Strategy 3:

Sustainably Grow Kentucky's Production of Biofuels

GOAL **By 2025, Kentucky will derive from biofuels 12 percent of its motor fuels demand (775 million gallons per year, which represents approximately 20 percent of Kentucky's current transportation fuels demand), while continuing to produce safe, abundant, and affordable food, feed and fiber.**

The goal for *Strategy 3* is part of Kentucky's Alternative Transportation Fuels Standard (ATFS), which states that "by 2025, Kentucky can displace 60 percent of its reliance on foreign petroleum by utilizing fuels such as those derived from biomass and coal, plug-in hybrid vehicles, and compressed natural gas."

INTRODUCTION

The United States has become increasingly dependent on imported petroleum to meet its energy needs. About 70 percent of the petroleum consumed in the United States is by the transportation sector. A portfolio of domestic, more diverse feedstock for our nation's energy must be found to reduce this dependency and to secure our nation's and Kentucky's future energy supply. Biomass resources are a sustainable and, for the most part, environmentally benign source that can contribute significantly to a diverse energy portfolio.

Strategies 1, 2 and *3* support the Renewable and Efficiency Portfolio Standard (REPS) for Kentucky that states that "by 2025, Kentucky will derive at least 25 percent of its projected energy demand from energy efficiency, renewable energy and biofuels while continuing to produce safe, affordable and abundant food, feed and fiber."

Strategy 3, as a means to decrease our dependence on foreign oil, identifies actions to increase Kentucky's biofuels production capacity to 775 million gallons per year. This capacity represents approximately two percent of Kentucky's total projected 2025 energy demand and 12 percent of our 2025 liquid transportation fuel needs. To achieve this goal, Kentucky must continue to support biofuels made from traditional feedstocks as well as investigate and develop new feedstocks.

As an alternative to petroleum fuels, biofuels provide many benefits to the commonwealth:

- Improve balance of trade from reduced dependence on petroleum imports.
- Spur economic growth, particularly in rural America, from newly developing bio-industries.
- Reduce carbon emissions.
- Provide a more diverse energy portfolio and greater energy security.

Biofuels can be derived from a number of resources already found in Kentucky. Feedstock materials available in Kentucky include corn, soybeans, switchgrass, corn stover, other crop residues, animal fat and woody biomass. For purposes of this discussion, we have assigned all of Kentucky's woody biomass energy potential to *Strategy 2* to be developed as a resource for electricity production and carbon mitigation. However, the actual end use of woody biomass will be dictated by market economics, technology, government policy and incentives.

Kentucky's Biofuels Potential

Rising fuel prices, environmental concerns, pressures for security from foreign sources of oil and federal energy policy are creating a strong market for biofuels. In the United States, corn-based ethanol is currently the largest source of biofuel as a gasoline additive, and recent federal energy legislation mandates further growth of both corn-based and advanced biofuels from other sources. Lending promise to the industry is the increasing availability of ethanol and biodiesel at fuel pumps across the nation (Department of Agriculture, 2008). An analysis by the University of Kentucky estimates that Kentucky has an ethanol production potential of 668 million gallons per year (Table 4). Given that ethanol has approximately 70 percent of gasoline's energy content, Kentucky has a potential gasoline-equivalent production capacity of 468 million gallons per year, representing nearly 22 percent of the 2005 gasoline consumption. In 2005 Kentuckians consumed 2.1 billion gallons of gasoline.

Recently, the U.S. Department of Energy (DOE) awarded a $30 million grant to Ecofin LLC to help pay for a $70 million cellulosic ethanol plant to be built in Springfield, Ky. The plant will produce ethanol and other value-added products using conventional feedstocks and cellulose, such as switch grass, corn cobs and corn stover. The company is also investigating the possibility of using algae systems to capture carbon dioxide and produce bio oil. The Kentucky Economic Development Finance Authority (KEDFA) has given preliminary approval for $8 million in tax incentives to the company.

Ethanol production could annually add up to $355 million in value-added benefits to the state's economy and create about 1,800 new permanent jobs directly related to biofuels feedstock production. With this level of ethanol production $3.1 million per year of new tax revenue would be generated, along with $130 million dollars of value-added benefits in Kentucky through the construction of ethanol production plants (Colliver et al., 2008).

