Economic Impact of Industrial Hemp in Kentucky

Dr. Eric C. Thompson
Dr. Mark C. Berger
Steven N. Allen

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Center for Business and Economic Research
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UNIVERSITY OF KENTUCKY
CAROL MARTIN GATTON
COLLEGE of BUSINESS and ECONOMICS

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Authors

Dr. Eric C. Thompson is the Associate Director of CBER and a research assistant professor of economics at the University of Kentucky. He developed and maintains the University of Kentucky State Econometric Model. Dr. Thompson received his Ph.D. in agricultural economics from the University of Wisconsin in 1992. He can be reached at (606) 257-1386 or ecthom1@pop.uky.edu.

Dr. Mark C. Berger is the Director of CBER and a professor of economics at the University of Kentucky. He has conducted research on the Kentucky economy for over 15 years and his research has been published in the leading journals in economics, including the *American Economic Review*, *Journal of Political Economy*, and *Review of Economics and Statistics*. Dr. Berger received his Ph.D. in economics from The Ohio State University in 1981. He can be reached at (606) 257-1282 or mberger@pop.uky.edu.

Steven N. Allen is a Research Associate at CBER. He has edited the *Kentucky Annual Economic Report* and conducted research on the Kentucky economy for several years. He can be reached at (606) 257-7678 or sallen@pop.uky.edu.

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Center for Business and Economic Research
335BA Gatton Building
University of Kentucky
Lexington, KY 40506-0034

Voice: (606) 257-7675
Fax: (606) 257-7671
Email: cber@pop.uky.edu
Web: http://gatton.gws.uky.edu/cber/cber.htm

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CAROL MARTIN GATTON
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FOREWORD

Hemp: Rhetoric & Reality

By John I. Gilderbloom, Ph.D., University of Louisville

For too long, the heated debate over hemp has been fanned more by rhetoric than reality. Scientific studies of hemp have been sparse. At last, a scientific study conducted by an established university has carefully and deliberately weighed the evidence on the economics and ecology of industrial hemp!

The study, "Economic Impact of Industrial Hemp in Kentucky," by Dr. Eric C. Thompson, Dr. Mark C. Berger, and Steven N. Allen of the University of Kentucky's Carol Martin Gatton College of Business and Economics fills the void with a bold, balanced, and sensible investigation. The University of Kentucky report pushes the hemp debate from the streets and into the halls of academic science. In a time when universities increasingly avoid controversial and cutting edge issues, the UK study provides a sober, thorough, and careful evaluation of all the credible studies and produces new economic estimates.

The demand for industrial hemp is great. A recent story in the *Wall Street Journal* found that the demand for hemp worldwide will increase from $75 million in 1997 to $250 million in 1999 – more than tripling in demand. In 1998, the total amount of hemp *imported* to the United States hit over 546 tons. A real strength of the report is its conservative posture. The estimates are made purposely low so that it will be unassailable from potential critics. Even these numbers make a powerful case for legalization of industrial hemp.

The UK study compares 14 common Kentucky crops and finds that hemp could be the third most profitable crop in Kentucky (tobacco products rank first and second). The authors back up their estimates by providing case studies of industrial hemp production in Canada and Germany. These case studies replicate the profit estimates found in the University of Kentucky study. However, the UK study predicts that the profitability of industrial hemp will decline in the long run to levels similar to the profits seen in other Kentucky crops.

Traditional economic theory might not apply to hemp because of its wide array of uses which makes it unique. All indicators, however, suggest that demand for hemp will continue to rise. The worldwide demand for industrial hemp has skyrocketed 233 percent in just two years. The UK study estimates that demand for industrial hemp would require 82,000 acres.

The UK study finds three reasons why Kentucky might gain a significant share of the industrial hemp industry. First, hemp meets the needs of Kentucky's horse industry by providing affordable animal bedding. Second, Kentucky's long growing seasons and appropriate soils make industrial hemp profitable. Third, if Kentucky becomes the first state to legalize industrial hemp, it will have a long-term advantage over other states in establishing the industrial hemp industry.

Jobs in rural Kentucky counties need to be created. Manufacturing plants are increasingly closing down. Kentucky's number one cash crop has come under greater assault with tobacco price supports ending or being reduced. Tobacco will also face greater taxation and regulation in the future. New kinds of industries need to be developed in these agricultural counties.

Industrial hemp can create jobs in these counties where unemployment is well above the national average. The work earnings would then result in a significant multiplier effect for poor agricultural counties in Kentucky. Multiplier effects result in more money in circulation to pay for basic retail items such as food, transportation, clothing, health, and housing. Increased dollars in circulation also result in a reduction in private and public sector welfare costs. The authors of the UK study measure the economic impacts of a scenario in which hemp industry locates itself in a agricultural county creating one decorticating facility, one industrial hemp paper pulp plant, and cultivating 25,600 acres for straw or straw/gain and 2,050 acres of certified seed; they estimate that 771 full-time equivalent jobs and $17,600,000 in worker earnings would be created. This is one estimate.

It is unlikely, however, that industrial hemp would only be produced in only a few Kentucky locations. The bulk and weight of hemp make transportation costs high. Hemp production cannot be centralized, its production needs to be decentralized. To be profitable, hemp needs to be processed within 25 to 50 miles of where it has been grown.

The UK authors seem to have taken a very conservative stance by underestimating the number of possible hemp production facilities. Their jobs and earnings estimate is based on one centralized location in Kentucky. If just a fraction of the agricultural counties in Kentucky went into the industrial hemp business, thousands of jobs and sizable earnings would be created. If just one-fourth of Kentucky's 90 agricultural counties went into industrial hemp business, approximately 17,348 jobs would be created and $396 million in worker earnings generated yearly. The vast potential of industrial hemp creating jobs and worker earnings needs greater study.

Hemp can have a positive environmental impact. Hemp requires very few pesticides, which is significant for Kentucky's land and water. The UK study states that industrial hemp does not need herbicides, but most agricultural experts, including references cited in the appendix, maintain that under some growing circumstances a small amount of herbicides is used for industrial hemp. Another by-product is that when crops are rotated on acreage that has grown industrial hemp in the previous year, crop yield for the new crop can increase 10 to 15 percent. These estimates might be conservative. In Austria, farmers claim that the crop rotation after hemp cultivation brings up to 25 percent more yield. In measuring the economic impacts of hemp, the indirect impacts of hemp production on other crops need to be put into the equation.

Hemp also can replace resources that are nonrenewable and, in some cases, in short supply. Hemp can provide a variety of needed products such as paper, textiles, cosmetics, and apparel. The UK study makes a major case for hemp animal bedding as a usable and profitable product for Kentucky. The potential of industrial hemp as a major source of paper (the Declaration of Independence and Bill of Rights was written on hemp) deserves more attention. Obviously, if hemp can take the place of trees as a major source of paper, our ecosystem which depends so much on our forests would be enhanced greatly.

A serious investigation also needs to be made of hemp as an alternative fuel source. Oil reserves continue to decline and alternative sources will eventually be needed. Industrial hemp is a renewable resource that can be made into diesel fuel and plastics. In fact, plastics were originally developed using an agri-base that included industrial hemp. This could be the most important product to come from hemp.

Consumer demand for environmentally and economically sustainable products will also propel hemp into a large industry. Consumers are increasingly becoming aware of the ecological consequences of a consumption-driven society. Consumers look to buy products that are recyclable, biodegradable, and that invest in the American worker. As consumers invest in their children's future by buying these kinds of products, more and more industries will invest in renewable resources to ensure their sustainability for environmentally conscious products continues to expand. Increasingly, corporations are producing products that are sustainable.

One product that will not be produced from industrial hemp is marijuana. With its psychoactive properties less than one percent, industrial hemp is a plant that is basically free of the key chemical found in marijuana. In fact, statewide hemp production will be a nightmare for marijuana growers. Studies at Indiana University indicate that industrial hemp would cross-pollinate and destroy any marijuana in its vicinity. Our neighbor Canada, along with Europe and China, has already legalized the production of industrial hemp.

I would hope that the UK study will ignite hearings in the Kentucky state legislature and United States Congress to consider legislation that would allow agricultural universities to begin experimental production of industrial hemp. Experimental growth of hemp in the United States will give us even better estimates of the ecological and economic consequences of hemp production. Current U.S. laws severely limit American universities from freely investigating the uses of industrial hemp. Hemp has been grown in scientifically controlled programs in Canada and Europe demonstrating its viability in northern climates. But our state's long history of hemp production establishes Kentucky as one of the world's premier locations for growing industrial hemp. The UK report could provide the spark for a serious review and evaluation of the benefits of industrial hemp for the state of Kentucky and the United States. The UK study has done an admirable job of looking at the rhetoric and letting us know the reality of industrial hemp.

