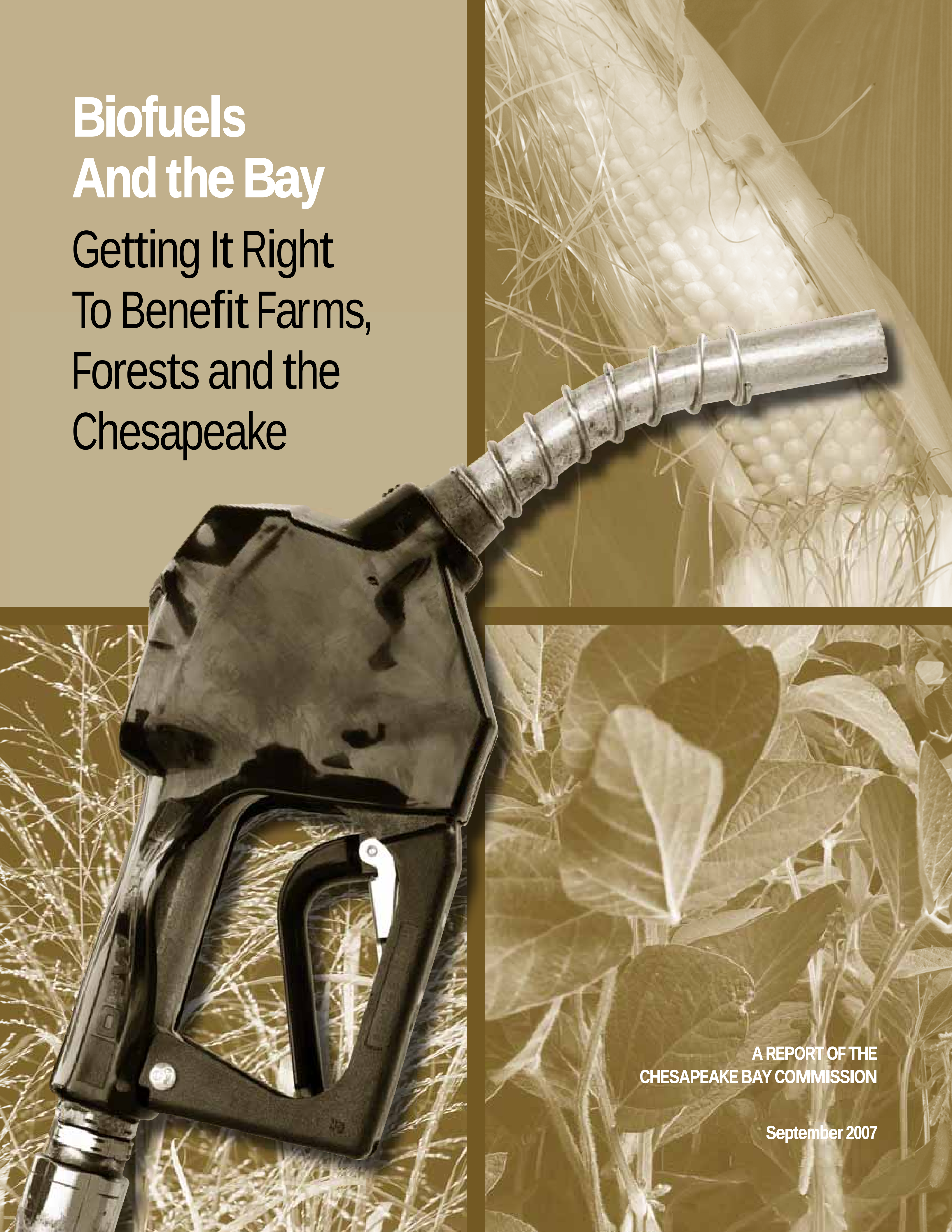
# Biofuels And the Bay

## Getting It Right To Benefit Farms, Forests and the Chesapeake



A REPORT OF THE CHESAPEAKE BAY COMMISSION

September 2007

Chesapeake Bay Commission
*Policy for the Bay*

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# Our Advisors And Reviewers

Throughout its existence, the Chesapeake Bay Commission has borne the responsibility to inform its members and the public on important emerging issues and opportunities for the restoration of the Chesapeake Bay. The following people were instrumental in assuring the accuracy and applicability of this report to our region. We are indebted to their contributions of both time and knowledge and wish to extend our appreciation for their invaluable assistance in the preparation of this report.

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# Introduction

There is a move on in America: a move away from fossil fuels and toward energy conservation, solar and wind power, and homegrown renewable fuels. It is being driven by two major forces which are growing daily in our society — the desire to be independent of imported gas and oil, and the need to deal with climate change by reducing greenhouse gases. Billions of dollars in venture capital are being invested this year in alternative energy technologies, estimated to be double last year's investment, which was double that of 2005.[1]

There is hardly a region of the country where large solar arrays, windmills or use of food crops for energy have not become public issues. Much of the attention is directed at biofuels, a category of energy products using crops, animal and plant wastes, wood slash or other organic sources (commonly referred to as "feedstocks"). Already this movement is having a major impact on agriculture, especially in areas of the country growing corn for ethanol production.

In the Chesapeake Bay region, demand for biofuel feedstocks has the potential to change forestry practices and the mix and volume of crops grown by farmers. Driven by public policies, subsidies, and the boom in venture capital investment, the demand for biofuels could bring about the most profound changes to the region's agricultural markets in the past hundred years. It could also have major effects on the health of the Bay and prospects for its restoration.

Handled correctly, biofuels have the potential to provide significant and permanent new income sources for farmers and foresters, while serving as a means to substantially reduce greenhouse gases and better manage agricultural nutrient loadings within the watershed. Handled incorrectly, biofuels could lead to shifts in crop patterns and acreages that create an uncertain future for farmers and foresters and seriously worsen the overload of nutrients to our rivers and the Bay. The good news is that we know what has to be done to handle it right. ■

# Background

In his January 2007 State of the Union message, President George W. Bush called for domestic production of 35 billion gallons of biofuel by 2017. Allowing for growth, this would represent 20 percent of total fuel consumption for transportation in the United States — an estimated 140 billion gallons of gasoline and diesel.[2,3] An additional 90 billion gallons are projected to be consumed for residential heating, where biofuels could also play a role.

How realistic is this 35 billion gallon goal? By all measures, biofuel production is increasing at an accelerated rate. Domestic production in 2006 approached five billion gallons. In 2005, Congress set a goal for 2012 of 7.5 billion gallons, which is likely to be met this year.

Looking longer term, a report by the 25 X ’25 Alliance, a group setting out a strategy to produce 25 percent of the nation’s energy from renewable sources by 2025, cites a University of Tennessee study that concludes the United States could produce 86 billion gallons of ethanol and 1.2 billion gallons of biodiesel by 2025. An Aspen Institute study set domestic potential at 100 billion gallons of biofuels and a Battelle Memorial Institute report estimated 50 billion gallons as possible.[4]

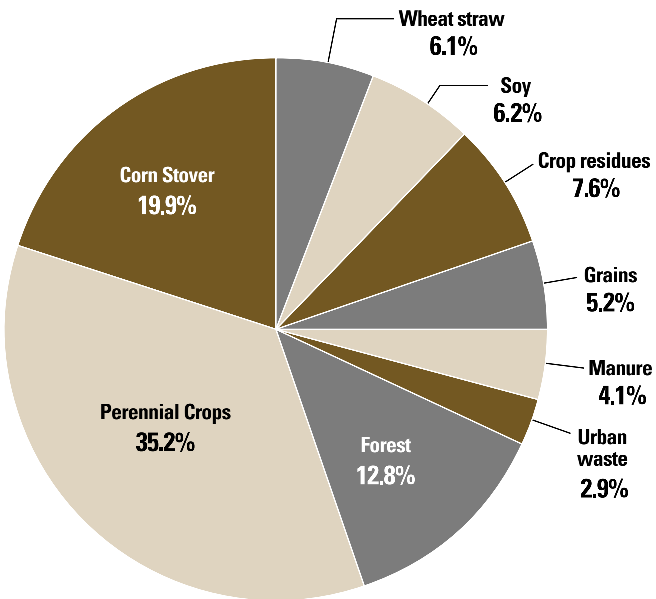
While these numbers might make the President’s goal look achievable, it will not be easy. Nearly all current U.S. biofuel production is corn-based ethanol, which most experts agree has an upper limit of 12–15 billion gallons per year. Factors limiting its growth include competing crops, other valuable uses for corn, federal farm policies and land limitations. Consequently, other sources of feedstocks will need to be part of the bioenergy solution (Figure 1). Although the technologies for using non-grain feedstocks to produce biofuels are still under development, the Administration’s proposals for the 2007 Federal Farm Bill include a new emphasis on research to stimulate these alternatives.

Another important consideration in the growth of biofuels is the current Doha Round of trade negotiations under the World Trade Organization. High crop subsidies in developed countries and tariffs on imports to those countries have become a key focus of the talks. Many ethanol-producing nations have protested the 54 cent per gallon tariff the U.S. has set for imported ethanol. Further adding to the displacement of market forces is a 51 cent per gallon tax credit given to ethanol blenders and a $1 per gallon tax credit to blenders for biodiesel, although these apply to imported as well as domestic feedstocks.

These financial mechanisms, set up to protect American farmers and encourage domestic biofuels production, are the subject of considerable debate. If removed, there may

FIGURE 1
**U.S. Biomass Inventory (2030 Projections)**

Total projected inventory: 1.3 billion tons.




SOURCE: "BIOMASS AS FEEDSTOCK FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY: THE TECHNICAL FEASIBILITY OF A BILLION-TON ANNUAL SUPPLY," U.S. DEPARTMENT OF ENERGY, U.S. DEPARTMENT OF AGRICULTURE, APRIL 2005

be an influx of low-cost biofuels from tropical areas where crops such as sugar cane are more efficient energy sources than corn. While ostensibly helping to address greenhouse gas objectives, this would do little for energy independence, since it would replace imported oil and gas with imported feedstocks and ethanol.

