstocks for biofuel and increase productivity of traditional crops to free land for energy production. The hope is that new technologies will make biofuel production more efficient and improve crop yields, reducing upward pressure on food prices and freeing land for energy production.

The next generation of ethanol production, for instance, will make use of more efficient feedstocks than corn and sugar cane. Corn, in particular, is factor intensive and causes soil erosion. Cellulosic alternatives such as grasses, woody crops, wood waste, and paper, offer several advantages over traditional ethanol feedstocks. They can be grown on marginal land, require little fertilizer or water, and have higher energy content.

Furthermore, because there is considerable land-area potential for cellulosic crops, there is no supply restriction. The United States has 76 million acres dedicated to corn, 12 percent of which is used for ethanol production. Total U.S. cropland exceeds 430 million acres. There is an additional 578 million acres of permanent pasture land that would be ideal for the production of switchgrass, a high-yield crop relatively tolerant to abiotic extremes.

Cellulosic feedstocks are in use in Canada at a demonstration project, but are not commercially produced. The sole barrier to the widespread adoption of cellulosic alternatives is technological, according to members of UC Berkeley's Energy Resources Group. The enzymes needed to convert cellulose are prohibitively expensive and inefficient, but new enzymes that will make this technology viable are said to be forthcoming.

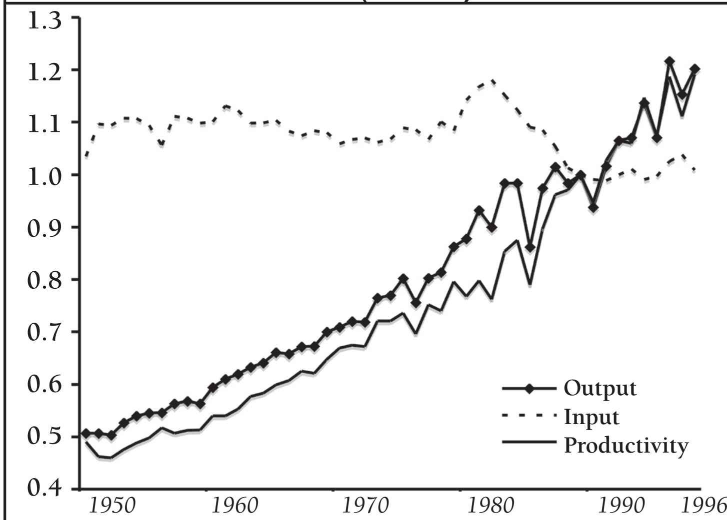
New enzymes that can convert starch to sugar more quickly and efficiently are already in the research pipeline, as well. Scientists are also working to replace yeast with bacteria that are less prone to infection and able to withstand extreme temperatures. Bacteria are less efficient than yeast, but genetic manipulation can resolve that deficiency.

Advancements are also being made to improve biodiesel production, which has traditionally been produced from soy. Once a few technological hurdles are overcome, mustard is expected to serve as a feedstock. Mustard can be grown on land that is worth less than land used to grow corn and soy and can be beneficial to wheat production if used in rotation. Furthermore, mustard is an adaptable crop that can be genetically altered to meet specific needs.

Biodiesel, like ethanol, burns cleaner than its petroleum counterpart and improves engine performance. Through a chemical process that converts vegetable oils, animal fats, and cooking grease to methyl esters, biodiesel has one of the highest energy balances of any renewable energy source. One gallon of liquid fuel yields 3.24 gallons of biodiesel. Petrodiesel, in contrast, produces only 0.83 gallons of diesel per gallon of liquid gas. Biodiesel production is low relative to U.S. consumption. The current generation of biodiesel could only replace 13.3 percent of domestic petrodiesel consumption if all vegetable oils, grease, and animal fats in the United States were employed in biodiesel production, according to a 1998 analysis by the USDA.

Biodiesel does play a key role in greenhouse gas

Figure 2. U.S. Agricultural Productivity: 1948-1996 Index (1987=1)



Source: USDA-ERS: www.usda.gov/nass/pubs/trends/productivity.htm

reduction efforts, however. U.S. EPA-mandated reductions in sulfur emissions require petrodiesel to be heavily refined, reducing the lubricity of the fuel. Adding even two percent biodiesel to petrodiesel can compensate for the lost lubricity.