The state's 2025 potential biodiesel production capacity is estimated to be 107 million gallons (Table 4). Based on biodiesel's energy content (92 percent of petroleum diesel), the potential diesel-equivalent production capacity is about 98 million gallons of biodiesel, representing about 11 percent of 2005 diesel consumption. Kentucky's diesel consumption was 867 million gallons in 2005.

Table 4: Kentucky's Potential Biofuels Production Capacity *

Biofuel	Feedstock	Million Gal/yr	tBtus/yr
Ethanol	Corn	186	14.1
	Switchgrass**	361	27.4
	Corn Stover + Residues	121	9.2
	Ethanol Total:	668	50.7
Biodiesel	Vegetable Oil **	107	14.9
	Grand Total:	775	65.6

* Source: Colliver et al., 2008
** While the potential for switchgrass and algae as biofuels feedstock for Kentucky exists, the Colliver et al. 2008 report only calculated the potential for switchgrass and vegetable oil; many other candidate species are currently being investigated.

With an agricultural base of 85,000 farms and 13.8 million acres of total farmland, of which five million acres are annually harvested cropland, Kentucky is well-situated to meet these production goals (Kentucky Department of Agriculture, 2006).

Producing 775 million gallons of biofuels per year will require that a number of strategies and production techniques be put in place. Corn ethanol and biodiesel plants are already operating in the commonwealth. Kentucky has the capacity to support this level of biofuels production; however, economics, risk and sustainability will certainly influence the development of this resource.

Commonwealth Agri-Energy--Ethanol

Agri-Energy is an ethanol production facility, built in Hopkinsville in 2004. This facility is cooperatively owned by the Kentucky Corn Grower's Association and the Hopkinsville Elevator Co-op. In 2008, the plant will use about 12 million bushels of corn per year to produce 33 million gallons ethanol, 107,000 tons of distillers dried grains (a production by-product used in livestock feed), 110,000 pounds of carbon dioxide for commercial use, and 3,000 ton of animal feed grade corn oil. The facility supports 32 direct jobs in the Hopkinsville community.

Ethanol from Starch Crops

While corn is the primary feedstock for ethanol production (because of the extensive experience that exists in utilizing it and the high starch content of the plant), other crops are being investigated as potential feedstock crops, e.g., non-food crops, and will be discussed later in this strategy.

Higher demand for ethanol can increase corn prices, which can provide an incentive for farmers to raise additional corn. Kentucky's farmers are already responding to these higher prices. The University of Kentucky estimates that these factors and other developments can facilitate the production of an additional 44 million bushels of corn per year, resulting in a total of 186 million gallons of ethanol produced per year (Colliver et al., 2008). To achieve these ethanol production levels, Kentucky would need three to four new 50-million gallon production facilities.

While corn-based ethanol production has generated national debate over food versus fuel issues, future biofuels production can help alleviate many of the concerns in the debate. Non-food biofuel feedstock can be produced on less fertile lands that are only marginally suitable for food crops. Increased biofuel supplies can also help alleviate some of the demand pressures driving gasoline prices upward. The DOE and USDA estimate that United States gasoline consumption would be 7.2 billion gallons higher in 2008 if there were no biofuels available; the added fuel has had a moderating effect on U.S. gasoline prices, saving the average household about $300 per year (DOE, 2008a).

Ethanol from Cellulose Plant Material

All green plants' primary building blocks are made of cellulose. This molecule is basically a long chain of smaller glucose molecules. These molecular chains are chemically broken with acids or enzymes, making the sugar molecules available for bacterial fermentation and ethanol production. While cellulosic ethanol production is technically feasible, the additional steps necessary to produce ethanol raise its cost of production to the point where it is not yet economically viable.

Switchgrass is frequently promoted as the candidate cellulose crop because it can be grown throughout much of the United States, not to mention its potential high yield per acre and need for limited pesticide use. Other cellulose sources being investigated include residue from other crops, woody crops and municipal waste. Research should be continued to identify the ideal cellulose crop for Kentucky. However, for the purposes of this discussion, switchgrass will be used as the model crop species.