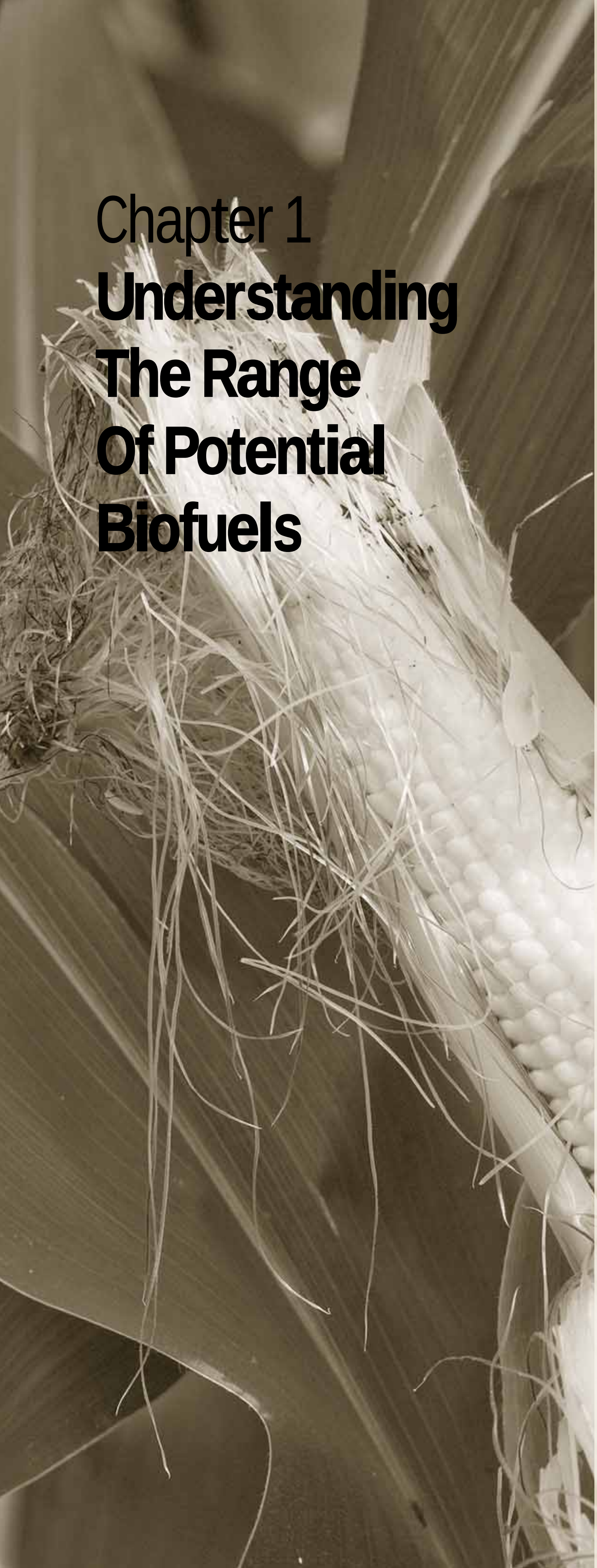
These national and international market forces, while difficult to predict, have a number of implications for the Chesapeake region. In seeking to lay out a "best strategy" for dealing with the effects of biofuels production in the Chesapeake, we must accept that much of what evolves with respect to biofuels is out of our control. Private sector investment decisions and technological breakthroughs, Congressional actions regarding subsidies and other production incentives, internationally set commodity prices, powerful Midwest-based political forces and even international trade negotiations could all have major impacts.

Brazil is often cited as a promising example of biofuel production and consumption. Ethanol, produced from the country's vast acres of sugar cane, now comprises half of Brazil's transportation fuel, and 77 percent of new cars in Brazil can run entirely on ethanol.[5] However, Brazil may also serve as an example of how rapid growth of biofuels can lead to unintended environmental consequences. The demand for sugar cane-based biofuel may accelerate the conversion of other agricultural lands and push grazing farther toward rainforests. Given the role of these vast forests in mitigating global climate change and in providing other ecosystem services, this may represent a major drawback to the continued growth of the biofuels industry in tropical regions.

The goal of this report is to examine how best to couple biofuels production with environmental protection in the Chesapeake Bay region. Key environmental issues of importance to the health of the Chesapeake Bay and its rivers include air pollution, greenhouse gases as they impact sea level change and the water quality effects of elevated nitrogen, phosphorus and sediment pollution from agriculture and other sources. This requires examination of the entire fuel cycle, from extraction or production of the fuel to its transportation, refining, processing and use for a variety of energy generation needs.

The stakes are high and the need to work together as a region is vitally important to our local and regional economies and to our efforts to restore the Bay. Already there is a national debate over the price of corn due to diversion of crops from food to ethanol. Food, feed and fuel dynamics are converging as key issues which can have major impacts to a wide range of stakeholders and businesses across this 64,000 square mile watershed. Given the central role of agriculture and forestry in the watershed, the Chesapeake Bay Commission offers this report as a contribution to the ongoing discussions surrounding biofuels and their potential for our region.

A first priority is to work together to identify opportunities and understand the potential costs and benefits of different biofuel choices. With this understanding, a strategy can be formed to achieve more prosperous working lands and new sustainable markets for our region's farm and forest products and byproducts with no increase, and even a possible decrease, in pollution to the Bay. Without such strategic thinking, the changes that are coming to our farms and forest industries could make the Bay worse off. The time to act on these issues is now. ■



# Chapter 1 Understanding The Range Of Potential Biofuels

There is a growing list of potential feedstocks for biofuels: numerous crops, organic waste products and even algae are being examined for their energy potential. This report provides a balanced view of what is known about the major alternatives. It is organized by type of biofuel, rather than by feedstock; therefore some crops will appear as potential sources of different fuels. For example, switchgrass can be burned on site for heat, potentially converted to cellulosic ethanol or perhaps, in the future, even converted to hydrogen.

This chapter provides an overview of the biofuel technologies most likely to be considered viable in our region in the coming decade, with particular emphasis on the potential environmental effects — both positive and negative — of these alternative energy sources.

## ETHANOL

Henry Ford designed the Model T to run on ethanol, and considered it to be the best fuel because it could be grown and produced anywhere. Since then, the production of ethanol from crops in the United States has been waxing and waning over the decades in response to the price of oil and the nature and amount of subsidies provided by Congress. The recent increase in production was first in response to the need for a non-toxic replacement for the fuel additive MTBE (methyl tertiary-butyl ether, an octane booster), which was found to be polluting groundwater. More recently, there has been a surge in ethanol production driven by the increased cost of crude oil, extension of the tax credit to refiners and the goals in the 2005 Energy Act, reflecting the desire to reduce greenhouse gases from petroleum-based fuels and to reduce dependency on increasingly costly oil imports.

1. Grain-based ethanol has been the source of all U.S. production to date, and nearly all of that has come from corn. One reason for this is that the corn ethanol production process is a scaling-up of well known grain fermentation and distillation processes. Twelve percent of nationwide corn production was used for ethanol in 2006, and it is conservatively predicted to reach 20 percent in 2007.[6] Other grains for ethanol feedstock such as hull-less barley are being experimented with in Virginia, Pennsylvania and on the Eastern Shore of Maryland. There are about 121 full-scale grain ethanol plants in operation in the U.S., and an estimated 72 more are under construction.[7]

While corn-based ethanol is seen as the most viable alternative transportation fuel in the short term, its widespread expansion has been controversial due to concerns over food and animal feed prices, environmental impacts and long-term economic sustainability. Current high profits for farmers and refiners depend in part on state and federal incentives and tariff protection from cheaper sugar-based foreign imports. Because fossil fuels are consumed in the refining process, the net reduction in either greenhouse gas emissions or dependence on foreign oil has been widely debated. The likely maximum yield of corn production for ethanol would fulfill about a third of the 2017 goal, or 7 percent of transportation fuel needs for the country at that time.

Although there are many varied opinions on current market forces, demand for ethanol production has been blamed for the increased price of corn for animal feed as well as the associated higher price of meat for human consumption. The shift to continuous corn from a crop rotation that included grasses and soybeans, as well as increased corn acreage, could have serious environmental implications. Corn uses large amounts of fertilizer and pesticides and is relatively inefficient at using applied nutrients compared to other crops, thus increasing the likelihood of nitrogen and phosphorus runoff to nearby streams and more distant estuaries.

Despite these concerns, there is every reason to expect an increase in corn production for ethanol in the next few years in the Chesapeake region. How much depends on a number of factors, including the price paid for other crops such as soybeans and wheat, which are also rising above traditional market levels. The challenge is to fund and implement sufficient conservation practices so that the increased production of all crops can happen while minimizing potential adverse impacts on the Bay.

Grain-based ethanol is further discussed in Chapter 3.

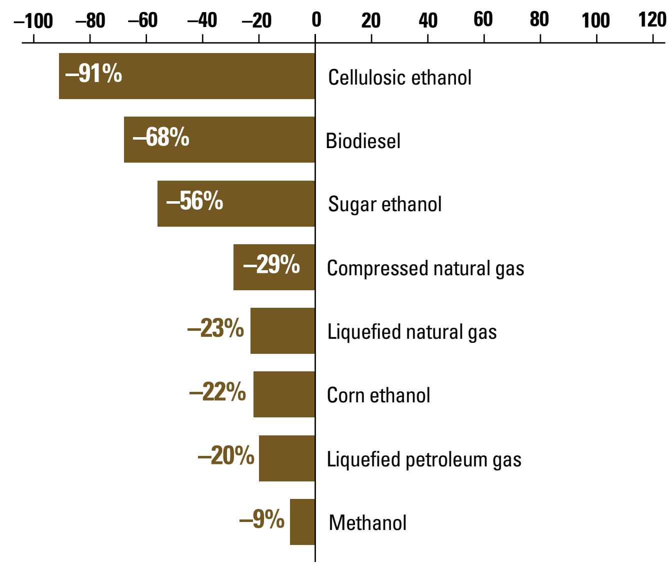
2. Cellulosic ethanol is the alternative to grain-based ethanol often touted as the future of ethanol, but there is not yet a viable commercial technology for its production. Major feedstock sources for cellulosic ethanol include corn stover (stalks and leaves), wood chips, forest slash, fast-growing trees and perennial grasses, all of which appear to have energy value and greenhouse gas advantages over corn (Figure 2). These potential sources have fewer of the land and environmental limitations associated with corn, which gives them the potential to replace a higher percentage of petroleum-based fuels.

Widespread production of cellulosic ethanol is dependent upon technology breakthroughs related to the breakdown of the lignin which binds the cellulose. Two different processes are under development, one using heat and the other, which is receiving the most public and private investment, based on enzymes. The enzyme process has the greatest potential for energy benefits because it does not require fossil fuel in the production process, and the byproducts can be used as a source of fuel for the refinery.

FIGURE 2

**Comparing Fuels**

Estimated change in greenhouse gas emissions if petroleum fuel were to be replaced with one of these alternative fuels. Estimates include emissions from all parts of the process of making the fuels, including fossil extraction, feedstock growth and distribution as well as averaging the different methods of producing the fuels.




SOURCE: ENVIRONMENTAL PROTECTION AGENCY/NEW YORK TIMES

Although increased public and private investments are funding the development of a range of cellulosic biofuels, there are currently no operating facilities in the United States. Presently, a few trial plants are under construction and there is a small facility operating in Canada. The U.S. Department of Energy recently awarded $385 million to cover up to 40 percent of the cost of constructing six cellulosic ethanol facilities with the goal of having cellulosic ethanol cost competitive with gasoline by 2012.[8] The federal government also announced loan guarantees for several large cellulosic ethanol plants, and construction has begun on two in the southern U.S. Additionally, cellulosic technologies are the focus of Administration proposals for the 2007 Farm Bill. However, most experts agree that large-scale operational plants are at least five to eight years off, perhaps longer.

Cellulosic ethanol is further discussed in Chapter 4.

## BIODIESEL

Rudolph Diesel's first engines ran on peanut oil, and as late as 1912 he proclaimed vegetable oils to be the fuel of the future. Petroleum-based diesel did not take over the diesel market until the 1920s, when it became cheaper to produce.

The development of technologies to produce biodiesel fuel has been the focus of a great deal of effort in Europe, but U.S. production was only a few hundred million gallons last year, compared to nearly 5 billion gallons of ethanol from corn. Due to the greater fuel efficiency of diesel engines and higher price of gasoline, the European Union moved years ago to develop modern diesel engines that are more efficient, quiet and powerful for automobiles than earlier models. In the U.S., concern over air pollution discourages their use and development beyond heavy trucks.

Although a large number of European vehicles run on pure biodiesel,[9] in the U.S. biodiesel is blended at 20 percent or less with petroleum-based diesel. Biodiesel can be made from virtually any animal or vegetable oil, including used oil from restaurants, but currently the overwhelming feedstock for domestic biodiesel is soybean oil. Europe is more dependent on canola oil from rapeseed. In the U.S., soybean meal is used primarily for animal feed, and to a lesser degree for food products, with industrial products such as biodiesel a minor use. The oil is used primarily for food but also for many industrial products, including biodiesel. As with corn, soybean prices have been on the increase, in part because of growing U.S. demand for soy for biodiesel production, and in part due to the conversion of soybean acres to corn. Consequently, the economics of soy-based biodiesel are questionable at these current high market prices.