About the author:

John Gilderbloom, Ph.D., is tenured Associate Professor in the School of Economics and Public Affairs and Director of the Center for Sustainable Urban Neighborhoods at the University of Louisville (http://www.louisville.edu/org/sun). Dr. Gilderbloom's expertise and advice has also been sought by members of President Clinton's National Economic Council, former Secretary of HUD, Henry Cisneros, and current Secretary of HUD Andrew Cuomo. In a 1994 speech to the US Conference of Mayors, President Clinton praised John Gilderbloom's work on economic strategies to revitalize inner cities. John Gilderbloom's research has appeared in two books, 20 scholarly articles, and numerous leading newspapers and magazines. He is also part of a progressive economics speaker's bureau for the Institute for America's Future in Washington D.C. (http://www.ourfuture.org). Dr. Gilderbloom is also a consultant on educational and research programs on sustainable development in developing countries in the Caribbean and Latin America (http://www.iglou.com/conferences).

The views expressed in this foreword do not necessarily represent those of the authors of the study, the University of Kentucky, the University of Louisville, or the Kentucky Hemp Museum and Library.

EXECUTIVE SUMMARY

In recent years, industrial hemp has been viewed worldwide as a versatile and environmentally friendly plant that has many industrial applications. Although it is currently grown in many European and Asian countries and even in Canada, industrial hemp is still prohibited from being grown in the United States.

This situation exists even though the current consumer and business environment in the United States may make industrial hemp cultivation and processing commercial feasible. Many consumers are starting to prefer products made from natural materials. The industrial hemp plant is a good source of natural raw materials for a number of products and is a superior source in some cases. Moreover, many farmers in Kentucky and throughout the nation are looking to alternative crops to replace their current crops, and some have touted hemp as an excellent rotation crop with much potential for agriculture.

Kentucky should be in a position to benefit from the establishment of an industrial hemp cultivation and processing industry in the United States. Historically, Kentucky has been a good location to grow hemp. Before hemp cultivation was outlawed, it had been a major crop in Kentucky and grew well in the climate. In the 1800s, Kentucky regularly accounted for one-half of the industrial hemp production in the United States (Hopkins, 1951). The climate, soil, and growing season in Kentucky also make the state a superior location for growing certified hemp seed to be planted by farmers raising an industrial hemp crop.

The Kentucky Hemp Museum and Library contracted with the University of Kentucky Center for Business and Economic Research to conduct an analysis of the potential economic impact of industrial hemp in Kentucky. This study looks at the different markets for hemp products, examining both the current markets in which foreign-grown hemp is being used, and potential or burgeoning markets that may have uses for industrial hemp.

In the report, we estimate costs for growing industrial hemp in Kentucky and provide information on potential prices farmers could expect for their hemp crop. We also compare the return from cultivating industrial hemp with the returns for other crops in Kentucky. In addition, we detail the costs of a hemp processing facility to separate the hemp into fiber and other materials. Finally, we estimate the potential jobs and earnings impacts of growing industrial hemp in Kentucky under several scenarios.

Among the key findings of this report are:

- A market for industrial hemp exists in a number of specialty or niche markets in the United States, including specialty papers, animal bedding and foods and oils made from hemp.

- Additional markets could emerge for industrial hemp in the areas of automobile parts, replacements for fiberglass, upholstery, and carpets.

- Using current yields, prices, and production technology from other areas that have grown hemp, Kentucky farmers could earn a profit of approximately $320 per acre of hemp planted for straw production only or straw and grain production, $220 for grain production only, and $600 for raising certified seed for planting by other industrial hemp growers. In the long run, it is estimated that Kentucky farmers could earn roughly $120 per acre when growing industrial hemp for straw alone or straw and grain, and $340 an acre from growing certified hemp seed.

- Industrial hemp, when grown in rotation, may reduce weeds and raise yields for crops grown in following years. Several agronomic studies have found that industrial hemp was more effective than other crops at reducing selected weeds. One study found that industrial hemp raised yields by improving soil ventilation and water balance.

- The economic impact if Kentucky again becomes the main source for certified industrial hemp seed in the United States is estimated at 69 full-time equivalent jobs and $1,300,000 in worker earnings. The total economic impact in Kentucky, assuming one industrial hemp processing facility locating in Kentucky and selling certified seed to other growers, would be 303 full-time equivalent jobs and $6,700,000 in worker earnings. If two processing facilities were established in Kentucky, industrial hemp would have an economic impact of 537 full-time equivalent jobs and $12,100,000 in worker earnings. If one processing facility and one industrial hemp paper-pulp plant were established in Kentucky, industrial hemp would have an economic impact of 771 full-time equivalent jobs and $17,600,000 in worker earnings.

- These economic impact estimates reflect possible outcomes for Kentucky given a national industrial hemp industry that is focused in specialty niche activities that have been demonstrated to work in Europe. It is important to remember, however, that technologies are under development that may allow industrial hemp products to compete in bulk commodity markets. The economic impacts that would occur if these technologies were found to be commercially feasible would be substantially greater than those identified in this report.

ACKNOWLEDGEMENTS

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INTRODUCTION

Agriculture in Kentucky and throughout the United States is an extremely competitive industry. In this environment, farmers often turn to new, specialty crops to maintain or even raise their incomes. Industrial hemp has been proposed as a crop that could be introduced and profitably cultivated in Kentucky. It is also hoped that a processing industry for industrial hemp would locate in the state, further raising rural incomes.

One reason that advocates believe that industrial hemp could be profitably cultivated in Kentucky is that industrial hemp historically was an important crop in Kentucky. The state regularly accounted for about half of national industrial hemp production during the 1800s (Hopkins, 1951). Hemp remained an important agricultural commodity in the state before and during World War II. Cultivation was subsequently stopped, however, as industrial hemp became embroiled in federal efforts to reduce the cultivation of marijuana. Much confusion has resulted over the differences in industrial hemp and marijuana. While the plants are botanically related, industrial hemp has extremely low levels of the chemical THC, which is responsible for marijuana's psychoactive effects.

The fact that industrial hemp cultivation has been banned raises the expectation for some that cultivation of industrial hemp in Kentucky could reach pre-World War II levels if cultivation is legalized. The world has changed in the last 50 years, however. Natural fibers have been replaced in part by lower cost synthetic fibers, including glass fibers. The impact of this replacement is that there has been a decline in the cultivation of hemp in some countries around the world where cultivation has remained legal (Vantreese, 1997). But because many of these countries are still developing economically, such a decline may in part be the result of the industrialization process. Further, much of the international data on hemp production includes Sunn hemp as well as industrial hemp, so it is not clear how much industrial hemp production itself has declined.

In any case, several factors suggest that the cultivation and use of industrial hemp could increase in the future in developed countries like the United States. First, recent increases in environmental concern among consumers may have increased consumer interest in purchasing products made with natural fibers that can be grown with few or no pesticides. This preference could include a willingness to pay a higher price for these products (Mole, 1997). This is not surprising since consumers' interest in paying to preserve the environment should rise as their incomes rise, much like their spending would rise on any normal good. Second, there has been a rising environmental concern among businesses in recent years, both due to regulatory pressures and voluntarily through programs like ISO 14000, which are the environmental management standards akin to the popular ISO 9000 management standards (Roulac, 1997). Third, the demand for industrial hemp may grow during periods of rising cost for alternative commodities. For example, cyclical increases in the cost of wood pulp can spark an interest in using industrial hemp in recycled paper. Fourth, the demand for industrial hemp may rise due to new potential uses for it such as in composite materials for automobiles. These arguments suggesting an increase in demand for industrial hemp are supported by cultivation data. For example, the acreage of industrial hemp in cultivation in France more than doubled between 1990 and 1997 (Bosca and Karus, 1998).

All of the evidence cited above suggests a potential for developing an industrial hemp industry in Kentucky. This study is an attempt to assess that potential for both industrial hemp farming and processing. The study was funded by the Kentucky Hemp Museum and Library.

This report begins by examining the uses for industrial hemp. The first issue is the potential to use industrial hemp as a substitute for wood pulp in paper products and cotton fibers in textiles. The report then focuses on the use for industrial hemp in a number of specialized products. This discussion includes an analysis of the many products in the United States that are currently being made with imported industrial hemp grain.

These uses suggest that a potential exists for industrial hemp to be used at least in specialty products in the United States. The next step is to examine whether the industrial hemp raw materials required in production could be provided more cheaply by Kentucky farmers and industrial hemp processors or by importing the hemp commodities from other countries. The analysis concludes that Kentucky farmers could initially earn relatively high profits by cultivating industrial hemp and in the long run could earn profits similar to those earned from cultivating other crops. This suggests that Kentucky farmers could help meet existing North American demand for industrial hemp commodities if industrial hemp cultivation is legalized.