These ongoing efforts to improve biofuel technology are encouraging and the next generation of biofuels will offer even greater potential to replace fossil fuels. But the most significant constraint on biofuel production remains the availability of land and the productivity of crops used as feedstocks. Transgenic crops can, however, significantly lessen that constraint with their ability to greatly increase yields and reduce costs. They are expected to permit continued agricultural productivity growth as new genetically modified crops are developed. Advancements in agricultural biotechnology, then, will directly benefit biofuel production.

Biotech Can Relieve Pressures on Agriculture

Devoting all U.S. corn production to making ethanol seems unlikely, as does using one-sixth of world crop land for biofuel production, particularly considering other pressures on agriculture like the increasing demand for food from a growing world population with rising income. But in the United States, agricultural productivity tripled from 1950 to 2000 (See Figure 2). And since the 1960s, while the world population doubled from three to six billion, world agricultural production more than doubled, increasing per capita output by 25 percent. These advancements are owed to new irrigation technology, better pest abatement tools, and crop breeding.

With the continued use of conventional technologies and biotechnology, there is potential to increase productivity by another 200 percent in the next several decades. Such growth could enable the agricultural community to continue meeting world demand for food, while also freeing nearly half of all crop land to energy production.

The current generation of transgenics has infused staple crops like corn and rice with the naturally occurring *Bacillus thuringiensis* (Bt), a relatively innocuous, naturally occurring pesticide. These GM crops have increased yield as much as 80 percent and reduced chemical pesticide applications by 70 percent.

Already, the next generation of GM crops is being developed. It will include crops that infuse additional nutrients into staple food sources like rice and wheat. It will produce less input-intensive crops and crops capable of growing on marginal land. It is expected to drive productivity growth and further reduce environmental externalities. It will also likely improve productivity of livestock systems by enhancing the efficiency of foods. The research community must assess to what extent these technological improvements can change supply and demand in the food system and make resources available for biofuel production.

More Research Could Yield Energy Fix

Although the diffusion of biotechnology has been extraordinarily fast by all accounts, there is strong opposition to it. Despite its proven ability to improve agricultural productivity (with particular benefit to poor and hungry regions of the world) and also mitigate environmental externalities, transgenics are criticized by policymakers and environmentalists who embrace the precautionary principle to stall adoption of GM technology. European leaders, for instance, have heavily regulated GMOs or banned them outright, limiting the market for transgenics and therefore the incentive to conduct additional research and development. Switzerland has called for a five-year moratorium on GMOs. And in California, initiatives have been placed on local ballots to ban GMO production within their jurisdictions.

Critics cite food-safety concerns and environmental hazards as reasons for their opposition to GMOs. However, neither concern has been substantiated in the regions of the world where GM crops are used. GM crops are regulated more heavily than conventional crops and more agencies oversee the safety of their food products. Furthermore, genetically altered food crops have been in use for the better part of a century through selective breeding. The new development is the use of recombinant DNA to more quickly alter genetics.

The environmental benefit of increased agricultural productivity is often downplayed and underemphasized. As Norman Borlaug pointed out in 2002, were the United States still employing the technologies of 1940, we would have needed an additional 575 million acres of agricultural land to meet current production. In other words, conventional technology and biotechnology have spared land for other uses equal to the area of the 25 U.S. states east of the Mississippi River. Furthermore, the current generation of agricultural biotechnology has significantly reduced pesticide applications. Monitoring of environmental impacts can continue without impeding growth of the technology.

The energy crisis and climate change call for policies that remove constraints on the expansion of biotechnology, allow the technology to grow, and invest in improving biofuel technologies.

Whereas the federal government, with its latest energy bill and limited approach to global warming, has yet to form a comprehensive response to these two issues, California is poised to be a pioneer in the development of these technologies and a leader in sustainable growth. With its educational-industrial complex—the interconnectedness of government, public research universities, and private entrepreneurs—California has a capacity for innovation unlike any in the world. The birthplace of many technological breakthroughs in the past half-century, from the Internet and information technology to biomedical advancements, California can be a leader in the response to global warming.

Conservation is certainly important and efforts to modify behavior are admirable, but California's contribution to the world should not emphasize reducing emissions and investing in tree-planting campaigns. California's contribution should be more profound than producing corn or switchgrass for biofuel production. Our contribution should be an investment in research, and we should lead with new technologies that will benefit the world and, once and for all, address the related challenges of global warming and energy security.

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