From an environmental standpoint, soybeans use less commercial fertilizer than corn and use it more efficiently. They fix needed nitrogen from the air. Overall, soybeans release to the environment between 50 and 100 percent of the nitrogen per acre delivered by corn, depending on climatic and soil conditions. This range also reflects considerable difference of opinion among experts, with the weight of opinion around 75 percent.

Another consideration is that, in contrast to grain-based ethanol, there is no loss of animal feed associated with the use of soybeans for biodiesel because the residue that is left after pressing the crop for oil is the part used for feed. The real concern for farmers needing animal feed is the rise in both corn and soybean prices.

Biodiesel is discussed further in Chapter 5.

## COMBUSTION AND GASIFICATION

Using a range of existing technologies and feedstocks, it is possible to create heat and gas for use in boilers to generate electricity or for other fuel applications. A number of experimental operations are in place or under construction in the region. The simplest method is burning manure, usually chicken litter, to generate heat and electricity. This energy can then be used to dry other manure and to heat the poultry growing houses. Given the important role of manure to the nutrient balance within the watershed, the Chesapeake Bay Program has recently produced a report examining the opportunities associated with turning poultry manure into energy.[10] There are also experiments with co-generation that use up to 10 percent manure in existing coal-fired power plants. While alternative uses of manure can reduce environmental problems associated with excess manure storage and application, the control of air pollutants remains an important consideration associated with these combustion processes.

With respect to liquid manures such as hog and dairy waste, experiments are underway to capture methane from waste lagoons and convert it to methanol or other biofuel products through anaerobic digestion. Other potential feedstocks include wood wastes and chicken litter. Efforts are underway to develop more biofuels through pyrolytic processes using high temperatures to create bio-oils, gases and hydrogen from chicken litter and other waste products.

Combustion and gasification are further discussed in Chapter 6. ■

# Chapter 2
# Biofuels And Economic Forces In the Bay Region

The economic viability of biofuels is largely influenced by national and international factors. However, local conditions such as site-specific agricultural, economic and geographic circumstances also impact their likelihood of success. In the Chesapeake Bay watershed, there are a number of these conditions that are particularly important. First, we are close to petroleum refiners. This may affect the number of new biofuel production facilities built here more than the availability of locally-grown feedstocks, since feedstocks can be shipped in from the Midwest and even overseas. Second, farms in the region are smaller than the U.S. average and produce more specialty crops than the Corn Belt, receiving only about half of the Federal assistance per unit of production as the rest of the country, measured in crop value.[11] Third, prime farmland for an expanding biofuels industry is comparatively expensive due to development pressures throughout much of the region. However, proximity to markets for food products is a major advantage, as are other relatively low transportation costs. Finally, livestock and poultry production gives a significant boost to the incomes of many farmers in the watershed, and provides a market for corn, soybeans and other sources of feed.

Forestry is another major economic sector with great potential in our region, especially if a growing cellulosic ethanol industry demands biomass feedstock. Pennsylvania is the number one producer of hardwoods in the country, and most of its forests are in the Bay watershed. Wood products are perennially first or second in Virginia in crop value, usually fighting it out for first place with eggs and chickens. Even in Maryland, considered a highly urbanized state, forest products are one of the top ten industries.

There are additional considerations for agriculture and forestry in the Chesapeake Bay region related to the ongoing effort to substantially reduce nitrogen, phosphorus and sediment loadings to tributaries and the Bay. Because the Bay is quite shallow and the land area draining into it is vast, the nutrient overload problems of the Bay are magnified and the effort to cut back on loadings is a Herculean undertaking that has impacts on every land use.

Forests cover nearly 60 percent of the watershed and release far less nitrogen, phosphorus and sediment into waterways than any other land use. The priority challenge in developing forest resources (chips, slash, downed wood) for biofuels is to do so while still maximizing their current roles in nutrient absorption and soil retention.

Agricultural lands cover nine million acres in the Chesapeake Bay watershed. Five million of that is planted in row crops, primarily corn and soybeans. Another million acres is harvested for hay. The rest is pasture, streamside buffers or idle land. Although agricultural lands comprise 22 percent of the watershed, they deliver 42 percent of the nitrogen, 45 percent of the phosphorus and 61 percent of total sediment loadings to the Bay (Figure 3).[12] Major reductions in agricultural loadings are called for by the tributary strategies developed by each state to achieve the Bay's water quality goals (Figure 4). In part, this is because many of the most cost-effective measures for nutrient and sediment reduction are within the agricultural sector.[13]

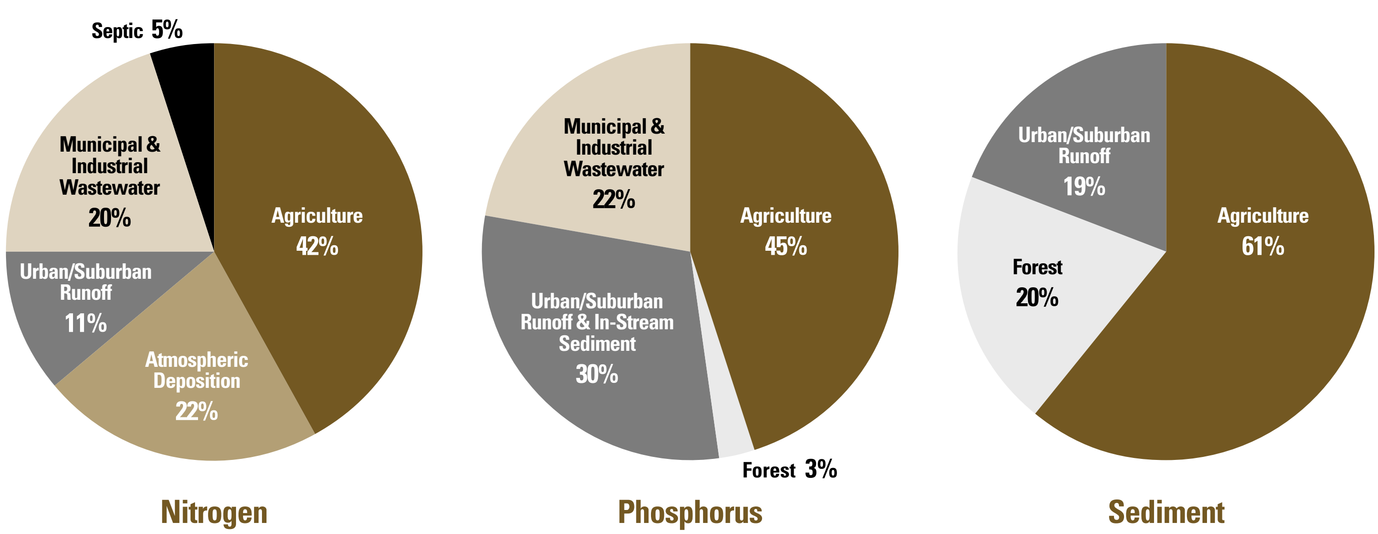
Rapid biofuels development based on increases in local crops for feedstocks could make it more difficult to achieve the Bay's nutrient reduction goals by, among other things, increasing the amount of land in crop production, increasing the use of fertilizer to try to maximize crop production, removing currently protected areas from conservation programs, and changing crop rotation patterns. Of immediate concern is that as demand for corn-based ethanol drives up the price of corn nationwide, there will be continued pressure to plant more acres of corn.

This conversion to corn, at least in the short term, could decrease soybean and other crop production, reduce soil quality, increase sediment and nutrient loading in the Bay and potentially cause the loss of buffers and other conservation practices on farmland. However, as will be shown in the next chapter, it is still unclear how much new corn acreage will be planted. Furthermore, if accepted nutrient conservation management practices are placed on the new and expanded corn acreage, this impact could be substantially reduced. Expanding these "best management practices" (BMPs) to all corn and other row crop acres could actually lead to large-scale pollution reductions in line with Chesapeake Bay goals. However, the Bay states are currently lacking the resources to promote these practices at the levels that this would require.

The region's livestock and poultry producers are apprehensive of the prospect of increased costs of corn feed and both increased cost and decreased availability of soybeans, which will place an economic strain on their operations. In a region such as ours, where meat production is critical to the profitability of many farms, these conditions could be especially troublesome, particularly for poultry. Sixty-five to 70 percent of poultry rations are comprised of corn[14] and, unlike cattle, swine and poultry's use of distiller's grains for feed is limited. The base price of corn is set essentially in the Midwest market, but regional livestock ration costs depend significantly on transportation costs. Locally grown corn is more expensive to grow but cheaper to ship, and comprises 25 to 40 percent of the total poultry feed purchased.[15]

The effect of rising feed costs to livestock producers as more corn is directed to ethanol production may help explain why the Chesapeake region is currently the largest corn-growing area of the country without an operational ethanol plant[16] — we are using our corn locally for feed,

FIGURE 3
**Pollutant Loads to the Chesapeake Bay by Source, 2005**




SOURCE: U.S. EPA CHESAPEAKE BAY PROGRAM OFFICE and refiners are just beginning to think about locating their plants close to petroleum refineries and importing the feedstock. Several ethanol refineries are now planned or under construction in and near the region: $150 million has been proposed for an ethanol plant in the Princess Anne/ Pocomoke area of Maryland's Eastern Shore, a 200 million gallon per year facility is being built near Pittsburgh, an even larger plant is planned for Norfolk (Chesapeake) and two plants are seeking approval for Baltimore Harbor sites. There will undoubtedly be more. And while local corn acreage is on the increase, plants of this size will not be relying on local corn purchases.

The nation's second largest petroleum refining and distribution system is in the Philadelphia area, within ready access for blending biofuels with petroleum-based products. Just as our region's food products have the advantage of reaching 40 million customers within the range of overnight shipping, biofuels can be sent to refineries at a fraction of the cost to other regions. This is especially true of ethanol, which does not lend itself to shipment by pipeline (unlike petroleum, it can be absorbed and ruined by water) and is currently transported long distances by barges, trucks and trains from the Corn Belt.

The combination of all these factors is likely to result in some increase in corn acreage in the region over the next few years. What are the foreseeable environmental consequences of this shift? The answer depends on a number of variables, including estimates of changes in crop patterns, fertilizer use, the characteristics of the land growing the crops, the use of byproducts, and application of conservation measures to minimize surface and groundwater contamination.