The potential for Kentucky lies in using some of the 2.15 million acres of land in non-alfalfa hay production (or "other-hay") for cellulose production. Depending upon market prices, it is estimated that approximately 550,000 acres of other-hay land could be converted to switchgrass production, providing 4.4 million tons of switchgrass (at approximately eight tons per acre). This level of production could produce 361 million gallons of ethanol per year from switchgrass (Colliver et al., 2008).

Crop residues, such as corn stover and wheat straw, could also be used to produce ethanol. Given Kentucky's corn and wheat production levels, and utilizing only 27 percent of total crop residue, 1.5 million tons per year of residue material could be provided, with an average ethanol yield of 80 gallons per ton. The potential from these resources would be about 121 million gallons of ethanol per year (Colliver et al., 2008).

Ethanol from Municipal Solid Waste

Municipal solid waste (MSW) is high in cellulose that could be utilized for ethanol production and has the added benefits of not competing for land or food crops. While many local governments struggle with solid waste disposal, utilizing these materials as a feedstock source could, at the same time, solve multiple problems. MSW suffers from some of the same challenges as other cellulose materials in that it must first be broken down to make the sugars available for ethanol production. Current research is focusing on improving conversion efficiencies, mitigating scale-up risks, mitigating risks associated with recycle stream contaminants, improving the co-product quality and marketability, and proving the capability of the plant to operate at near zero discharge. As an example, a commercial-scale MSW-to-ethanol facility is slated to begin construction in Pikeville in 2009, with a capacity to produce 20 million gallons of ethanol annually (WYMT News, 2008). A facility of this size is estimated to process approximately 1,500 tons of waste per day (Biomass Magazine, 2008).

Biodiesel from Oilseeds

Biodiesel is a renewable fuel produced from a wide range of vegetable oils and animal fats. Kentucky's current production of biodiesel comes from soybean oil and animal fats. These fats and oils are chemically reacted with an alcohol to produce chemical compounds known as fatty acid methyl esters. Pure biodiesel, or biodiesel blended with petroleum diesel,

Owensboro Grain Biodiesel

Owensboro Grain is a Kentucky-based company that started 101 years ago as a small grain merchant. In January 2008, the company opened a biodiesel plant in Owensboro, KY, with the capacity to produce 50 million gallons per year. The biodiesel plant is located adjacent to their vegetable oil refinery that processes soybeans from Kentucky and across the region. Annually the vegetable oil refinery produces 75 million gallons of soybean oil that provides a consistent-quality feedstock for biodiesel production. The biodiesel plant received funding assistance in the form of a grant from the Kentucky Agriculture Development Board and a low-interest loan from the Agriculture Finance Corp. The entire oil and biodiesel facility employs 160 individuals, adding nearly $19 million to the local economy while generating approximately $148 million in annual sales.

can be used to fuel diesel vehicles. Compared with petroleum diesel, using biodiesel in a conventional diesel engine substantially reduces emissions of unburned hydrocarbons, carbon monoxide, sulfates, particulate matter and other pollutants (DOE, 2008b).

The analysis by the University of Kentucky indicates that Kentucky has the potential to produce approximately 107 million gallons of biodiesel. To achieve this level of production, approximately 25 percent of Kentucky's soybean acreage and 25 percent of Kentucky's wheat acreage would be converted to canola/sunflower in double-cropped rotation (Colliver et al., 2008). This would provide the feedstock necessary to produce approximately 11 percent of Kentucky's 2005-level diesel consumption. To achieve these biodiesel production levels, Kentucky would need one to two new 50-million gallon per year production facilities.

Development of new cropping systems that significantly increase the availability of biodiesel feedstock is necessary if biofuels are to displace traditional petroleum-based distillates. Production of oilseed crops by Kentucky farmers will be determined by market economics, land availability, consumer demand, competing crop prices, and government policies and incentives.

An alternative to oilseeds for biodiesel is animal-derived products and recycled cooking oils and greases. While recycled materials require more pre-treatment than virgin oils, they are still an economical alternative at today's prices and help address a waste disposal problem.