The next section of the report moves beyond existing demand for industrial hemp products and examines how the demand for industrial hemp may grow in future years. In particular, the focus is on assessing how the demand will grow if industrial hemp begins to capture a significant share of existing specialty markets in areas such as animal feeds, animal bedding, specialty paper, and composite materials. Where possible, this analysis proceeds by comparing the existing costs for these products with the likely costs for making these products with industrial hemp.

The last section examines the potential economic impact on Kentucky should the cultivation of industrial hemp be legalized in the state. This section considers the economic impact both of cultivating industrial hemp and of establishing processing plants for industrial hemp in the state. It also addresses whether or not an industrial hemp industry would develop in Kentucky versus other states. Compared to other states, the potential for developing a hemp industry in Kentucky is favorable for several reasons. Historically, Kentucky has been the center in North America for producing certified industrial hemp seed for replanting. This advantage is due to Kentucky's growing season and soil. Due to its equine industry, the state also has an advantage at earning a higher price when selling industrial hemp for use in animal bedding. Finally, Kentucky may gain an initial comparative advantage in producing industrial hemp simply by being the first state, or one of the first states, to legalize cultivation.

Throughout the last section of the report, estimates of the potential size of the industrial hemp industry are based on existing technologies. In particular, there is a focus on niche markets for industrial hemp that have already been developed in Europe. The value of this approach, naturally, is that it reduces the likelihood that the resulting projections will be too optimistic because they are based on technologies that may or may not turn out to be commercially viable. This is essentially the same approach to estimating the potential size of the hemp industry that has been used by the nova Institute (1996) and in the book *The Cultivation of Hemp* published by HEMPTECH (Bosca and Karus, 1998).

The drawback of this approach is that it fails to consider how much the industry might grow if new industrial hemp processing technologies currently under development turn out to be commercially viable. These technologies hold the potential for processing hemp into various products at a price low enough to compete with existing bulk commodities. For example, technologies are under development to make plastic fibers from industrial hemp that are competitive with bulk plastics. Work is underway to develop a processing technique to "cottonize" industrial hemp fiber so that it is more cost-effective for making clothing apparel. Finally, oil from hemp grain and other natural oils may be substituted for petroleum in future manufacturing of inks in order to meet environmental regulations to reduce organic volatile emissions, to which ink manufacturing is a major contributor.

To meet the hemp straw and grain requirements of these bulk commodity uses, hundreds of thousands of acres of industrial hemp would need to be cultivated in North America, and perhaps more. In addition, many hemp processing facilities would need to be built. This would clearly raise the potential economic impact of the industrial hemp industry far above the numbers presented in this report.

USES OF INDUSTRIAL HEMP

Before beginning a discussion of the uses for industrial hemp products, it is worthwhile to define a few terms. The term industrial hemp straw refers to the stalk of the plant. This stalk can be separated, or decorticated, into two components: hurds and fiber. Fiber refers to the long strands of material that come from the outer rings of hemp straw. Hurds refer to the inner material of the straw. Industrial hemp grain refers to the seeds cultivated for use in producing industrial hemp oil and meal. Industrial hemp certified seed refers to hemp seed that has been cultivated for the purpose of replanting. Industrial hemp grain is often referred to as hemp seed in common usage. However, it is called industrial hemp grain in this report to draw a clear distinction between grain for processing and certified seed for planting.

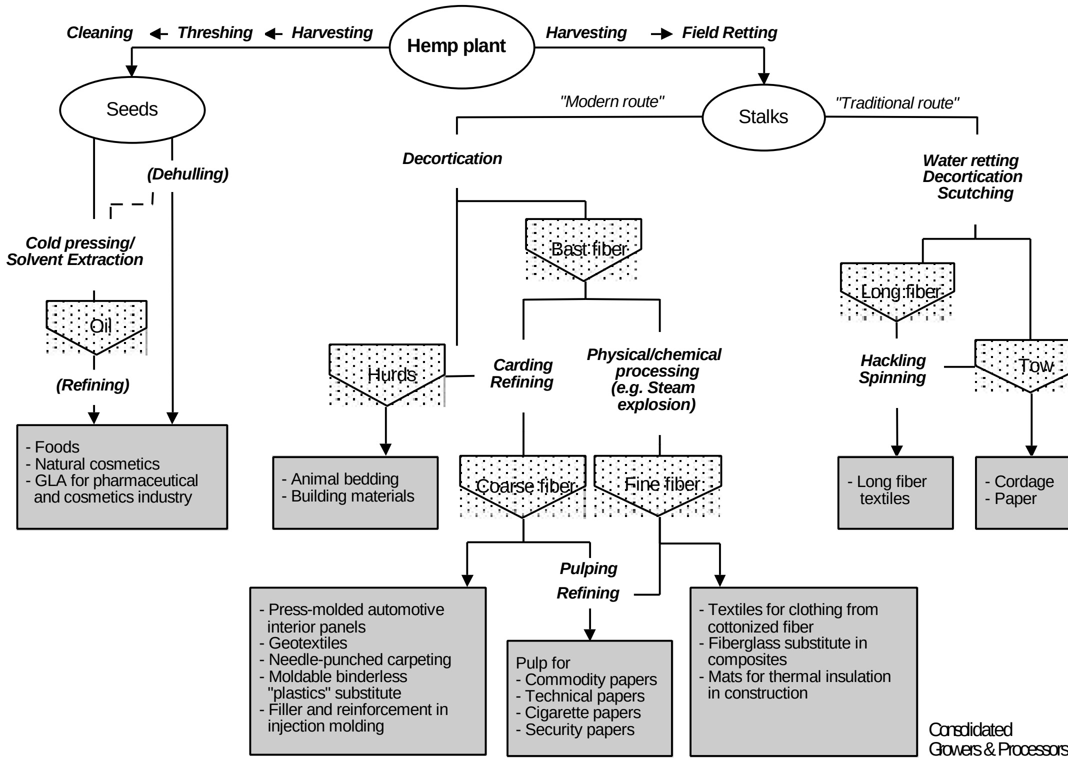
One of the frequently cited positive qualities of industrial hemp is that there are many applications and uses available for it. Applications have been discovered for using hemp in everything from food products to textiles to structural materials. Consequently, the viability of industrial hemp as an agricultural crop is strongly linked to these markets and products for which hemp can feasibly be used to produce.

This concept of feasibility includes 1) whether industrial hemp can physically be used to make a certain product and 2) whether it is profitable to use industrial hemp rather than some alternative fiber, synthetic, or food. This section concentrates on listing products that can be made using industrial hemp. Some preliminary comments are also made on the potential for the profitability of industrial hemp products. It is worth noting, however, that even in light of cheaper alternatives, certain “niche” markets for hemp products may still exist. Some consumers may prefer products made from hemp rather than cheaper alternatives simply because they receive some intrinsic value from purchasing hemp products.

The cost of growing, harvesting, and processing industrial hemp straw and grain is naturally a major factor determining whether an industrial hemp product can be profitable. Moreover, these costs vary depending on the particular form of processing (whether for fiber, grain, or both). Thus, special attention will be paid to whether a product is made from: 1) industrial hemp hurds and fiber, which require substantial processing, or 2) industrial hemp grain, which is already processed into food and cosmetic products at many sites in the United States. Figure 1 outlines some potential uses for the different components of industrial hemp and also illustrates some alternative methods for separating hemp fiber from hemp hurds.

The potential price that an industrial hemp product may receive is also an important factor influencing profitability. Given the current costs of industrial hemp cultivation and processing, there is reason to believe that hemp can better compete in the higher price “high-value” product markets than in bulk commodity markets. Thus, the nature of the market in which each industrial hemp product is sold will also be evaluated.

FIGURE 1: Industrial Hemp: Processing Routes and Products



Textiles, Apparel, and Paper Products

Using industrial hemp in the production of textiles and apparel potentially represents a major market. In particular, textiles and apparel made with industrial hemp can be produced and sold in the high-value end of these markets. Industrial hemp may appeal to consumers willing to pay more for apparel items such as clothing, hats, and bags or textile items like upholstery and rugs made with non-cotton natural fibers in general, or industrial hemp in particular. Industrial hemp products, however, would have more trouble competing in the bulk portions of this market where consumers will focus on price.

Among these uses, industrial hemp canvas, rugs, and upholstery may be better able to compete on price with cotton or synthetic products than apparel products made with industrial hemp. This is because industrial hemp fibers, when properly grown and processed, more closely match the specifications of existing state-of-the-art canvas and rug weaving machinery than textile and apparel machinery (Kime, 1998). Yet, machinery does exist to weave industrial hemp fibers into textiles, and to process it further into apparel. Such production is already occurring in some middle-income countries, such as Hungary, and lower-income countries such as China, Romania, Russia, and the Ukraine. Production has been more limited in western European countries and North America, both due to lower levels of demand in the West and higher production costs resulting from higher labor costs. As a result, textiles for use in producing hemp clothing are often imported from lower-income countries such as China and Romania.