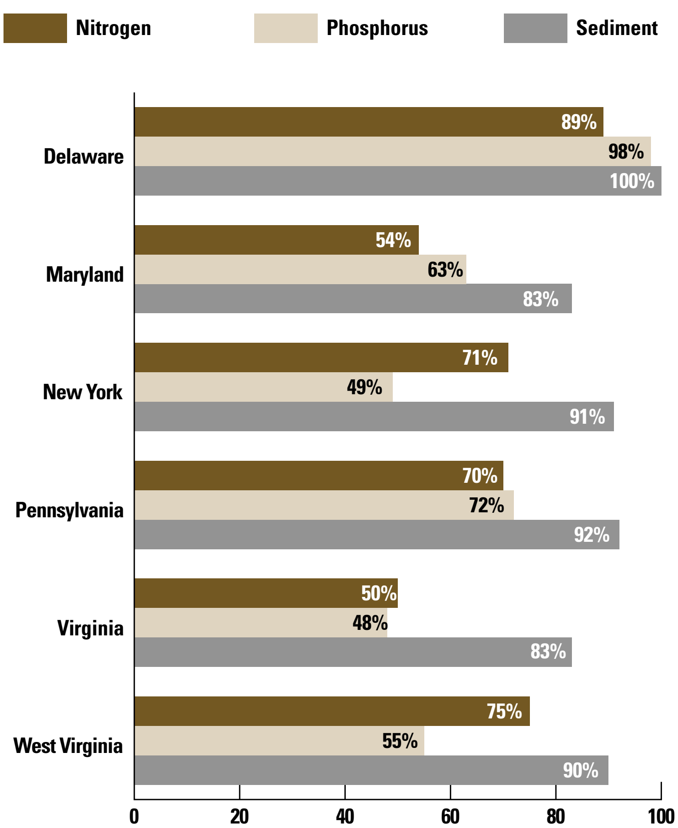
Similar issues face the region with the development of other forms of biofuel. If the region moves to cellulosic ethanol, what is the best way to assure sufficient corn stover is left on the fields for soil nourishment and erosion control? What is the best way to integrate perennial grasses with corn and soybean cropping patterns? What is the impact of converting row crop acres or pastures to energy crops such as perennial grasses? How much manure can safely be applied as fertilizer on perennial grass?

Although it is difficult to predict how the interplay of corn and soybeans will be resolved in the watershed, the consensus of expert opinion in mid-2007 is that corn acres will increase somewhat and soybeans will decrease somewhat over the next few years. The Technical Review Committee assembled for this report reached consensus that the best estimate to use for analysis of impacts would be 300,000 new acres of corn in coming years; this is twice the increase incurred from 2006 to 2007.

In response to a request from the Chesapeake Bay Commission to assist with the analysis in this report, the Chesapeake Bay Program technical staff used data analysis and modeling capabilities to estimate the impacts on nitrogen loadings to the Bay from alternative shifts in cropping patterns for biofuels and on proven management measures to reduce the loadings. The results are summarized in Figure 5, and are discussed in detail in the chapters on alternative biofuels which follow.

In general, the results show that with 300,000 additional acres of corn and at current levels of conservation practices on existing corn acres, there would be about 5 million additional pounds of nitrogen sent to the Bay. To put this in perspective, an additional 5 million pounds per year represents nearly half of the 10.4 million pounds of nitrogen load reductions credited to agriculture over the five year period 2000-2005. Bay Program partners are striving to achieve a 90 million pound reduction in nitrogen loads from all sources. Converting a similar amount of

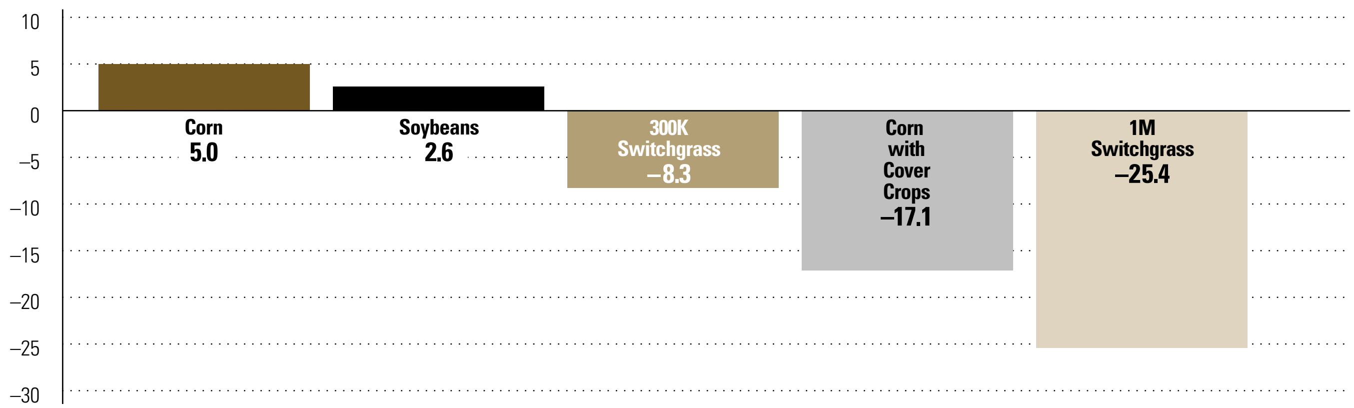
FIGURE 4
**Reliance on Agriculture to Attain State Nutrient and Sediment Reduction Goals**
(2003–2010 Tributary Strategy delivered load reduction)




SOURCE: CHESAPEAKE BAY COMMISISON

FIGURE 5
## Maximum Nitrogen Load Changes for Biofuels

Millions of pounds per year of nitrogen delivered from the Chesapeake Bay watershed to the Bay under five modeling scenarios.




**Assumptions for Alternative Scenarios:**

- **Corn:** 300,000 additional acres of corn with typical levels of management practices
- **Soybeans:** 300,000 additional acres of soybeans with typical levels of management practices
- **300K Switchgrass:** 300,000 acres of switchgrass, converted primarily from hay and pastureland, with no fertilization
- **Corn with Cover Crops:** Cover crops on all existing and new (additional 300,000) corn acres and one quarter of all other row crops, watershed-wide.
- **1M Switchgrass:** 1 million acres of switchgrass, converted primarily from hay and pastureland, with no fertilization

SOURCE: U.S. EPA CHESAPEAKE BAY PROGRAM OFFICE

land to soybeans would also cause an increase in loadings, but it would be about half the amount estimated to come from corn.

The Bay Program estimates also show that the additional loadings can be offset, and existing loadings even substantially reduced, by proven conservation measures. If cover crops were placed on all existing and new corn acres, and other relevant row crops, it would result in 17 million fewer pounds of nitrogen entering the Bay compared to current loadings.

Assuming actions such as comprehensive use of cover crops are taken to reduce the impact of these projected changes in agricultural crops, there are considerable positive environmental and economic benefits of biofuels industry development in the Chesapeake region. Biofuels represent the opportunity to move farming in the region from a chronically low margin sector of our economy into an area of sustainable growth and opportunity. More viable feedstock-producing farms mean continued investment in farm communities, preservation of farmland and increased on-farm resources for additional conservation practices. Wherever they are located, new biofuel refineries will bring investment to their localities and fewer farmers will face the need to sell their land to developers. Thus, we could witness less urban sprawl by maintaining strong farming regions in our watershed. Expanded programs for agricultural best management practices, alternative uses for manure, and ultimately more Bay-friendly crops such as perennial grasses could result. Forestry could also eventually benefit from the additional income of cellulosic feedstocks, thus helping to preserve forests and retain the water quality benefits they provide.

Amid the speculation about biofuels and their impact, the one constant is that biofuel demands and opportunities will grow. This will continue to test our thinking about how existing economic conditions and environmental programs will need to change to meet the times. For example, the economics and markets for biofuels are driving research in new feedstocks and conversion processes that could uncover innovative ways to deal with nutrients, perhaps even using algae as a future feedstock. The next four chapters examine the major biofuel types and the regional challenges and opportunities they raise. ■

Chapter 3
# Grain-Based Ethanol: The Current Focus

Grain-based ethanol, primarily from corn, will be the focus of U.S. biofuel efforts for the next five or more years. This chapter examines the potential economic and environmental implications for the near term expansion in the Chesapeake region of corn production and ethanol refining. It also explores the reasons why, in time, other feedstocks for biofuels are likely to supplement corn and possibly replace it as the dominant biofuel source.

As regional and national demand for corn for ethanol grows, corresponding increases in corn and other commodity prices are expected to lead farmers to put more acres of land into production. Some have expressed fears that this may tempt farmers to increase fertilizer applied beyond levels set by nutrient management plans.

These actions could have a significant effect on nutrient loads to the Bay, possibly offsetting important gains made over the last several years. The scope and severity of the potential risk is based on a number of variables:

- The amount of land converted to corn and other commodity production from other uses;
- The amount of fertilizer applied in light of the new market conditions; and
- The availability of incentives, funds and technical support for Best Management Practices (BMPs) to mitigate increased nutrient loadings.

The amount of land likely to be converted to new corn production for biofuel is a matter of some speculation. To give an idea of how quickly the prospects are changing, there was an increase of 11,000 corn acres in the Bay region from 2005 to 2006. The fall 2006 USDA Prospective Planning Report predicted 139,000 additional new acres of corn for 2007, and current estimates are that at least 160,000 additional acres were actually planted.

Predicting the future trajectory of this production curve was a task given to the Technical Review Committee convened for this report. At the low end, one expert felt the conversion had peaked, and that local drought and market conditions would lead farmers back to more reliable crops. At the other extreme, there were estimates that up to a million new acres of corn might ultimately be planted. After extended discussions and consultations with national authorities, including the Center for Agriculture and Rural Development at Iowa State University, the experts reached consensus on a total of 300,000 new corn acres over the next few years in the region, or about double what has already been added. This takes into account estimates of the value of alternative crops in the same time frame, the availability of Midwest corn sources for regional ethanol refineries, the relative response to date of corn prices in this region compared to elsewhere, and other factors. These acreage estimates do not take into account potential yield gains that could occur through the development of new hybrids, genetically engineered corn or the implementation of precision agricultural practices. While there is the potential for incremental yield gains in our region from these technologies, this would likely not be of sufficient magnitude to reduce corn acreage needs over the short term.

Estimates for additional nutrient loadings depend on assumptions of what the new corn acres were used for previously. For example, if the converted land was previously in soybeans or part of a corn/soybean rotation now shifting to all corn, the change may not be that much, especially if winter cover crops are used. If the new acres come from hay, there will be more nutrient pollution, and even more so from converting pasture to corn, since pasture is not fertilized. Additionally, pasture land is often comprised of hilly terrain which could exacerbate erosion and therefore increase phosphorus runoff.

Scientists and modelers at the Chesapeake Bay Program have made estimates of the likely sources of new corn acres. At the estimated level of conversion, they show much of the new land coming from current soybean acres and haylands.

Corn demands heavy fertilization, more so than most other crops. Corn typically requires application of around 150 pounds of nitrogen per acre. In addition, corn is a relatively inefficient user of these nutrients, consuming only 40 to 60 percent of the fertilizer applied. The remaining 40 to 60 percent, if not absorbed by a winter cover crop or held in the corn residue, moves into groundwater and streams and adds to nutrient overloading in the Bay. Barring conservation management practices, an estimated 20-40 pounds of nitrogen per corn acre is released to groundwater and streams leading to the Bay. It is safe to say that farmland that is converted to corn production from virtually any other agricultural use will have a greater nutrient loading potential to the Bay's waters unless mitigated by added conservation practices.

Each Bay state has recommendations for cover crops, nutrient management, precision agriculture and other best management practices that, if closely adhered to, would serve to mitigate much of these additional nutrient loadings. But to put these practices in place at the volume needed will require levels of technical assistance, outreach and financial support far greater than what is currently available to our farmers.

To begin to understand the implications of both new corn acreage and changes to the traditional rotation cycle (corn-wheat-soybean) in estimating increases in nutrient loadings, Bay Program modelers needed to make a number of assumptions. These are fully explained at: www.mawaterquality.org.

The model projections suggest that if 300,000 acres of new corn are planted in the watershed, about 5 million pounds of additional nitrogen could be added to the Bay. Widespread use of cover crops is an easily modeled example of the management practices currently available to reduce this impact. If universally applied to both existing and new corn acres, as well as about one quarter of other relevant row crops, the model estimates that cover crops would reduce nitrogen loadings by 17 million pounds.