Table 5: Comparison of Oil Yields for Various Crops

Crop	Oil Yield (gal/ac)
Corn	13
Soy	47
Safflower	83
Sunflower	102
Castor	150
Canola	171
Jatropha	192
Jojoba	192
Algae	1600 - 8500

Source: Sun and Hobbs, 2008

Algae Biodiesel

Research is currently underway on the potential of algae as an oil source for biofuels. However, among the myriad algae species available, there has been little research to identify the best species for commercial utilization in Kentucky. The ideal species should be a freshwater species, abundant, and suited to Kentucky's environmental conditions. Diatoms are a common algae and are a likely feedstock candidate as they store their photosynthetic energy as oil (Steinitz-Kannan, 2008).

Diatoms, as an oil production organism, can help capture carbon dioxide from the atmosphere. Pairing diatom culture facilities with carbon-rich stack emissions from coal-fired power plants can provide dual benefits to society by removing carbon dioxide from power plant emissions, while generating a potential biofuels feedstock. Biodiesel fuels produced in this manner ultimately displace the release of carbon from non-renewable fossil fuels. More discussion on carbon capture and sequestration is presented as a part of *Strategy 6*.

Since diatoms demand nutrient-rich waters to grow, they also have the potential to "treat" wastewater effluent by removing nitrogen and phosphorus, helping dischargers comply with new nutrient permit limits. Pilot-scale studies still need to be conducted to refine methods for growing high oil-yielding diatoms using sewage or agricultural wastewater. Oil extraction techniques also need to be developed.

While diatoms have numerous physical characteristics that make them well-suited to large-scale culturing, it is important to note that they can be grown on marginally fertile land that does not compete with food-crop production. Oil yields of algae (Table 5) far surpass other candidate crops for biodiesel oil production, ranging from 1,600 to 8,500 gallons per acre (Sun and Hobbs, 2008).

Although Kentucky may not realize these upper yield levels due to limited sunlight intensities, algae production levels are still estimated to be on the order of 30 times the oil production of traditional food crops (Baum, 1994).

Implementation Challenges

While there is much promise in biofuels as a significant contributor to the commonwealth's energy needs, there remain many challenges. Some aspects of biofuels production and distribution still rely on leading-edge technology, and additional research is needed to develop these into commercially viable processes. Strategies for R&D to overcome barriers in the feedstock system include:

- Producing biomass feedstock in large enough quantities and with the desired properties that they can be more cost-effectively converted to useful fuels, power, or products.
- Reducing the cost of harvesting, transporting, and storing biomass material.
- Ensuring sustainable, environmentally sound agronomic practices.

But overcoming these barriers is feasible and highly likely.

As Kentucky sets its course towards energy security with this energy plan, the following challenges will need to be addressed for biofuels (DOE, 2007):

- **Geographic challenges**

  Kentucky's farm profile is characterized by many small land owners, which presents challenges in economies of scale for production of biomass feedstock, such as use of lands marginally suitable for food crops, to meet increased demand and pricing; marketability of feedstock in a way that entices producers into the market; and economics of smaller-scale farms. These issues increase the importance of risk evaluation tools and methods to offset or reduce financial risk. This can be done.

- **Feedstock**

  For Kentucky feedstock to significantly contribute to the biofuels energy picture, research breakthroughs are needed in a number of key areas, including:

  - Identification of the ideal non-food feedstock crop for Kentucky (i.e., switchgrass or other candidate).
  - Development of economically viable and scalable algae oil production and extraction technologies.
  - Advances in plant science to improve the cost effectiveness of converting crops and residues to fuel, power and products.

Agronomic challenges related to feedstock production at the farm-scale include:

- Seasonality of feedstock crop vs. year-round biofuels industry; high initial costs for new crops, e.g. three-year delay to first harvest for switchgrass.
- Soil fertility and stability with continued harvesting of crop residue.
- The impact on Conservation and Grassland Reserve Programs due to increased feedstock demand.

In addition, R&D should focus on maintenance for perennial feedstock crops and advanced harvesting methods such as single pass harvesters and precision forest residue machinery. This will enable greater amounts of feedstock to be harvested at a lower cost. R&D is also required for the collection, storage and transportation of crop residue, as current infrastructure is not equipped to handle these processes.