This, however, may change. As demand rises, there will be more incentive to establish new production facilities in North America. As is the case in many industries, these facilities may be able to compete with factories in lower income countries by utilizing more sophisticated machinery that will require fewer workers to operate and produce a higher quality product. One such business has already begun operation in North America. American Hemp Mills has begun to spin industrial hemp textiles in the United States using imported fiber (Goldstein, 1998). The company hopes to produce a cloth of higher quality and with a greater variety of colors and patterns than is available with imported cloths.

As with textiles, the current demand for industrial hemp paper is in high-value paper products. For example, paper pulp made from industrial hemp can be used in higher cost "tree-free" office and stationary paper. The paper based on hemp pulp requires less bleaching and fewer chemicals than paper made from wood pulp and also is more resistant to decomposition and yellowing as it ages. Thus, hemp-based papers potentially could form a niche market in higher value office papers and stationery. Under current technologies, however, paper made with industrial hemp cannot compete with low-cost office papers. Other higher value paper products that might be made from industrial hemp include food wrappings, cigarette papers, tea bags, currencies, and packaging board (Leson, 1997).

Other Specialty Products Made From Hemp Stalks

There appears to be a number of additional uses for industrial hemp stalks in specialty products. European research indicates that industrial hemp fiber may be a lower-weight and lower-cost alternative when used in composite materials. Essentially, industrial hemp can be mixed with other products to produce high-value industrial goods at a lower price. The advantages of the composites are lower prices, a lighter weight, and lower recycling costs. German researchers have been able to make an industrial hemp and polypropylene composite which offers a lower cost than polypropylene alone for use in automobile interior paneling and headliners (Riedel, 1997). Other German researchers also believe that industrial hemp composites could be used in automobile, airplane, and office furniture parts (Doring, 1997).

It must be emphasized, however, that these findings are preliminary and that all the researchers felt more experimentation was needed before hemp composites could be used in commercial manufacturing applications. Finally, a new plaster product made of a mixture of hemp hurds and lime can make strong and high quality plaster to be used in building rehabilitation and construction (Schiller, 1997). This plaster can be made at a lower price than conventional plaster materials, at least given relative prices in Germany. Researchers in France have also used hemp products for building materials such as blocks and insulation (Le Texier, 1997).

High-value animal bedding is another market in which industrial hemp products can compete. Firms in England, France, and The Netherlands are producing horse bedding made from industrial hemp hurds. This form of horse bedding has been found to compete well with higher-cost bedding made from wood shavings and treated straw because of its absorbency and biodegradability (Lowe, 1998). Another potential product for industrial hemp might be biomass fuels. Industrial hemp could be converted to create methanol or ethanol, fuels that burn more cleanly than fossil fuel. Further, industrial hemp-based fuels only release CO_2 into the atmosphere that the hemp plant had drawn in during photosynthesis.

Specialty Products Made from Hemp Grain

Industrial hemp grain, and oil made from industrial hemp grain, can be used to make a number of high-value products. Essentially, hemp competes in these markets with other high-value products made from natural oils. Currently, many of these products are already produced in the United States by processing imported industrial hemp grain. Markets for these higher value products are growing, and while the future is hard to predict, it is reasonable to believe that markets for these luxury goods will rise as disposable incomes continue to rise in the United States.

Shampoos and skin care products are one of the most promising groups of products made from industrial hemp grain oils. In addition to having a fashion appeal, skin care products made with industrial hemp are able to penetrate three layers of skin, improving their effect. According to a German cosmetics manufacturer, the prices of hemp shampoos and cosmetic oils are high but competitive with other natural cosmetic products (Stamm, 1997). Shampoos and skin care products made from industrial hemp grain can be successful at the high end of the market due to their high quality and potential fashion appeal.

Besides personal cleansers and cosmetics, there are other industrial uses for hemp oil. For example, oils have been used in various printing and painting applications. Paints made from hemp oils have been found to penetrate wood better than other paints, and hemp oils have also been used for printer's colors in offset printing (Wirtshafter, 1994). Indeed, hemp oil historically was a major component in paints and varnishes. Moreover, hemp oil can be used in cleansers for printing equipment. Finally, hemp oil has been used in some glues and industrial lubricants.

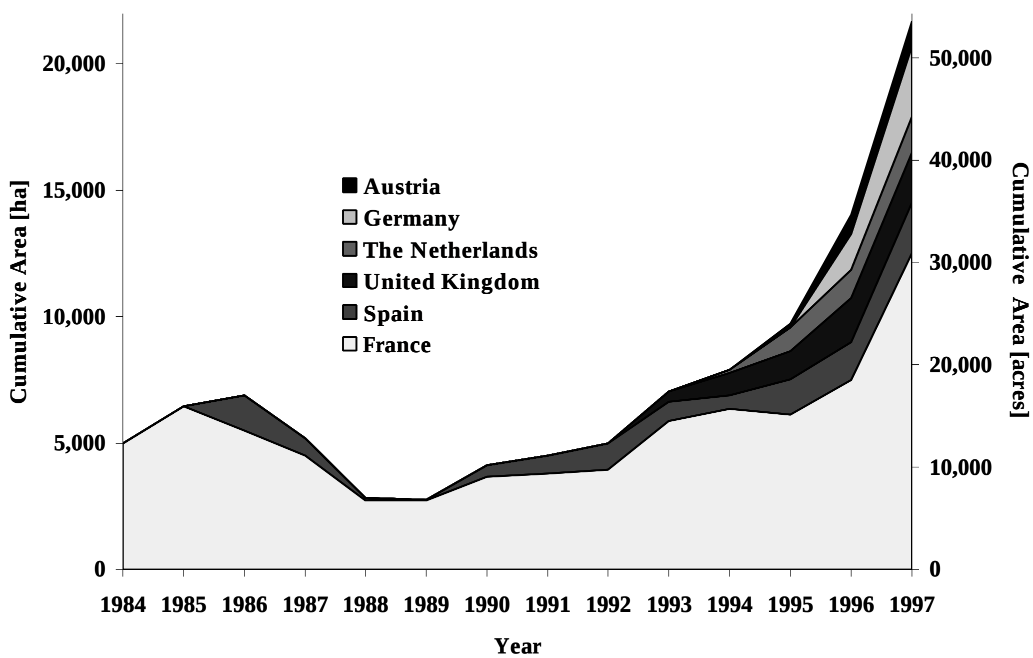
Specialty food products are another higher value market where industrial hemp products can compete. Firms have experimented with a variety of products such as cheese, margarine, beer, and candy bars. In addition, the availability of dehulled hemp grain in recent years has made it easier to utilize industrial hemp in food, including in food oil (Rose, 1998). Indeed, one of the largest potential markets appears to be food oil made from hemp grain. This hemp oil is eaten with food such as potatoes or used as a marinate salad dressing (Wirtshafter, 1994). This oil has an advantage over substitutes such as flax oil because it has a much longer shelf life (Wirtshafter, 1994). Such food oils are already being produced in the United States from imported grain and sold competitively.

Like other high-value industrial hemp products, there may be inherent appeal in the demand for food made with industrial hemp. However, there also are dietary reasons why food products made from industrial hemp can compete with foods made with other crops. Industrial hemp oil has a better profile of key nutrients, such as essential fatty acids and gamma-linolenic acid, than other oils (Wirtshafter, 1994), and a similar profile of other nutrients, such as sterols and tocopherols. Also, industrial hemp meal has a high protein efficiency ratio (Rose, 1998), which means that it has a high percentage of proteins that are easy to digest.

Hemp grain and its byproducts also have been found to be useful as animal feed. For example, industrial hemp grain has been used in birdseed in the United States for decades (Wirtshafter, 1997). In addition to the whole grain, researchers also have examined the market potential for hemp meal, which is a byproduct from making hemp oil, as an animal feed. Horse and cow feeds made with hemp press cake have been found to be competitive in the U.S. with other feeds (Wirtshafter, 1997), in part because the feeds made with hemp meal improve hoof and hair quality (Coulter, 1998; Billings, 1998). However, animal feeds with a hemp meal component were not found to be appropriate for poultry or swine (Slansky, 1997).

Finally, it should be mentioned that the demand for industrial hemp in a variety of uses has grown rapidly in western Europe in the last decade. Cultivation has quadrupled from 1990 to 1997. This very rapid growth occurred in part because countries such as The Netherlands, United Kingdom, Germany, and Austria only recently legalized industrial hemp cultivation. Even in France, however, where the cultivation of industrial hemp has remained legal during the last 50 years, cultivation of industrial hemp has more than doubled in the 1990s. This growth is illustrated in Figure 2 below.