Put into perspective, the 2000 Chesapeake Bay agreement calls for a reduction of 90 million pounds of nitrogen by 2010 to meet water quality standards. Cover crops alone on all current and new acres would achieve almost 20 percent of the reduction goal, even with the expected new corn acres. These findings alone should serve as a basis for action by Bay Program leaders to adequately fund programs to offset the potential impacts from corn production.

While the demand for corn for biofuels (and resulting price pressure on farmers) is already upon us, we must also realize that the increase in corn acres is likely to plateau or even be reversed in coming years. Compared to other, emerging sources of biofuel feedstocks, the long-term growth potential of corn-based ethanol is questioned by most experts for a number of reasons:

- Grain-based ethanol will not likely contribute more than 12 to 15 billion gallons per year to the President's 2017 goal of 35 billion gallons, given other demands for corn, limited land available from other row crops and the supply of land which is not currently in row crops.
- In our region, corn yields are only about 70 percent of Iowa yields per acre. We can increase acres and profits from corn now that prices are high, but we cannot compete as a region when supply catches up and prices drop.[17]
- Corn-based ethanol nationwide is not considered an economically sustainable technology, both because it is dependent on subsidies and tariffs to keep out cheaper overseas sources, and because there is growing scientific consensus that it provides a limited net energy benefit over the energy required to produce it, especially when compared to the likely net energy benefits from cellulosic ethanol.[18]
- Because corn-based ethanol uses fossil fuels for production, it is not a major contributor to the reduction of greenhouse gases. The natural gas consumed in ethanol production is equivalent to almost half of the energy represented by the ethanol produced. To that must be added the diesel fuel used in the fields to grow the corn, the diesel used to haul corn to the

refinery, the energy used to produce the commercial fertilizer used on the corn, etc. Using coal in place of natural gas in ethanol production results in more greenhouse gases than simply burning gasoline instead of ethanol.[20]

- Burning ethanol in cars does not necessarily reduce their pollution. In fact, ethanol at low mixes, as will be the case in the United States for many years until more E-85 (85 percent ethanol-fueled) cars are on the road, actually causes an increase in airborne nitrous oxides, the source of 30-50 percent of the nitrogen already entering the Bay, coming from vehicles, power plants and volatilization from manure.
- The distillers' grain by-product of the corn-based ethanol process can be used as a food supplement primarily by cattle, but has a very high phosphorus concentration relative to corn grain and soybean meal. This could set back the diet and feed advances that are occurring throughout the region to reduce the nutrient content of dairy manure. However, distillers grain may be exported and may also be burned as a fuel, potentially providing a considerable portion of the fuel needs of the production plant.[21]
- The increasing price of corn for food is becoming a worldwide concern. In addition to recent riots in Mexico over corn availability and cost, China has called a halt to new corn-based ethanol plants for food security reasons.

Despite these long-term issues, there is every likelihood that biofuels are bringing a new era of increased opportunities for farmers in the region. Consequently, the Chesapeake Bay states must respond by working with farmers and the alternative fuels industry to ramp up technical assistance and conservation programs in order to ensure that financially stable farms prosper hand-in-hand with clean water. ■

## SUMMARY Findings With Respect to Grain-Based Ethanol

- There will be investment decisions over the next five years or so to build corn-based ethanol plants in the region. The volume and pace of investment will be affected by the availability of corn grain feedstock at a price that promises profitability.
- There will be near-term market pressure to grow more corn in the region — more acres, more continuous corn and more corn per acre. Although some say the market might, at peak levels, bring pressure to apply additional fertilizer per acre, and to convert current buffers, steep pastures, erodible lands and CRP lands to corn, expert opinion is that the increase will stop well short of such effects in this region.
- Due to fertilizer requirements and the relatively inefficient uptake of nutrients, more corn will likely increase nitrogen and phosphorus loadings to the Bay, unless offset by aggressive programs to plant cover crops and put in place other conservation practices. Hull-less barley and canola are two cover crop options which also provide feedstock for biofuels, providing win-win opportunities.
- Despite current subsidies and tariffs, corn-based ethanol is limited by available crop acres and market forces nationwide and cannot contribute more than a fraction of the national biofuels goal. Furthermore, it does little to help greenhouse gases or reduce demand for fossil fuels.
- Without subsidies, corn-based ethanol is not likely a long-term sustainable technology, and plants cannot yet be readily converted to cellulosic feedstock.
- Overall, grain-based ethanol should be considered a short-term windfall for farmers and refiners, a necessary step toward future development of an ethanol industry that includes cellulosic sources, and a stimulus for near-universal cover crops and other agricultural conservation measures to prevent adverse effects on the Bay.

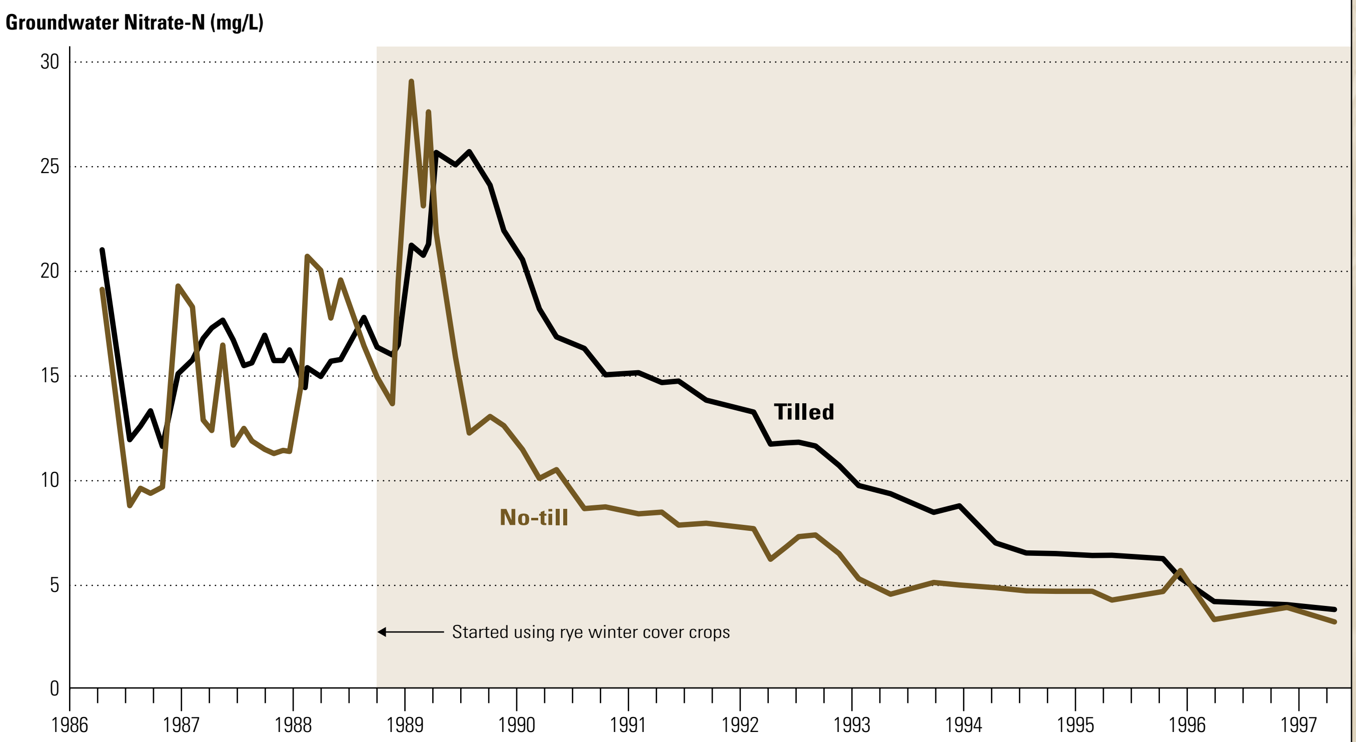
# STRATEGY Making Corn More Bay-Friendly

Growing corn using a full suite of conservation practices can reduce nutrient losses to levels well below those achievable with a Nutrient Management Plan. Ten specific practices that will help reduce nutrient losses associated with corn production are listed below:

1. Eliminate preplant inorganic nitrogen applications. This reduces the period when soil nitrate concentrations are elevated, thereby reducing the risk of leaching and runoff. Readily available techniques exist for applying all nitrogen at planting and after corn is actively growing.
2. Split inorganic nitrogen applications. Corn nitrogen uptake rates are highest later in the growing season. Delaying major nitrogen applications as long as possible minimizes the period of elevated soil nitrate concentrations.
3. Use subsurface application for all inorganic nutrients. This will reduce the potential for spikes in runoff nutrient concentrations early in the growing season.
4. Use no-till or reduced tillage methods. Tillage tends to increase the potential for soil erosion, breakdown soil structure, reduce rainfall infiltration and stimulate nitrification. Spring tillage can increase soil nitrate concentrations early in the growing season, increasing the potential for leaching losses. Loss of soil structure tends to increase the efficiency with which infiltrating

### Conservation Practices Deliver Water-Quality Benefits

Average Nitrate-N concentrations in shallow groundwater under two field watersheds planted continuously with corn at 140 lbs. N/acre, 1986-1997.




SOURCE: STAVER AND BRINSFIELD. J. SOIL AND WATER CONS. 53: 230-240, 1998.

precipitation leaches nitrate downward in the soil profile. Benefits of reduced tillage must be balanced against potential problems with surface applied organic wastes (see #5).

5. Incorporate organic wastes. This will reduce the potential for elevated levels of dissolved nutrients and other pollutants in surface runoff and will reduce the need for additional inorganic nitrogen applications because ammonia volatilization will be minimized. Erosion potential will be increased, which could be problematic on highly sloping land but reduced tillage strategies are available for incorporating wastes.

6. Delay tillage and spring burn-down of cover crops or weeds. Tillage tends to stimulate nitrification. Tillage and herbicide applications eliminate nitrate uptake capacity of weeds and cover crops. Maintaining plant nitrate uptake capacity suppresses soil nitrate concentrations and the potential for nitrate leaching.

7. Plant cereal grain winter cover crops as soon after fall harvest as possible. Even when yield goals are met, soil nitrate concentrations tend to increase in late summer and early fall after corn nitrogen uptake has stopped. Rye is the most effective of the winter cover crops for planting after corn but if planted early all the winter cereals can remove most of the nitrate from the root zone before winter. Without cover crops it is highly unlikely that nitrogen reduction goals can be met for agriculture whether or not corn production increases.

8. Manage soil P concentrations at minimum levels needed for optimum crop production. Phosphorus losses tend to increase with increasing soil P concentrations. This is not specific to corn production but organic wastes often are used as a nitrogen source for corn. Managing excess P in organic wastes will require farming system and regional approaches.