- **Processing and Conversion**

Processing and conversion of feedstock to biofuels must be made more efficient. Science should strive to replicate processing systems found in nature. Greater efforts are needed to utilize byproducts of feedstock conversion and add value. Although improvements have been made in enzyme technology, significant improvements must still be made to further cut enzyme costs and increase the speed of reactions. Locating modular, decentralized processing and conversion facilities in proximity to both feedstock and retail markets will reduce transportation and distribution costs.

- **Infrastructure**

R&D is critical in assessing transportation and infrastructure of biofuels. Kentucky relies heavily on truck transport and storage at bulk plants, which can greatly increase transportation costs and increase the price of fuels. The most cost-effective method of transporting products in fluid form is through pipelines. But currently, biofuels cannot be transported through the same pipelines as petroleum fuels; this barrier must be overcome. The industry must develop partnerships for all legs of the distribution chain, including dedicated storage and blending facilities.

- **End-Use Markets**

To develop end-use markets, efforts are needed to evaluate and develop biofuels that are suitable for mass markets. Retail sales of biofuels, of course, also require fueling station outlets for the consumer. This will require a comprehensive education and marketing campaign to develop a customer base for alternative fuel vehicles. Continued research is also needed to identify possible new uses for co-products to keep the actual fuel costs as low as possible.

- **Education and Training**

Education of both decision-makers and the public on the benefits of biofuels is needed. Workforce education also will be required as Kentucky lacks the technical workforce to harvest, handle, and integrate biofuels feedstock into existing infrastructure.

These challenges are not insurmountable for Kentucky but will require acknowledgement, as well as commitment and support to address them. The need for a sustainable renewable fuel supply will drive the market economics and the determination to address these issues. Government's role, both at the state and federal level, is to provide incentives and to support research designed to remove these technical barriers.

ACHIEVING THE GOAL:

By 2025, Kentucky will derive from biofuels 12 percent of its motor fuels demand (775 million gallons per year, which represents approximately 20 percent of Kentucky's current transportation fuels demand), while continuing to produce safe, abundant, and affordable food, feed and fiber.

Underlying much of *Strategy 3* is a concerted effort to stimulate R&D to address technical or infrastructure challenges that have the potential to hinder the biofuels market. Many of these recommendations are adapted for Kentucky from the U.S. Department of Energy's "Roadmap for Bioenergy and Biobased Products in the United States."

To achieve our goal for biofuels, Kentucky will begin a statewide initiative to ensure that the needed infrastructure, human resources, research and development support, and policies are in place to enable meaningful and sustainable growth in biofuels.

Near-Term Actions (1-3 years)

1. Kentucky will invest in algae and other non-food crops as a feedstock for biodiesel.

    - The EEC, in partnership with Kentucky's research institutions, will evaluate high oil content crops best suited for biodiesel production in Kentucky and oil extraction techniques for algae. Priority will be given to crops that do not negatively influence food prices or availability.
    - Carbon capture initiatives will be integrated with the production of algae biodiesel (see *Strategy 6*).
    - The Center for Applied Energy Research will demonstrate a small-scale (estimated 50,000 gallons per year) pilot algae oil production plant and will convert the algae oil into biodiesel.
    - With a positive evaluation of high-oil content crops, the EEC, Kentucky's research institutions, the Governor's Office of Agricultural Policy, and the Kentucky Department of Agriculture will develop an aggressive strategy to introduce these crops on a commercial scale.

2. Kentucky will aggressively seek federal support for and invest in ventures that promote a market for ethanol from non-traditional feedstock, especially feedstocks that do not negatively affect food prices or availability.

    - Kentucky's research institutions will be encouraged to aggressively seek federal grants to address challenges in the production of cellulosic ethanol; the EEC will support federal grant opportunities with matching funds.