FIGURE 2: Hemp Farming in the European Union, 1984-1997



Source: Figure 1A in *The Cultivation of Hemp* (1998).

POTENTIAL FOR INDUSTRIAL HEMP CULTIVATION IN KENTUCKY

The many uses for industrial hemp and its historic cultivation in Kentucky suggest that there is a potential for industrial hemp products to be grown and processed in the United States and Kentucky. Whether this occurs, however, is a function of the cost and feasibility of growing industrial hemp in Kentucky and the United States versus the price of importing industrial hemp from other countries.

The feasibility of growing industrial hemp refers not just to legal questions but to the presence of industrial hemp processing facilities. The establishment of industrial hemp farms in Kentucky or elsewhere in the United States would be extremely difficult if there were no processing facilities in the United States to receive industrial hemp straw and grain. Any such farms also would have difficulty in profitably exporting industrial hemp products to overseas processors. This is because industrial hemp straw is very bulky, which leads to high transportation costs. Farms that grow industrial hemp straw must be located near a processing plant, typically within a 50-mile radius.

Thus, the location of processing facilities in Kentucky becomes a key factor influencing the feasibility of establishing industrial hemp straw cultivation in the state. This is because there are currently no industrial hemp straw processing facilities in Kentucky or elsewhere in the United States, although there is one slated to begin operation in Chatham, Ontario, Canada (near Detroit) in 1998, and another in Tilsenburg, Ontario. Short of locating an industrial hemp processing facility in Kentucky, it may be possible to process industrial hemp using modified tobacco processing equipment. However, this might not be as cost-effective as using equipment designed for decorticating industrial hemp.

Feasibility is less of a concern for industrial hemp grain farming. Currently, there are firms that process industrial hemp grain located in the United States, even in states adjacent to Kentucky. As is discussed below, these firms could process grain grown in Kentucky, if Kentucky farms are price competitive.

Price competitiveness refers to whether the industrial hemp industry in Kentucky and the United States can compete with foreign competitors. In the case of industrial hemp grain, this refers to whether industrial hemp grain can be grown for less than the cost of importing grain from China, Romania, and other countries. For industrial hemp straw, this is a more complicated question because raw hemp straw would be unlikely to be transported from other countries due to the high transportation costs of this bulky commodity. In this case, the question would be whether the combination of industrial hemp farmers and processors could be cost-competitive with other nations.

The following section discusses why processors of industrial hemp straw need to be located near industrial hemp farms and why processors of industrial hemp grain do not. This section is followed by an analysis of how much industrial hemp is currently demanded by industrial hemp processing facilities in the United States. Finally, the price competitiveness of

Kentucky industrial hemp producers is analyzed in order to determine whether manufacturers of hemp-based products would purchase domestically-produced industrial hemp or imported hemp.

Location of Industrial Hemp Processing Facilities

The potential for developing an industrial hemp industry in Kentucky may be influenced by whether processing facilities also locate in the state. In particular, if it is true that industrial hemp facilities need to be located very near where industrial hemp is grown, then the establishment of industrial hemp farming in Kentucky will depend on the location of processing facilities in the state, along with action by farmers. Another possibility would be to process industrial hemp using modified tobacco-processing equipment.

The choice of where to locate industrial hemp processing facilities is influenced in large part by transportation costs. In particular, if all other economic factors are equal, processing facilities are located in the area that minimizes total transportation costs. This minimum transportation cost location, naturally, is selected based on the volume-miles of product that needs to be hauled at alternative locations. The weight that must be hauled is also a factor.

The implication of this drive to minimize transportation costs is straightforward for agricultural crops and forest products. For bulky crops and forest products where the primary processing facility takes in a bulky commodity and reduces its weight and bulk during processing, there is an incentive to locate the processing facility near where the commodity is harvested. An example of this is logs and sawmills. Logs are very heavy and bulky, even compared to cut board. There is a substantial reduction in weight and bulk as sawmills cut logs into board. As a consequence, most sawmills are located in or near the forest from which logs are cut.

Thus, for bulky commodities where the bulk is reduced substantially by processing, processing facilities are located quite near where the commodity is grown.[1] For commodities that are not bulky, or where processing does not reduce product weight or even increases it, then it will not be as necessary to locate the processing facility near where the commodity is grown.

These two scenarios are important for the cases of industrial hemp straw and grain. For industrial hemp grain, which is not a bulky commodity, it is not imperative to locate processing facilities near the farms where the industrial hemp grain is cultivated. These processing facilities could be located throughout the country according to other economic factors besides transportation costs, such as labor costs or just the preference of the business owner. The most obvious evidence of these outcomes is the fact that grain is currently imported into the United States for further processing while hemp straw is not (with some very rare exceptions). If it is commercially feasible to import industrial hemp grain from overseas, this indicates that it may

[1] For bulky commodities where processing facilities are very large, such as beef processing plants, these plants may be located relatively far from many of the farms that produce cattle.

not be necessary to locate facilities near industrial hemp farms in order for those farms to be commercially feasible.

The situation is different for industrial hemp straw. Industrial hemp straw is a very bulky commodity that loses both volume and weight as it is separated into hurds and fiber. In any case, hurds and fiber may be sent to different destinations after being separated. This is a situation that calls for processing facilities to be located near where the industrial hemp straw is grown.

The need to locate industrial hemp processing facilities near where hemp straw is grown has been verified in several research studies and in the actual practice of the industrial hemp industry in several countries. Analysis in the comprehensive study of the industrial hemp industry, *The Hemp Product Line Project*, by the nova Institute of Germany, reported that industrial hemp farms must be located within 30 kilometers (about 19 miles) of the hemp processing facilities. The KENEX corporation, which has set up a decorticating facility just outside of Chatham, Ontario, Canada, reported that it will be purchasing hemp grown within a 50 mile radius of their processing facility. Hempline, Inc., which has set up a decorticating facility near London, Ontario, Canada reported that it will be purchasing industrial hemp grown within a 50 kilometer (31 mile) radius of their processing facility. Similarly, farms growing industrial hemp to supply an industrial hemp decorticating facility in The Netherlands are located within 50 kilometers of that facility.

All of this suggests that decorticating facilities for industrial hemp straw, and perhaps further processing facilities, will need to be located nearby to industrial hemp farms. Thus, the establishment of an industrial hemp industry for growing straw will require that either processing facilities locate in Kentucky, or existing tobacco-processing equipment can be modified to process industrial hemp at a competitive cost. However, the establishment of industrial hemp farms in order to grow hemp grain will not ensure or require that seed processing facilities will locate in the state.

Demand for Industrial Hemp by Hemp Processors

The amount of industrial hemp that would be grown in Kentucky if cultivation were legalized naturally would depend on the demand for the product. Demand refers to the likely tonnage of industrial hemp straw and grain that would be demanded by processing facilities. This tonnage demanded can first be estimated based on current demand by processors. Although, the quantity of industrial hemp demanded is likely to grow if domestic cultivation of industrial hemp significantly lowers the price of industrial hemp fiber, hurds, and grain.

Due to this uncertainty, estimates for future demand for hemp will be presented under a number of alternative scenarios in a later section of this report. Estimates presented in the current section will depend on the current demand for industrial hemp. The current demand for industrial hemp will serve as a lower bound for the future. Other scenarios would assume continuing growth in demand for products currently being made from industrial hemp, or growth in demand based on the adoption in North America of uses for industrial hemp currently found in Europe.

A substantial quantity of industrial hemp grain is currently demanded, and therefore imported, into the United States by domestic grain processing firms. Further, grain processing firms are being established in Canada that will use grain cultivated in that country but will help meet the demand for hemp oil and other hemp grain products in the United States. An estimate of the current demand in the United States for hemp grain products was developed by contacting these firms and asking how many tons of industrial hemp grain they currently purchase per month for their production process. Processors in Canada were asked about how much industrial hemp grain they planned to cultivate in 1998. Based on this, it is estimated that there is a total demand for 1,300 tons of industrial hemp grain in North America at current prices.[2] At a yield rate of 1,000 pounds of seed per acre, this implies that there would be enough demand for industrial hemp farmers to cultivate 2,600 acres of grain production under current conditions. This yield of 1,000 pounds per acre is based on current yields in Germany, and is the same yield used in farmer profit per acre estimates for industrial hemp discussed later in the report.

As for hemp grain prices, farmers certainly cannot charge more than it costs to import hemp grain from overseas, including Canada. Therefore, one estimate of the price that farmers in the United States could expect to receive is the price that farmers in Canada are going to receive from the hemp grain and fiber processing facilities operated by KENEX of Chatham, Ontario. Another way to estimate the price levels that farmers can expect to receive is based on the current price of importing hemp from other countries. Based on these sources, and an assumed $0.01 per pound cleaning cost, the price per pound that farmers are expected to receive for uncleaned grain is $0.39 per pound. This price excludes the part of the cost going to sterilize grain, since this part of the cost would not be received by the farmer. This means it is important to keep in mind that the current price of importing industrial hemp grain, including the sterilization cost, is substantially higher that $0.39 per pound.