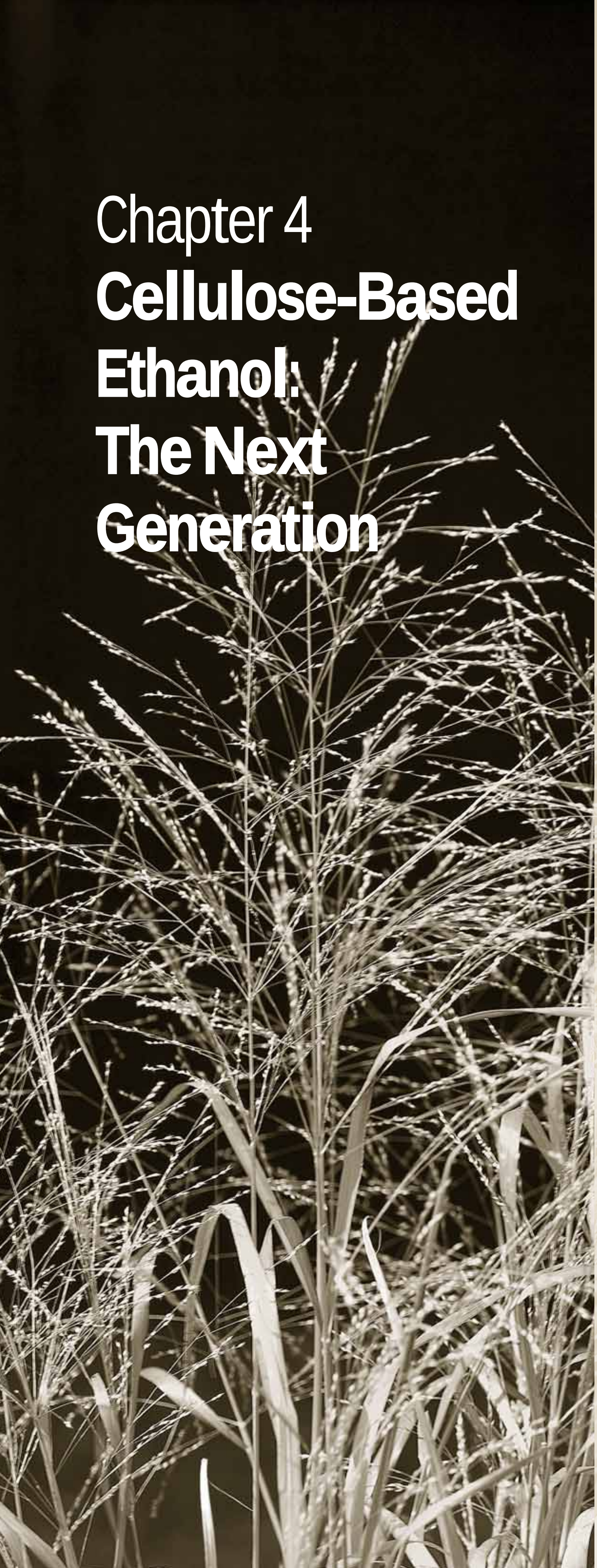
9. Establish grassed waterways. Areas of concentrated surface flow in fields are prone to erosion and the loss of a high percentage of applied nutrients. Establishing grassed waterways minimizes channel erosion, removes larger sediment fractions from surface runoff, and minimizes the potential for transport of dissolved nutrients applied to areas of concentrated flow.

10. Establish riparian buffer zones. Minimal buffer zones adjacent to surface waters can reduce the inadvertent application of both inorganic and organic nutrient sources directly to waterways. Wider buffer zones can remove sediment and nutrients from surface runoff if flow is not highly channelized. Deep rooted grasses can remove nitrate from shallow groundwater in riparian zones where water table depth is not excessive.

The relative importance and effectiveness of these ten practices in the short term will depend on local site conditions and weather patterns. Very coarse-textured soils, steeply sloping fields, irrigated fields, and fields that are tile-drained will require the most rigorous approaches to reduce nutrient losses. But used collectively these practices have the potential to reduce long-term nutrient losses associated with corn production to well below current levels without major reductions in production. Thus far in the Bay restoration effort, erosion control and nitrogen application rates have been the only water quality aspects of corn production that have been addressed in a comprehensive manner. Although these were logical first steps, they were insufficient to achieve nutrient reduction goals. Clearly, a more comprehensive approach will be needed to meet nutrient reduction goals for agriculture whether or not corn production increases.

SOURCE: KEN STAVER, UNIVERSITY OF MARYLAND, WYE RESEARCH AND EDUCATION CENTER

# Chapter 4
# Cellulose-Based Ethanol: The Next Generation



According to the Department of Energy, the key to making ethanol competitive with gasoline is to obtain low-cost biomass from a variety of cellulosic feedstocks, and to develop an enzyme-based conversion technology that cheaply and effectively separates cellulose from the binding lignin.[22] If this can be done, cellulosic ethanol appears to be the preferable option for both farmers and biofuel producers.

Cellulosic ethanol addresses nearly all the concerns currently raised against grain-based ethanol. Cellulosic feedstock could be safely grown on marginal farmland or forest acres. It would have far less impact on food supplies or prices. It would require less energy to produce and would result in far lower greenhouse gas emissions — up to 90 percent less than gasoline. Its feedstocks would build on vast renewable resources of what currently are, in some cases, waste products. It would have less adverse impact on water quality and could actually reduce nutrient loadings in some circumstances. It would provide a permanent new income source for farmers and foresters and would have almost unlimited capacity to replace gasoline.

The biggest challenge we face with cellulosic ethanol is time. The technology to produce cellulosic ethanol is estimated to be five to eight years away. Meanwhile the U.S. will continue investing in grain-based refineries with little planning for how the refineries could later be converted to process cellulosic feedstock.

Cellulosic ethanol will not solve all of America's energy problems, or even all of the problems associated with ethanol production. Imported feedstocks may raise issues of destruction of tropical forests for new cropland. Transport of ethanol will still be primarily by trains, barges and trucks, with their attendant pollution and fuel consumption. And use of forests and marginal lands to grow cellulosic feedstocks will require care to protect the land and water quality.

In many respects, the Chesapeake region is at an advantage in preparing for the emergence of cellulosic ethanol. We are the corn-growing area of the country that is the least invested in grain-based ethanol. We are concerned about protecting the profitability of our poultry industry in the face of rising corn prices and our transport costs to energy and food markets are relatively low. Our farmers are committed to control nutrient runoff from their lands and understand the implications of crop decisions on our rivers and the Bay. Additionally, we already produce a number of potentially profitable cellulosic feedstocks.

However, progress in this direction could be slow, given the technological barriers involved. The trick is figuring

PHOTO © DAVID HARP, CHESAPEAKE PHOTOS

**Ken Staver wades through decade-old research plots at the University of Maryland, Wye Research and Education Center, used to evaluate nutrient uptake ability and biofuel potential for switchgrass.**

out how to inexpensively break down the lignin that binds the cellulose fibers. Once unbound, the cellulose can be converted to sugar and then fermented into ethanol. Most efforts are focused on finding the right combination of enzymes to attack the lignin. These efforts are far reaching, ranging from investigation of jungle rot fungi from the South Seas, termite digestive enzymes, and even a fungus from Russia now used to fade new blue jeans.[23] Any lignin remaining from the ethanol conversion process can be used to generate power or electricity for the plant itself or for sale to the grid.

The net energy used to produce cellulosic ethanol is potentially less than zero, if the replaced electric generation is factored in.[24] If the technology can be developed and the region is able to build the infrastructure to produce, handle and deliver thousands of tons of cellulosic feedstock produced annually, the Chesapeake watershed could see tremendous benefits to farmers and other sectors of the regional economy.

There are at least three major potential regional sources of the cellulose feedstock:

Corn Stover: The most available source is corn stover — the stalks and leaves left after harvest. The stover remaining on the field has value to the farmer as a soil amendment and as protection against soil erosion. Thus, there is concern that diverting stover to cellulosic ethanol production could create erosion and soil structure problems. Additional research is needed to determine the optimum split between field needs and use of the remainder for ethanol production. The USDA Renewable Energy Assessment Project is examining this specific issue for our region.[25] These studies should also consider off-setting practices for partial stover removal such as cover crops, crop rotation and no till. There is a newly operational ethanol plant in China using stover that should be monitored for results.

Forest Slash, Chips and Fast-Growing Trees: The second source that has enormous regional potential, but about which less is known, is related to wood products. Forest slash consists of the branches and leaves that remain after the logs are removed. Sixteen percent of wood is slash, amounting to 49 million tons produced in the U.S. in 2004.[26] Accessing and collecting this material has been the major obstacle to date, but technologies are emerging. John Deere is marketing a slash bundler which compresses the branches and leaves into large "logs" that can be transported on regular logging trucks.[27] Advanced Biorefinery, a Canadian firm, is designing a modular system that can be transported to the forestry site and set up there to convert the slash to fuel and then truck it to the petroleum refinery.

There are 24 million acres of forests in the Chesapeake watershed and forestry is a major industry in the region. In clear-cut pine areas of the southern watershed, some slash is chipped and sold. In areas of selective cutting such as some hardwood forests, residual slash can become a fire hazard, but it also provides wildlife habitat. As with stover, there is a need to establish a desirable level of slash to be left for nutrients and to control erosion, especially in clear-cut areas. The remainder could then be directed to ethanol plants.

Some cellulosic facilities could use locally produced wood chips as part of the cellulosic mix. These can be supplied through urban tree management programs or wood-consuming industries. Feedstock can also be produced from fast-growing trees planted in buffers or other uncropped farmlands. Along these lines, attention is being given to poplar and willow species, especially in the northern parts of the watershed.

**Perennial Grasses:** As an innovative crop source for cellulosic ethanol, nothing has received as much attention as switchgrass, a native perennial grass that establishes deep roots, absorbs fertilizer more efficiently than corn, and produces substantially more energy per acre. On the downside, switchgrass produces its first crop in the second year, and a third is needed to reach full potential yield. For this reason, if new switchgrass acreage is displacing an existing income crop, then farmers need to make up lost income for the two years it takes for an established switchgrass crop. But, switchgrass can also be planted on less costly marginal lands, storing carbon, trapping nutrients and preventing erosion.[28]

There is some question as to whether regionally-produced switchgrass and other perennial grasses would benefit from the use of at least some fertilizer (excluding areas adjacent to stream buffers and other sensitive land). If production is improved, then manure could be a source. In fact, because switchgrass is a highly efficient user of nutrients, it might serve as part of the strategy to manage the excess manure produced in the watershed. Assuming placement of 100 pounds of nitrogen per acre on switchgrass, 70 to 90 percent will be absorbed; corn typically uses 150 pounds per acre and is only 40-50 percent efficient, requiring nutrient management practices to prevent the rest from entering streams and the Bay.[29] More scientific investigation is needed to determine just how much manure switchgrass can safely absorb under various conditions. And it may make the most sense to use switchgrass as an unfertilized buffer around fields, fitting into the landscape in a mosaic with existing croplands and even suburbanizing lands, serving as a sink for excess nutrients.

To provide preliminary information on what a substantial number of new acres of switchgrass could mean to the watershed, modelers at the Chesapeake Bay Program provided estimates of nutrient loadings for this report. The results are included in Figure 5 (page 12) for two levels of production: a mid-range projection of 300,000 acres, which allows comparison with the other feedstocks analyzed, and a more aggressive scenario using one million acres, which represents projected maximum potential production over a longer time frame. As with the corn estimates, a number of assumptions were made about where the new acres came from; if they are converted from corn, they would have a more beneficial impact than if they consumed existing stream buffers. Most experts believe that farmers will not convert rowcrop acres to switchgrass, but will use pasture, hayfields and other lands. The modeling and related analysis were therefore configured to take only six percent of the acreage from such row crops in the 300,000 acre switchgrass scenario, and 23 percent of row crops in the one million acre scenario. It was also assumed for the scenario that no fertilizer was placed on the switchgrass acres.

The estimated environmental benefits from converting agricultural land to switchgrass were indeed impressive. As also shown in Figure 5, there would be a reduction in nitrogen loadings to the Bay of between eight to 25 million pounds compared to current levels, depending upon the assumed acreage of switchgrass that is planted.