- The EEC and the Governor's Office of Agriculture Policy will work with Kentucky's Cooperative Extension Service to develop programs to instruct farmers and rural communities on how best to grow and support biomass feedstock production systems.
- Establish a Biofuels Assistance Program that provides financial incentives to:
  - Kentucky producers to harvest, store and transport feedstock to biofuels facilities,
  - Kentucky's post-secondary institutions to conduct applied research to test best practices for cost-effective and environmentally sound harvesting, storage, and transporting of biofuels feedstocks.
- Kentucky's research institutions will identify and develop feedstock crops that have improved yields, properties, and growth cycles consistent with Kentucky's needs. Evaluation should include the potential of cellulosic feedstock crops such as southern pine, willow, switchgrass, hybrid poplar, and miscanthus.

3. Establish an escalating renewable fuel standard (RFS) for the state vehicle fleet.

- The state will establish an initial renewable fuel standard of 10 percent, or 560,000 gallons (10 percent of an estimated 5.6 million gallons consumed annually by all state fleet vehicles) for E10 biofuel.
- The state will require all eligible fueling stations under government contract to provide, at a minimum, E10 gasoline and B2 biodiesel by the year 2012.

4. Create incentives that encourage production, distribution, and demand for biofuels in Kentucky, in an environmentally sustainable manner.

- There will be a focus to fund initiatives that expand Kentucky's biofuels research capacity. This focus will include programs, such as "Bucks for Brains", which use state funds to match private donations, to attract and retain some of the nation's top researchers and scholars in biofuels.
- The EEC will work with state and federal agricultural agencies to ensure proper incentives are in place to support best management practices for protection of the environment, while enhancing sustainability of feedstock production.
- The Governor's Office of Agricultural Policy will provide financial and educational assistance to agricultural producers to enable them to be more competitive for federal energy efficiency grant and loan programs through the USDA, DOE and other agencies.
- The Kentucky Agricultural Development Board (KADB) will provide grants and other funding opportunities for research, education, pilot projects, and farmer investments in the areas of on-farm energy efficiency, and commercial production of commodity-based renewable fuels. The KADB must receive its full share of the Master Settlement Agreement as referenced by the Kentucky statute (KRS 248.703) to support agri-energy initiatives in Kentucky.
- The Kentucky Agricultural Finance Corporation will provide low-interest loans for on-farm infrastructure development and improvements as well as low-interest financing for the construction of commodity-based biofuels facilities.
- Agricultural agencies will ensure that crop insurance programs provide adequate coverage for energy crops.
- The EEC will determine how existing infrastructure can be best utilized to transport biofuels in bulk. Results will be used to support the deployment of new infrastructure as necessary.
- Provide new incentives for fuel retailers to install biofuels (E10/E85) fueling infrastructure

with targets of 50 percent of all fueling stations by 2012 with E10 biofuel and 100 percent by 2025; 30 percent of all fueling stations with E85 by 2025. As a part of this initiative, Kentucky will establish and promote a Biofuels Trail, with designated E10/E85/Biodiesel fueling stations.

Mid-Term Actions (4-7 years)

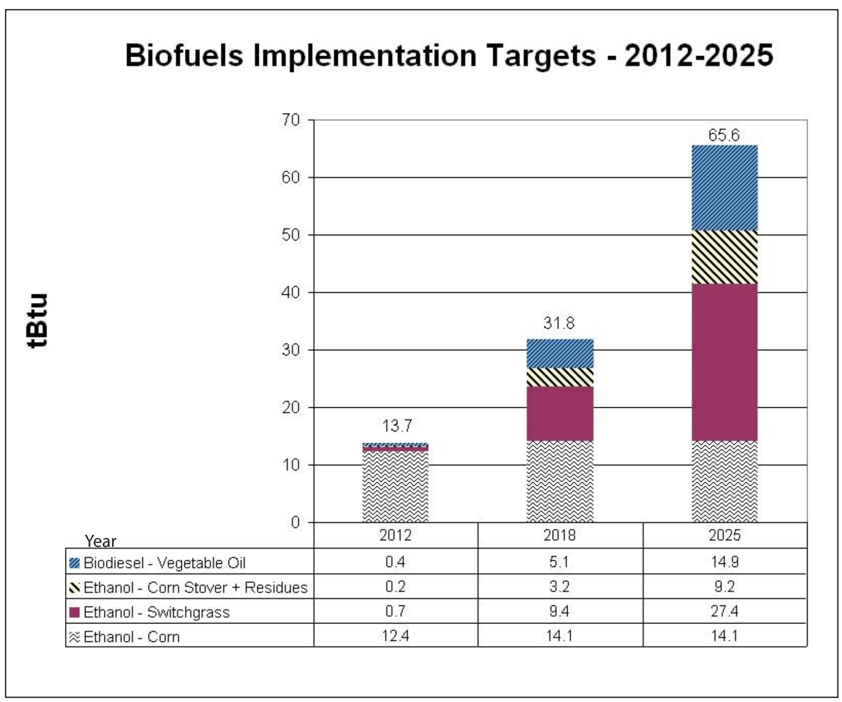
1. A program of incentives will be created to reduce the risk of capitalizing and financing an additional three biofuels plants, including tax incentives to attract biofuels plants to Kentucky.
2. Kentucky research institutions will evaluate algae as a carbon capture mechanism for coal-fired power plants, supporting algae-based biodiesel production. There is also a need for low-cost methods to diversify feedstock if goals are to be met. Therefore, research will develop a diverse feedstock portfolio to ensure supply security and reduce the impact of price swings for a single crop.