Relative to the demand for grain, the demand for industrial hemp straw is more difficult to estimate. As discussed above, the demand for industrial hemp cultivated in Kentucky will be determined by both the overall demand for industrial hemp fiber and hurds regionally and nationally, and by whether an industrial hemp processing facility happens to locate in Kentucky, or very near its borders. Thus, determining the demand for industrial hemp straw will not simply depend on counting the current demand at existing industrial hemp processing facilities, of which there are only two in North America located near Chatham and London, Ontario, Canada. Instead, determining the demand for industrial hemp straw depends on determining whether it is economically feasible to develop industrial hemp processing facilities in Kentucky given the price of imported industrial hemp, as well as the demand for industrial hemp fiber and hurds. One estimate of the current demand for industrial hemp fiber is import data assembled by the United States Trade Administration (USTA). Table 1 shows the tons of hemp products that were imported into the United States in 1996 and 1997, according to USTA

[2] The level of demand, even at current prices, might be higher if cultivating industrial hemp was legal. In particular, the government's ban on industrial hemp grain may discourage some manufacturers from utilizing the grain even though it is available legally, and sterilized, from brokers in the United States.

figures. There were 417 tons of industrial hemp stalk, fiber, or yarn imported into the United States in 1997, along with 700,000 square meters of woven fabric. Only a small share of imports was raw stalk that was not decorticated, that is, where the fiber of the hemp was separated from the woody interior. The rest of the imports required processing. It should be noted that the figures in Table 1 do not include imported hurds or string, since these were not reported separately in USTA data. These import figures do not primarily represent industrial hemp fiber imported from Canada.

TABLE 1: Imports of Industrial Hemp Products in 1996 and 1997

Product	1996	1997
Raw Hemp Stalk, Not Decorticated (Tons)	21.8	6.7
Raw Hemp Stalk, Decorticated (Tons)	36.6	97.0
Hemp Yarn (Tons)	6.5	313.1
Woven Hemp Fabrics (1000 Square Meters)	435.3	705.3

Source: United States Trade Administration

Several hundred acres of industrial hemp cultivation would be required to meet the level of demand illustrated in Table 1, as is discussed later in this report in the section on Textiles. However, given this current demand, it is unclear how many acres of industrial hemp would be cultivated in the United States even if cultivation were legal. There are no industrial hemp processing facilities in the United States at this time. It might be possible to process industrial hemp with existing equipment in the United States, such as modified tobacco or flax processing equipment. However, given that this equipment was not designed for processing industrial hemp, industrial hemp fiber processed with it might have difficulty competing on price and quality with imported hemp products, particularly fiber imported from the two new processing facilities in Ontario, Canada. Still, some industrial hemp straw might be cultivated and processed in the United States, perhaps on new acreage devoted to cultivating industrial hemp for straw. Much of the demand from industrial hemp processors in the United States might be met by industrial hemp straw from acreage cultivated primarily for grain.

The price that a U.S. farmer would receive for a ton of industrial hemp straw would be based on the expected price of the byproducts of industrial hemp straw: hurds and fiber. In particular, given that industrial hemp straw is separated into 30 percent fiber and 70 percent hurds, the expected price of fiber and hurds can be used to calculate the total return from one ton of hemp straw. Subtracting the cost of decorticating the hemp from this amount of return will yield the price farmers can receive at the factory gate for a ton of industrial hemp.

The average price for raw industrial hemp fiber in the long run is expected to fall within the range of $400 to $600 a ton. The price paid to processors for industrial hemp hurds is expected to vary even more. As is discussed below, the price paid for industrial hemp hurds in the long run is expected to be $100 a ton for use as animal bedding, which is a limited market, down to $40 a ton for use in medium density fiber board, which is a large market (Lloyd, 1998). These varying prices for hurds and fiber suggest that farmers may receive a widely varying price for industrial hemp straw. Table 2 shows the prices that farmers could be paid for industrial hemp straw in the long run under alternative assumptions for hurd and straw prices. These figures use $100 a ton cost for decorticating. This cost is explained in Appendix 1 below.

Based on Table 2, the price that farmers would receive would range from $40 to $140 a ton under the alternative assumptions. This figure is less than the US$200 a ton price that the KENEX corporation expects to pay for raw stalk in Canada (Laprise, 1997). Current import prices are much higher, but these Canadian prices set a lower bound for the price under current conditions. Thus, the current price of industrial hemp for its very specialized uses at this time is expected to be the price in Canada. KENEX indicated a price of $200 a ton in U.S. currency. Hempline, Inc. will be offering farmers a similar base price, although it will offer a bonus if farmers can deliver stalk grown to specification (Kime, 1998). Market forces in the long run, however, are expected to push the price down to the levels in Table 2 as the industry grows more competitive and the uses for industrial hemp fiber and hurds expand. The price paid for hemp straw harvested from fields where industrial hemp is cultivated primarily for grain is expected to be $120 a ton. It is expected to have a lower value because the quality of industrial hemp fiber is expected to be lower in industrial hemp cultivated primarily for seed. Finally, while overseas producers currently selling industrial hemp fiber in North America might be expected to drop their prices in order to maintain their North American customers, domestic producers are expected to be able to maintain a price advantage. This is because transportation, brokerage, and import fees would increase the cost of industrial hemp imported from Europe or Asia by as much as 20 percent (Kime, 1998).

TABLE 2: Potential Price Paid to Farmer for Ton of Industrial Hemp Straw Under Alternative Prices for Straw and Hurds

Fiber Price	Hurd Price	*Per ton* Returns*	Decorticating Costs	Price Paid To Farmer
$400	$40	$139	$100	$39
400	100	180	100	80
500	40	167	100	67
500	100	208	100	108
600	40	195	100	95
600	100	236	100	136

* All calculations of the return assume that one ton of hemp straw yields 0.68 tons of hemp hurds, and 0.28 tons of hemp fiber. It is assumed that .04 tons of material is lost during the decorticating process.

Under moderate levels of industrial hemp production, it is anticipated that industrial hemp hurds will be sold for close to $100 a ton for animal bedding, as is explained below. This implies prices nearer to $100 a ton for farmers. If hundreds of thousands of tons of hemp are produced, however, then hemp hurds will need to be sold for lower-value uses such as fiber board. This implies prices closer to $70 a ton for industrial hemp straw if there is large scale production of industrial hemp straw.

Another potential market is certified seed. Certified seed is seed which can be used for planting and growing industrial hemp as opposed to grain which is grown for use in processing and manufacturing. The demand for certified seed in North America naturally is determined by the amount of industrial hemp that will be planted and grown for grain and straw. Thus, the demand for certified seed under alternative scenarios can be estimated based on the demand for industrial hemp grain and straw under each alternative scenario. Under the current demand conditions, it is estimated that 2,600 acres of industrial hemp for grain will be grown. This implies a demand for 30 acres of certified seed under current conditions given the seed requirements illustrated in Table 3 in the following pages. The price per pound of seed is estimated to be roughly $1.20 per pound. This is less than the $2.50 per pound that seed companies are expected to charge for certified seed. The difference in price is expected as a return for the seed company for developing the seed variety. It is expected that holders of the seeds will lease the right to grow certified seed to farmers at a price roughly three times the price paid for industrial hemp grain, which was $0.39 per pound. This is in line with the premium for growing certified seed in other industries. It is further assumed that the yield for seed that qualifies as certified will be roughly 75 percent of the yield for grain.

Potential Price Competitiveness of Kentucky Industrial Hemp Growers

The next step in estimating how much industrial hemp would be grown in the United States is to assess whether growing industrial hemp would yield higher profits than growing other crops. The outcome, naturally, depends on the prices that farmers could expect to receive for industrial hemp straw and grain. Farmers would only be expected to switch to growing industrial hemp if they anticipated earning a higher profit from growing industrial hemp than could be earned from growing other crops. Making these comparisons, though, is a difficult process, even for crops where production methods and technologies are well known, such as for wheat, corn, tobacco, and hay. Estimating costs is complicated by changes in the production technologies farmers may use from year to year as well as changes in the prices of inputs of fertilizer and labor, weather, and other factors.