Because switchgrass can be relatively benign as far as nutrient pollution, there is some talk of growing it to replace seasonal grasses, and in swales and other sensitive areas. While more studies must be done to determine the most economically and environmentally beneficial patterns of row crops and switchgrass, some are concerned that the lands chosen for switchgrass might include forested and grass buffer areas or acreage currently protected under various land retirement programs, such as the Conservation Reserve Enhancement Program (CREP).

Other sources of grass-like feedstock include wheat stems and hay. One grass species that has received a lot of attention is *miscanthus*, a family of fast-growing tropical grasses, with one native species growing in temperate zones of Asia outside of the zone of heavy frost.

However, none are native to North America. This species grows up to 11 feet in one season and produces heavy yields.[30] While *miscanthus* is now grown in Europe, there is little U.S. experience. Still, it is a tempting alternative as it is estimated to produce twice the biomass per acre than other grasses and use less water, making it drought tolerant and easier to handle and convert to ethanol.

The examination of *miscanthus* and other tall grasses raises the interesting question of the utility of *phragmites* as a source of cellulosic ethanol. *Phragmites,* an invasive reed from Europe, has taken over wetlands throughout the tidal areas of the Chesapeake and forms vast fields of thick roots, crowding out all other plants. The value of *phragmites* as a cellulosic feedstock should be considered along with others, including an analysis of the impact of large-scale harvest of the species.

With our supply and transport advantages, the Chesapeake region could play a major role in cellulosic ethanol production once the technologies are commercialized. Given the environmental, economic and energy advantages, cellulosic ethanol appears particularly attractive for the region. How the transition from grain-based to cellulosic ethanol will occur will depend on which crop emerges as the best cellulosic feedstock. Most experts believe that if stover is a primary source, there will continue to be reasons to plant a large acreage of corn. If it is switchgrass, then there will likely be little impact on rowcrop acres, and the switchgrass acreage will most likely be woven into and placed around the rowcrops; thus providing its own environmental benefits. If it is wood-based, we may see more acres of small, fast growing wood species like willow and poplar emerge. ■

## SUMMARY Findings With Respect to Cellulosic Ethanol

- The technology is still under development, and operational refineries are at least five to eight years off.
- Cellulosic feedstocks, if properly managed, could consume vast volumes of underutilized and waste products in the region — corn stover, forestry slash and possibly even *phragmites*.
- At the same time, there are soil and nutrient retention roles played by stover and slash which need to be maintained, thus reducing the volume available for ethanol.
- There is the potential for switchgrass to be woven into the landscape in such a way that it surrounds crops that are less efficient at using nutrients, thereby absorbing some of the excess nutrients and reducing loadings to rivers and the Bay; switchgrass may also be a safe sink for manure.
- Switchgrass takes three years to grow to full capacity, requiring ways to deal with potential short-term income loss to farmers if they are planting it on income-producing land.
- Even with breakthroughs in cellulosic conversion technology, the financial returns from switchgrass and other cellulosic feedstocks will not necessarily be competitive with the returns from traditional crop production, including corn for ethanol.
- Overall, cellulosic ethanol offers a promising source of additional income for farmers and foresters beginning 2012–15, and can be managed to help reduce nutrient overloads to the Bay.

# Chapter 5
# Biodiesel: The Past Returns

Biodiesel technology has been around for well over a hundred years, and was the dominant source of diesel fuel into the 1920s. Biodiesel is made from new or used vegetable oils and animal fats which are chemically reacted with an alcohol, usually methanol. Besides producing biodiesel for fuel, the process also produces glycerol which can be sold for cosmetics and other uses. About 55 percent of the current biodiesel production can come from any fat; the rest is limited to vegetable oils, the cheapest of which is soybean oil.[31]

Data on the environmental impacts, economics and energy efficiency of biodiesel are variable, but there is reasonable consensus on a few key points. From an environmental standpoint, biodiesel is biodegradable, non-toxic and when burned creates 60 percent less net $CO_2$ emissions than petroleum-based diesel.

Biodiesel is currently more expensive than domestic petroleum-based diesel, but it is cheaper in parts of Europe. In the U.S., biodiesel is blended with petroleum-based diesel, with the B number (B10, B20) indicating the percent biodiesel. The energy content of biodiesel is about 90 percent that of petroleum-based. Soybeans comprise 90 percent of the current U.S. feedstock, but many believe that there are better alternative crops that would increase production in the region without major acreage increases. For example, in Europe rapeseed (canola oil) is used more widely and produces almost three times as much energy value per acre as soybeans.[32]

The National Biodiesel Board estimates 2006 production at 260 million gallons, and estimates current annual production capacity at 865 million gallons. The Department of Energy estimates near-term potential production capacity of 1.9 billion gallons per year. Even at this optimistic level, 1.9 billion gallons would account for less than five percent of national transportation demand. Current constraints in the Chesapeake region include the high price of soybeans, and limited processing facilities.[33]

The biodiesel debate centers around the net energy gain from production. Conclusions drawn from the literature cannot be made at this time. There is agreement, however, that compared to petroleum-based diesel, particulate emissions are reduced, but NOx emissions are higher. In the Chesapeake region, where airborne NOx is a major source of nitrogen loadings to the Bay, more research is needed to accurately determine emission levels and potential reduction and control measures.

Biodiesel plants can be built anywhere, but given the high cost of feedstock and transport, locations near the soybean acreage make sense. However, the Bay region's first large-scale plant, currently under construction at

PHOTO © DAVID HARP, CHESAPEAKE PHOTOS

**James Warren, President of Cropper Oil and Gas of Berlin, Md., inspects a beaker of biodiesel fuel produced by blending soybean oil with reprocessed vegetable oil.**

Baltimore Harbor, is planning to use 100 percent imported soybean oil from Brazil. Since the $1 per gallon Federal subsidy is currently paid to the fuel "blender" (the plant owner) and not to the feedstock producers, it is currently more economical to import from Brazil than to use local soybeans brought by truck or train. Another proposed Baltimore plant plans to use chicken fat purchased from the local poultry industry  Given the proximity of the Chesapeake region to markets and refining facilities, there should be some economic advantages to building biodiesel plants here.

Assuming that there could be demand for more soybean acres, what would be the effect on the Chesapeake? Scientists at the Chesapeake Bay Program undertook an estimate of nutrient loadings similar to that described previously for corn. The results were provided in Figure 5 (page 12). If 300,000 acres of new soybeans were planted in the watershed, the increase in loadings of nitrogen to the Bay are estimated to be 2.6 million pounds. This assumes the soybean acres come primarily from pasture and idle lands, with some conversion from row crops. The soybean impact is about half of the impact of the same number of acres of new corn, which is in the mid-range of scientific opinion.

Alternative biodiesel crops such as rapeseed (canola oil) can be grown throughout our region and serve as a winter cover crop as far north as southern Pennsylvania. It is clear from the list presented in Figure 6 that there will be a great deal of competition for biodiesel feedstock from highly productive oil crops, especially in tropical nations. Although many of these cannot be grown in the Bay region, the movement toward these alternatives will affect demand for and prices of soy and other regionally-produced feedstocks.

Algae as a feedstock warrant some noteworthy attention. Research on the use of algae ponds to feed biodiesel plants is still in the early stages. One study estimates that algae-based systems would require only 0.3 percent of the land area of the U.S. — much of it in the desert — to meet all U.S. transportation fuel needs and the residuals could be processed into ethanol.[34] Significant for the Chesapeake region, there is some potential to grow the algae at sewage treatment plants. We are aware of one pilot plant operational in New Zealand. However, for algae-based biodiesel production to take hold in our region there must be considerably more study. ■

FIGURE 6
**Biodiesel Production Capacity**

Biodiesel yield per acre (in gallons).

| Crop | Gallons per Acre | Crop | Gallons per Acre |
|---|---|---|---|
| Corn | 18 | Rapeseed (canola) | 127 |
| Cotton | 35 | Pecans | 191 |
| Soybeans | 48 | Avocado | 282 |
| Coffee | 49 | Coconut | 287 |
| Rice | 88 | Oil Palm | 635 |
| Sunflowers | 102 | Algae | 5,000 |
| Peanuts | 113 | | |

SOURCE: WITH PERMISSION FROM THE GLOBAL PETROLEUM CLUB, www.wikipedia.org/wiki/biodiesel,

## SUMMARY Findings With Respect to Biodiesel

- While biodiesel is unlikely to be as large a source of biofuel as ethanol, there are a wide variety of possible feedstocks in this area — most likely soybeans, canola and poultry fat.
- At the present time the cost of soybeans and limited crushing capacity are holding down regional biodiesel production.
- Any substantial increase in soybean acreage will have some negative impact on nutrient loadings to the Bay unless it is converted from corn. But like corn, the acreage converted could include forests, buffers, and CREP lands.
- There is a nascent effort to investigate the use of sewage treatment plant basins for the growth of algae to produce biodiesel on a highly concentrated basis. Given the extent of such facilities in the region, this could have a high potential.
- The long-term future of corn ethanol could result in the conversion of corn acres to soybeans for biodiesel; more likely those acres will be kept in corn for the grain ethanol, with the stover used for cellulosic. Another possible scenario is to return to more corn/soybean rotations.
- Overall, biodiesel production provides a potential but unlikely source of future extra income to farmers; its impacts on the Bay depend on the feedstock used, the ability to use BMPs to reduce nutrient loadings, and the relative loadings compared to corn or other preceding uses of the acreage.

Chapter 6

# Combustion And Gasification: Acting Locally

A developing set of technologies utilizes combustion, anaerobic digestion and gasification to generate energy from manure and other feedstocks. The focus in our region is primarily on using manure, especially poultry litter. Many counties in the Chesapeake watershed produce more manure than can be safely used on crops, creating the need for alternative uses. The goal is to find uses for manure that are more valuable than applying it on the land in place of formulated commercial fertilizer.

These new uses are still in the formative stages. Purdue currently operates a plant that pelletizes chicken litter and sells it as fertilizer to golf courses and for agricultural purposes. Allen Family Foods is supporting a processing plant that turns chicken waste into feed.[35] But many alternative uses under consideration involve energy production through combustion or other processes. Investigations are still underway and much of the information in this chapter should be considered preliminary.

**Combustion:** The simplest biofuel is created by taking organic material and burning it. This could be a small scale operation, for on-site heating of poultry houses and farm buildings in winter, and to generate power year round. Surplus power could then be sold to the grid. The required investment to set up such an operation is currently beyond the reach of most farmers. Air emissions, especially NOx and particulates, present a significant dilemma for these small, on-site facilities. However, if net emissions can be reduced as a result of sharing the power grid, then such facilities should be allowed to operate.

Pollution controls are expensive and combustion units for poultry litter and manure have a tendency to corrode and foul. Options for cleaner burning sources or combinations of feedstocks are being explored. As an alternative to chicken litter, bales of switchgrass are being burned at the University of Maryland Harry R. Hughes Center for Agro-Ecology, Inc., as part of a project to provide heat to several buildings while analyzing costs and effects.[36]

Manure can also be used in co-generation facilities, combined with grasses or coal. Air pollution is still a concern with these larger scale facilities, and transportation costs for the manure must be factored in. The USDA National Energy Technical Laboratory in Morgantown, W.Va., is researching alternative ways of using manure and other bio-feedstocks with coal, including the possibility that the ammonia from litter will combine with nitric acid from coal and create inert nitrogen and water. Burning switchgrass in coal fired plants to generate electricity is also proposed (about five percent of total plant feedstock) and is said to be carbon neutral and non-fouling. It reduces overall $SO_2$ and NOx and helps meet the plant's regulatory requirements. Notably, some experts believe that *miscanthus* can be used at a 50-50 ratio in current coal plants. All these undertakings have yet to reconcile the technical, environmental, economic and regulatory considerations.