Long-Term Actions (>7 years)

1. Kentucky research institutions will expand research on the production and utilization of promising non-traditional biomass feedstock (e.g., algae, canola, sunflower, cellulose, sweet sorghum, and short rotation woody crops) for biofuels.

IMPLEMENTATION SCHEDULE

The biofuels energy potential of 65.6 trillion Btus equates to 775 million gallons of transportation fuel (Figure 15). To capture this potential, focused research and development are essential and need to be coupled with incentives that drive the commercialization of emerging technologies and processes. House Bill 1 contains incentives to increase the production and sale of alternative transportation fuels, such as ethanol and biodiesel. Eligible projects include alternative fuel facilities that are carbon-capture ready and use biomass resources as the primary feedstock, with a minimum capital investment of $25 million. Tax incentives are available for up to 25 years, up to a maximum of 50 percent of the capital investment.



Year	2012	2018	2025
Biodiesel - Vegetable Oil	0.4	5.1	14.9
Ethanol - Corn Stover + Residues	0.2	3.2	9.2
Ethanol - Switchgrass	0.7	9.4	27.4
Ethanol - Corn	12.4	14.1	14.1

Figure 15: Biofuels Implementation Targets - 2012-2025

Kentucky's research institutions must collaborate with industry and the federal government to develop opportunities that benefit the commonwealth. The Ecofin LLC partnership with the University of Kentucky, U.S. Department of Energy and the commonwealth provides an excellent model. Additionally, Kentucky's Cooperative Extension Service and agricultural agencies must be involved and fully integrated to help farmers and rural communities develop new opportunities and learn how to grow new non-traditional energy crops.

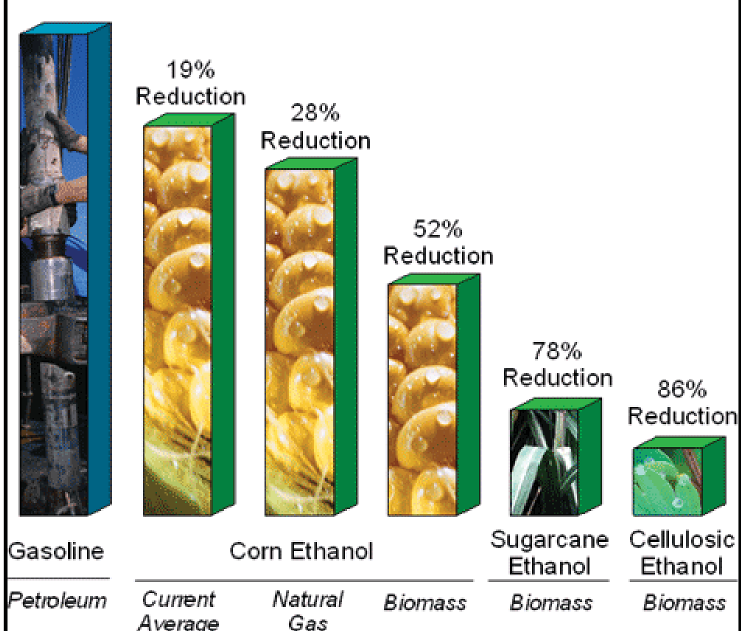
As can be seen in Figure 10 in *Strategy 1*, biofuel is just one component to Kentucky's energy future. For biofuels to reach the goal stated in this strategy there will be a start-up period as market transformations occur. For more leading-edge technologies, such as cellulosic ethanol and oil extraction from algae for biodiesel, the initial growth curve will be delayed. The production targets presented in Figure 15 consider these start-up challenges and have been based on production trajectories in the mandated renewable fuel standards of the Energy Independence and Security Act of 2007 (RFA, 2008).