As was mentioned above, the price that farmers can expect to receive for industrial hemp straw, grain, and certified seed can be based on the current price of imports into the United States, and the prices paid in Canada. These prices were estimated to be $0.39 per pound of grain, $1.20 per pound of certified seed for planting, and $200 per ton for hemp straw. Again, these prices are expected at the current small levels of production and consumption of industrial hemp. Prices likely would need to fall as industrial hemp becomes a larger industry in terms of production and consumption. Furthermore, hemp straw harvested from fields where industrial hemp is cultivated primarily for seed is expected to be worth $120 per ton, due to its lower fiber content. Given these prices, and estimates of growing costs for growing industrial hemp, it should be possible to estimate profits per acre to farmers for growing industrial hemp. These profits can then be compared to profits from other crops to determine whether many Kentucky farmers would be likely to cultivate industrial hemp.

A variety of data sources were consulted to develop estimates of the cost of growing industrial hemp for fiber, grain, or certified seed. These sources included production cost estimates developed for Kentucky by Dave Spalding of the University of Kentucky College of Agriculture; production cost estimates for Canada assembled by Gordon Reichert of Agriculture and Agri-Food Canada; production cost data based on hemp cultivation at Laprise farms in Chatham, Ontario; and production cost estimates for hemp cultivation in Germany. The cost estimates prepared by Dave Spalding will be used in this study to calculate the returns to Kentucky farmers from cultivating industrial hemp. These cost estimates are presented in Table 3 below, after being updated.

Spalding's data are used for three reasons. First, the alternative data sources, taken together, generally support the cost estimates developed for Kentucky by Spalding. Second, Spalding's work provided the only estimates that utilized Kentucky costs for factors such as labor or fertilizer. Third, Spalding's work was the only study that produced estimates for all three types of industrial hemp cultivation that this report will study: hemp straw, hemp grain, and certified hemp seed. Other studies made estimates for hemp for straw or hemp grain, but no other estimates provided a consistent source for cost estimates for all three purposes.

Spalding's estimates were made for 1993. Thus, the estimates must be updated to 1997 values. Following Byars and Pagoulatos (1997), costs will be updated based on the increases in costs for growing corn that occurred in Kentucky between 1993 and 1997. For example, if the cost for machine repair in corn production grew 10 percent from the 1993 to 1997 according to the *Field Crop Enterprise Cost And Return Estimates For Kentucky* in each year, then Spalding's repair costs for growing industrial hemp also will be increased by 10 percent.

Spalding's estimates for cultivation costs in 1993 were taken from the publication *Report to the Governor's Hemp and Related Fiber Crops Task Force* and updated to 1997 according to this approach, with a few exceptions. The first exception had to do with certified seed costs. A price of $2.50 in 1997 is substituted for Spalding's $2.00 per pound in 1993 because the $2.50 a pound seed price is the price to be charged by KENEX of Chatham, Ontario. Second, a requirement of 50 pounds per acre of certified seed for cultivating industrial hemp for straw is substituted in Table 3 for the 40 pounds per acre used in the *Report to the Governor's Hemp and Related Fiber Crops Task Force.* This 50 pounds per acre requirement recently was recommended as a revision by Spalding (1998), and is more consistent with seeding requirements experienced in Canada. In addition, the repair costs in Spalding's data were increased by 50 percent since Spalding did not account for higher repair costs for equipment when harvesting industrial hemp. Reichert argues that repair costs will be higher in his estimates published in Marcus (1997). Reichert also argues that industrial hemp cultivation for grain alone will require either a greater seeding rate than in Table 3 or the use of herbicides since sparser seeding of the hemp plants when cultivating industrial hemp for grain alone will not allow the rapidly growing industrial hemp to crowd out weeds. While Bosca and Karus (1998) argue that herbicide is not required at the seeding rate for grain cultivation reported in Table 3, a herbicide charge will still be added in order to err on the side of caution. Following Reichert, a $10.95 per acre charge for herbicides is added to costs. Finally, storage costs and transportation costs to the processing facility are added to these estimates by Spalding. Such estimates are typically not included in growing cost estimates, but it is appropriate to add these costs here. It is appropriate since the prices for industrial hemp straw and seed quoted below when determining farmer profits are the price paid at the processing facility for year-round delivery. The cost for hauling a ton of straw or seed to a processing facility is assumed to be $8.00 per ton for a 25-mile trip based on a 2.5 hour trip, and the cost of operating a truck and trailer. A storage cost of only $5 per acre is assumed since hemp straw can be stored outdoors under a tarp.

Given these adjustments, the resulting 1997 costs are reported below in Table 3. The increase in price from 1993 to 1997 special adjustments excluded was roughly 15 percent, which is slightly more than the overall inflation rate of 11 percent over the period.

The higher growing costs for certified seed compared to grain occurred for two reasons. Monitoring costs for certification are the reason for higher fixed costs for certified seed. Extra labor costs for certified seed reflect the increased labor involved in growing seed for planting.

The above cost estimates did not include any cost for government monitoring of farmers growing industrial hemp. This is done because, while there are expected to be monitoring costs that are passed along to farmers as well as processors and importers, these costs are expected to be limited. Consider the case of Canada, where the cultivation of industrial hemp has been legalized. Canada will monitor industrial hemp farmers through the government agency Health Canada, which is the Canadian Health Ministry, and through local police. Health Canada's policy is to pass along monitoring costs to the farmer (Health Canada, 1997). Further, Health Canada has carefully developed policies to monitor farmers growing industrial hemp. This policy includes a 10-year background check of farmers for drug convictions, satellite monitoring of the plots where industrial hemp is grown, a minimum 10-acre requirement for growing industrial hemp, and restrictions on growing industrial hemp near schools or densely populated areas (Lecuyer, 1998).

Even with this comprehensive policy, however, per acre monitoring costs are not expected to be high for farmers. Farmers are expected to pay US$20 dollars annually for the background check (Lecuyer, 1998). Further, farmers will incur a cost of US$30 per year to obtain satellite coordinates for the fields where they will grow industrial hemp (Lecuyer, 1998).[3] This US$50 total monitoring cost, divided by an average of 25 acres per participating farmer, leads to an estimate of US$2 per acre in monitoring costs. These modest monitoring costs in Canada suggest that licensing and monitoring costs in the United States need not significantly lower profits for industrial hemp farmers in Kentucky, provided that these licensing and monitoring costs are based on cost recovery, as in Canada, rather than punitive charges.

[3] In the initial year, KENEX will determine the satellite coordinates for the farmers that they are working with. Although, in future years, KENEX may charge for this service. The cost to KENEX for determining the coordinates is US$ 800 for purchasing the necessary equipment, and approximately US$800 for the wages and benefits of a worker to spend a week determining the coordinates. There are 54 growers working with KENEX, so this translates into approximately US$30 per farmer.

TABLE 3: Growing Costs and Returns for Industrial Hemp using Current Technology, Yields, and Prices

Variable Costs		Straw $/acre		Grain $/acre		Seed Certified $/acre		Straw & Grain $/acre
Seed (lbs.)	(50)	$125.00	(10)	$25.00	(10)	$25.00	(50)	$125.00
Fertilizer		45.01		45.01		45.01		45.01
Herbicides		0.00		10.95		10.95		0.00
Lime (tons)	(1)	12.12	(1)	12.12	(1)	12.12	(1)	12.12
Fuel, Oil (hrs)	(4.5)	18.43	(2.2)	14.06	(2.2)	14.06	(2.2)	22.25
Repair		16.14		30.38		30.38		23.12
Interest		8.38		5.24		5.24		8.94
Storage		5.00		5.00		5.00		5.00
Transport to Processor		27.20		8.00		5.60		24.00
Total Variable Costs		$257.28		$155.76		$153.36		$265.44
Fixed Costs *		$50.27		$45.00		$70.73		$75.05
Operator Labor (8)	(8)	$56.00	(8)	$56.00	(10)	$70.00	(9)	$63.00
Total Enterprise Costs		**$363.55**		**$256.76**		**$294.09**		**$403.49**
Stalk Yield		3.4 t / acre		0.5 t / acre		0.5 t / acre		2.25 t / acre
Price per Ton		$200 / t		$120 / t		$120 / t		$200 / t
Total Stalk Revenue		$680 / t		$60 / t		$60 / t		$450 / t
Seed Yield				1,069 lbs. / acre		700 lbs. / acre		700 lbs. / acre
Price per Pound				$0.39 / lb		$1.20 / lb		$0.39 / lb
Total Seed Revenue				$476.91		$840.00		$273.00
Profit		**$316.45**		**$220.15**		**$605.91**		**$319.51**

* Fixed costs include depreciation, taxes, and insurance. Figures are updated to 1997 and based on estimates by Dave Spalding published in the Report to the *Governor's Hemp and Related Fiber Crops Task Force*. Several additional adjustments to Spalding's estimates are included in the text. Herbicide, storage, and transport to processor costs are added onto Spalding's estimates. Spalding's estimates for repair were increased by 50%. 50lbs of hemp seed per acre were assumed for cultivating hemp for fiber rather than 40lbs as in the report cited above. Although, it should be noted that Hempline of Ontario, Canada, a processor which is focusing on industrial hemp fiber for textiles, is recommending that its growers use 60 to 65 pounds of certified seed per acre (Kime, 1998).