**Anaerobic digestion:** On-site small-scale facilities have also been proposed to use anaerobic digestion processes. Smithfield Foods recently announced a plan to capture methane from hog waste in anaerobic digesters and use it in boilers for heat. Various digestion technologies have been developed over the years, but they have had limited economic success. Perhaps the most successful effort in the region is in Pennsylvania, where, according to the National Association of State Departments of Agriculture Bioenergy Feedstock Report, anaerobic digesters have been placed on more than two dozen farms in the state in the past three years, with excess energy sold back to electric companies.

Another application under consideration is the use of anaerobic digesters to replace fossil fuel consumption in the grain ethanol production process. These digesters would process the manure generated from dairies or feedlots co-located at grain ethanol plants, where animals would be fed the wet distillers grain that is a byproduct of the corn-to-ethanol process. The methane from anaerobic digestion of the manure would be used to power the plant. With current technology, about 30 percent of the usable energy content of the manure is recovered.

**Gasification:** A variety of emerging technologies use high temperature pyrolysis to break down manures and other feedstocks, resulting in biodiesel-type fuel which can be used on-site for heat or power generation or sent to a refinery for blending. There are a number of proposals to set up such facilities, some adding switchgrass directly or as an add-on to an ethanol plant. The Beltsville Agricultural Research Center has plans for a thermo-chemical gasification facility to experiment with various on-site bio-feedstocks, including wood chips, methane capture and manure gasification to support all of the center's energy needs.[37]

It is clear that few if any of the processes described in this chapter are anywhere near the level of development and production of ethanol or even biodiesel. Still, they are important to consider, given that they could help to address the region's overproduction of animal manures and their environmental effects. If biofuel solutions can be part of the mix, farmers will have a new source of income or reduced operating costs, and will be better able to minimize farm pollution. Given our need for solutions to land-based sources of nutrient pollution, combustion and gasification technologies are certainly worth encouraging to keep the region at the cutting edge of developments. ■

## SUMMARY Findings With Respect to Combustion and Gasification

- On-site plants that use manure as well as other feedstocks including grasses will become cost-effective at replacing traditional power sources for poultry houses and other farm processes. Operational technology and economics are not there yet, but it is likely a matter of a few years.
- The individual farmer will be able to choose among alternative technologies and applications; the private sector will provide consulting services.
- Air pollution could be an issue with these facilities and some accommodation may be needed to realize their benefits for the Bay. Airborne NOx will be a particular focus.

Chapter 7

# Conclusions And Solutions: Developing A "Best Strategy" For Biofuels In the Bay Region

Given the dynamic forces surrounding biofuels and their potential effects on the Bay region now and in the future, what is the "Best Strategy" for biofuels in the Bay watershed? How can leaders in the Chesapeake region work together to craft a comprehensive strategy that anticipates future economic and environmental benefits and makes the best use of them, yet avoids the pitfalls for our farmers and for the Bay?

## Establish a Watershed-Wide Bioenergy Strategy

**1** The Chesapeake Executive Council, working closely with the state General Assemblies, local governments and stakeholders, should develop a sustainable bioenergy strategy that:

- Strengthens rural economies by expanding options for sustainable income for farmers, foresters and local communities from biofuels;
- Supports state and regional environmental goals, including the restoration of the Chesapeake Bay and state climate change and energy independence strategies;
- Develops and facilitates a holistic approach to the siting, permitting, and business planning of biofuels facilities that considers the full environmental impacts of feedstock sources and transportation and distribution of the final product, as well as the operation of the plant itself; and
- Eliminates or minimizes conflicts among these three goals.

While there is debate over the future mix of feedstocks for our nation's renewable energy goals, there is growing consensus over basic principles that should be incorporated into decisions and planning for the growing bioenergy industry. Environmental performance standards and energy efficiency policies are two key components of sustainably produced bioenergy. The Chesapeake Bay Program and its partners should leverage the extraordinary expertise in this area to become a model for the nation by developing a regional strategy for a diversified portfolio of biofuels that capitalizes on our potential for "next generation" biomass and perennial feedstocks while optimizing environmental benefits.

## Support the Strategy with Regionally Based Policies

**2** Increased corn production will add to nutrient pollution if not accompanied by conservation measures, and should be seen as an opportunity to greatly expand cover crops and support for other agricultural best management practices.

Without extraordinary nutrient management efforts, increased corn production will result in more nutrient loadings to the Bay. A great deal can be done to offset these additional loadings with expanded programs of BMPs such as cover crops, tilling practices and precision farming (see pages 16–17). In fact, the influx of corn and the threat it brings for significant increases in nutrient loadings to the Bay may be just what is needed to improve technical assistance and ramp-up implementation of BMPs on farms that until now had little financial incentive or ability to do so. For example, widespread planting of hull-less barley as a non-fertilized buffer crop can absorb excess nutrients left from the previous corn crop, as well as provide alternative feedstock for grain-based ethanol.

The states should examine their funding programs and work to devote resources to establish long-term, sustained funding sources for needed agricultural conservation measures. The Bay states should also take full advantage of Federal cost-share opportunities.

In the meantime, special efforts should be made by Bay states and USDA to protect forests, buffers and CRP lands from being converted, and to ensure that all new and existing corn acres use management practices that protect water quality.

### 3 The Chesapeake Bay watershed should lead the nation in the evolution from grain-based to cellulosic ethanol.

As cellulosic technologies are perfected, our region is in a unique position to move quickly to this new, abundant and promising source of ethanol. We are the least invested region of the country in the corn-based technology and we want to relieve our livestock industries from high corn prices. We have great alternative sources of feedstock for ethanol plants. We are located near petroleum refineries for blending. Also, cellulosic technologies not only have less negative impact on the Bay's water quality; in some cases, they can be part of the solution to both nutrient reduction and greenhouse gas reduction goals.

A number of key research efforts leading to small commercial-scale cellulosic ethanol production can begin immediately in a cooperative effort with investors and the regional centers of learning to:

- encourage research and experimentation with cellulosic feedstocks — corn stover, fast-growing trees, forestry slash and perennial grasses;
- determine how much stover and slash should be left on the land as nutrients and to control erosion and nutrient runoff;
- experiment with *phragmites* as potential additional cellulosic feedstocks; and
- establish proper manure application rates for switchgrass.

### 4 Combustion and gasification using poultry litter, manure, and other feedstocks should be encouraged as on-site bioenergy sources to provide heat and power for farming operations.

A variety of different combustion and gasification technologies are in the early stages of development. What they all have in common, whether using combustion to generate heat or gasification to produce a variety of fuels, is the ability to use poultry litter and other feedstocks as a source of power to operate the facility. Given the problem of surplus manure within the Chesapeake watershed, anaerobic digestion and other measures that convert waste material to energy offer both energy and environmental gains.

Ideally, these units should be able to develop surplus electric power that can be sold to the grid and reduce the use of fossil fuels for power generation. Major attention is also needed for the control of air emissions, especially NOx and ammonia from such facilities.

Leadership is needed within state legislatures and Governors' offices to establish partnerships and institutions for private/public sector investment in litter and manure-based energy technologies. With sufficient support, these technologies could become cost effective in a matter of years.

### 5 A funding source should be identified to encourage the private sector to find solutions to technical and infrastructure constraints on regional biofuel options that will help both farmers and the Bay.

Many private sector decisions to experiment and invest in new technologies are constrained by the risks involved, as well as the need to coordinate the availability of feedstocks and processing facilities. Few farmers will plant switchgrass, for example, without a refinery to sell it to; and no refiner will commit to build without a secure supply of switchgrass. Investment is also discouraged by unanswered questions about how regulators will deal with potential adverse environmental effects of new technologies.

To overcome these constraints, the Chesapeake Executive Council (EC) should work with its partners, both public and private, to explore the use of incentive awards. Used in the past for exploration and more recently to encourage solutions to global warming, commercial space travel and other complex societal issues, incentive awards are a new way to engage and reward the ingenuity of the private sector to tackle and solve complex problems. Potential financial support could come from new sources or from existing funds within the states, the EPA Targeted Watershed Grants, the NRCS Conservation Innovation Grants, the Chesapeake Bay Funders' Network or others, either alone or in combination.

At periodic intervals, (each year or every five years, for example) the funders could work with the EC to announce the Chesapeake Incentive Awards, or ChIPs. For instance, ChIPs that could be "thrown on the table" might be:

- Offer reward dollars to the first group of farmers to plant 50,000 acres of switchgrass, and commit to harvest it for 20 years.
- Offer reward dollars to the first person to build and operate successfully for five years a 100,000 gallon per year cellulosic ethanol refinery using stover or grasses or a 50,000 gallon plant using primarily forest slash.
- Offer reward dollars to a sewage treatment plant to demonstrate the ability to generate 10,000 gallons of biodiesel from algae without adverse impact on nutrient or other discharge limits.

### 6 Leaders in the Bay watershed should use the 2007 Farm Bill to encourage greater emphasis on conservation practices, perennial crops, biofuels, and energy efficiency on farms. Federally supported, multi-state efforts are needed to implement effective regional strategies that promote sustainable farming and rural economies, advance energy independence and protect our environment.

Capitalizing on America's increasing recognition that farmland and forestland have a yet-untapped potential for "growing" energy, the Energy Title of the 2007 Farm Bill should be used to promote the next generation of biofuels and renewable energy. Research and development funding should promote biofuel production policies that promote sustainable farming while ensuring the protection of the nation's fish, wildlife, soil, nutrient management, and water quality protection goals.

Furthermore, the Farm Bill should promote regional efforts to reduce nutrient and sediment runoff through enhanced support for conservation practices, technical assistance and outreach.

Once the Farm Bill has been reauthorized, the region's agricultural leaders must work closely with USDA to ensure that any grant guidance or rules of implementation maximize the opportunities made available to the Bay region and seize all possible opportunities to explore new and innovative feedstock or technology opportunities.

### 7 Biodiesel production should be considered a potential long-term source of additional income for farmers, and as a potential technology for sewage treatment plants.

While the volumes of biodiesel produced in the United States are unlikely to approach that of ethanol, biodiesel provides another new market opportunity for agriculture. As with feedstocks for ethanol, steps must be taken to assure the protection of groundwater, streams and the Bay from additional nutrient loads caused by increased soybean or other feedstock acreage. Cover crops, buffers and other management practices should be encouraged or required. New feedstock acres should not come from converting existing buffers, forests or CRP lands without implementation of water protection practices and efforts should be made to identify more efficient feedstocks as alternatives to soybeans.

Another potential feedstock for investigation is the growth of algae at sewage treatment plants, a technology just beginning to emerge as a source of biodiesel. Given the potential production per acre, and the ability to monitor and manage the process as part of the sewage treatment plant operation, algae-based biodiesel could be an important new source of revenue for sewer authorities. ■

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## CHESAPEAKE BAY COMMISSION

The Chesapeake Bay Commission is a policy leader in the restoration of the Chesapeake Bay. As a tri-state legislative assembly representing Maryland, Virginia and Pennsylvania, its mission is to identify critical environmental needs, evaluate public concerns, and ensure state and federal actions to sustain the water quality and living resources of the Chesapeake Bay.

The Commission maintains offices in Maryland, Virginia and Pennsylvania. Commission staff is available to assist any member of the General Assembly of any signatory state on matters pertaining to the Chesapeake Bay and the Chesapeake Bay Program.

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