If current energy usage is projected to reach 2,815 trillion Btu by 2025, and given production capabilities in Kentucky, biofuels can help reduce our dependence on traditional energy sources by 65.6 trillion Btu. Figure 15 shows the projected contribution of biofuels to the energy efficiency and renewable energy goal as 13.7 trillion Btu by 2012, 31.8 trillion Btu by 2018, and 65.6 trillion Btu by 2025.

ENVIRONMENTAL BENEFITS & LIMITATIONS

Biofuels provide an opportunity to reduce transportation-related greenhouse gas emissions. By burning a renewable energy source, tail-pipe emissions represent no net gain in atmospheric carbon dioxide. In 2005, transportation-related carbon dioxide emissions for Kentucky were 33.5 million metric tons and are projected to reach 43.4 metric tons by 2025 (EIA, 2008). Even taking into account feedstock production, processing, and distribution of biofuels, ethanol provides substantial reductions in overall carbon dioxide contributions versus conventional petroleum-based fuels.

Since every fuel is used and produced differently and requires different energy inputs to produce, the associated levels of greenhouse gas emissions with a particular biofuel will vary accordingly (e.g., coal, natural gas, biomass) (Figure 16). Corn ethanol, for example, has the potential to reduce greenhouse gas emissions by as



Sources: Wang et al., *Environ. Research Letters*, May 2007; Wang et al., *Life-Cycle Energy Use and GHG Implications of Brazilian Sugarcane Ethanol Simulated with GREET Model*, Dec. 2007

Figure 16: Greenhouse Gas Emissions by Transportation Fuel and Type of Energy Used in Processing

much as 19 percent over petroleum-based fuels, when evaluated on a full fuel-cycle basis, while biofuels made from cellulosic feedstock, such as switchgrass, woody biomass, or agricultural residues such as corn stover, have the potential to reduce greenhouse gas emissions by as much as 86 percent, when compared to gasoline (DOE, 2008c). Biodiesel can reduce carbon dioxide emissions by 78 percent (National Renewable Energy Laboratory, 1998). Implementing *Strategy 3* can reduce carbon dioxide emissions by 3.2 million metric tons.

In addition to greenhouse gases, biofuels can help reduce other air pollutants associated with petroleum-based transportation fuels. Approximately 257,519 tons of sulfur dioxide and 148,433 tons of fine particulate matter (EPA, 2008b and 2008c) were attributed to road vehicles in 2002. Because of the low-sulfur content of biofuels (often one percent that of coal), sulfur oxides and particulate matter will be reduced through their use as fossil fuel replacements (Hughes, 2008; EPA, 2008a). Another benefit is an expected 75-85 percent reduction of polycyclic aromatic hydrocarbons, which have been linked to cancer (Kentucky Division for Air Quality, 2008). The use of biodiesel will be particularly beneficial in areas that do not meet national ambient air quality standards, because they emit significantly fewer contributors to non-attainment for particulates and ozone.

As previously stated, biofuels reduce demand for fossil fuel production when evaluated on a fuel-cycle basis; i.e., the energy input-to-output ratio is lower for ethanol than for petroleum-based fuels, even when considering energy inputs from feedstock production, processing and distribution. Ethanol produced from corn produces a net energy return of 1.34 (energy input to output), meaning that it yields 34 percent more energy than it takes to produce it, with a net energy value of 41,105 Btu per gallon (Department of Agriculture, 2002).

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