As was mentioned, these growing cost estimates are consistent with the cost estimates from other sources. One such source was growing costs for straw hemp which were reported during a telephone interview with Jean Laprise of KENEX, Inc., of Chatham, Ontario (Laprise, 1997). Laprise reported growing costs without storage and transportation that were very similar to those of Spalding's updated 1997 growing costs without storage and transportation. Laprise, however, had higher storage costs than those reported by Spalding, probably because storing industrial hemp under a tarp is not feasible during much harsher Canadian winters. Cost estimates for purchasing fertilizer and certified seed were very similar in the updated Spalding estimates and production costs for the 1997 season reported by Laprise. As is discussed in more detail in Appendix 2, Spalding's costs also are consistent with those from Reichert and from German cultivation data (see Appendix 1).

The yield information in Table 3 comes from Germany (nova Institute, 1996). The usable yield of 1,069 pounds per acre is based on German agricultural data. The German yield of 1,069 pounds of grain per acre is very similar to the 1,000 pounds of seed per acre quoted for Canada by KENEX (Laprise, 1997). The yields for straw come from the German data and are consistent with yields reported by KENEX.

The cost for growing industrial hemp for grain and straw simultaneously is also reported in Table 3 because this is the cultivation method that is used in France, a developed country where hemp cultivation has remained legal (Van der Werf, 1994). When this is done, hemp straw is planted just as densely as when hemp is grown for straw only. However, the hemp straw is harvested several weeks later in order to let the grain form. Therefore, the cost for growing and harvesting industrial hemp for straw and grain is similar to that for cultivating it for fiber alone. The difference is that the hemp plant must be combined first to remove the grain before being chopped as stalk. The additional costs of combining are added to the costs of growing hemp for straw alone to yield the costs per acre for cultivating industrial hemp for straw and grain, which is reported in the fourth column of Table 3. It also should be noted that cultivating industrial hemp for both grain and straw leads to a yield per acre for both straw and grain which is substantial but is less than that achieved for grain when hemp is grown for grain alone, or straw when industrial hemp is grown for straw alone.

Given the yields, prices, and production costs illustrated in Table 3, farmers would receive a profit of $220 per acre from land and management for growing grain. That profit, however, would fall to $160 per acre if the farmer cannot also sell the industrial hemp straw that is a byproduct of grain cultivation. The profit from growing certified seed for planting would be $605 per acre, or $545 per acre if the hemp straw byproduct could not be sold. The returns to land and management for growing industrial hemp for straw alone is estimated to be $316 per acre. The profit for growing industrial hemp for grain and straw would lead to a profit of $320 per acre.

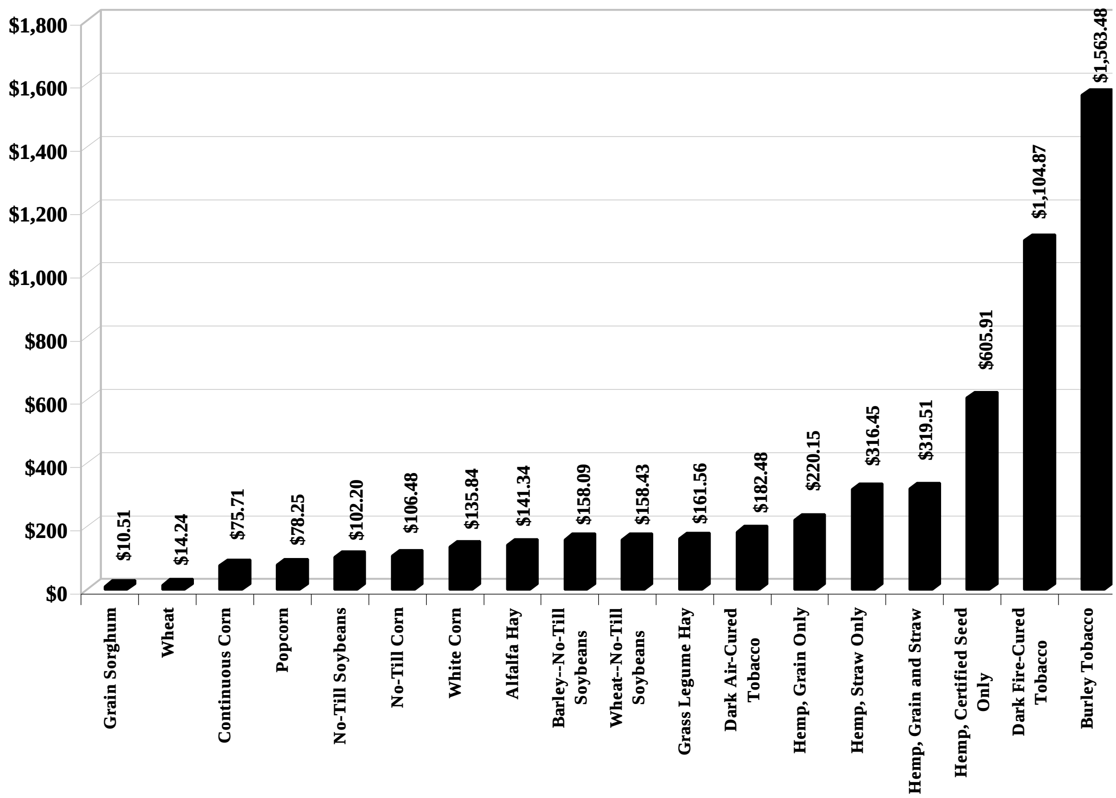
These profits from growing industrial hemp can be compared with the expected profits from growing other crops. These alternative profits are listed in Table 4 and shown graphically in Figure 3. The profits from growing industrial hemp for straw, grain, certified seed, and straw and grain are near or exceed the profits for most of the crops in Table 4. Further, note that the profits listed in Table 4 do not include storage costs for crops, and thus, overestimate the profits from growing these Kentucky crops. Storage costs were included in estimates of profits from cultivating industrial hemp. The return estimates for existing crops in Kentucky for 1997 illustrated in Table 4 come from the University of Kentucky Cooperative Extension Service report *Field Crop Enterprise Costs and Return Estimates for Kentucky* (Benson, *et. al*., 1997). This is an annual report that is used by Kentucky farmers to estimate what their growing costs would be for various crops.

As can been seen in Table 4 and Figure 3 below, these returns are slightly higher than the potential earnings from growing other crops, with the exception of tobacco. But the returns from growing certified seed are closer to those from tobacco. The relatively high expected return to operators from growing industrial hemp suggests that some Kentucky farmers might choose to grow industrial hemp if it were legal to cultivate the crop.

TABLE 4: Relative Returns to Land, Capital, and Management Per Acre for Industrial Hemp and Common Kentucky Crops

Crop	Estimated Return to Land, Capital, and Management
Hemp, Grain Only	$220.15
Hemp, Straw Only	316.45
Hemp, Grain and Straw	319.51
Hemp, Certified Seed Only	605.91
Alfalfa Hay	$141.34
Continuous Corn	75.71
No-Till Corn, Rotation Following Soybeans	106.48
Popcorn, Reduced Tillage	78.25
White Corn, Rotation Following Soybeans, Reduced Tillage	135.84
Grass Legume Hay, Round Bales	161.56
Grain Sorghum, Conventional Tillage	10.51
Soybeans, No-Till, Rotation Following Crop	102.20
Barley- No-Till Soybeans, Double Crop, Following Corn	158.09
Wheat- No-Till Soybeans, Double Crop, Following Corn	158.43
Burley Tobacco, Bailed, Non-Irrigated	1,563.48
Dark Air-Cured Tobacco	182.48
Dark Fire-Cured Tobacco	1,104.87
Wheat, Reduced Tillage	14.24

FIGURE 3: Relative Returns to Land, Capital, and Management Per Acre for Industrial Hemp and Common Kentucky Crops



Price for Industrial Hemp in the Long Run

The profit estimates presented in Tables 3 and 4 indicate that industrial hemp farming should be profitable for Kentucky farmers under current conditions. Indeed, it appears that cultivating industrial hemp is as profitable or more profitable than growing many other crops, particularly cultivating certified industrial hemp seed.

This finding that cultivating industrial hemp is relatively profitable, however, does not mean that Kentucky farmers can expect always to earn higher profits when growing industrial hemp than when growing other crops. This is because competitive market pressures are expected to drive the price of industrial hemp crops downward, which will reduce profits. In particular, to the extent that there are higher returns from growing industrial hemp than other crops, there will be pressure for the price of industrial hemp crops to drop. This should occur via a bidding process among farmers. Industrial hemp processing facilities are expected to contract with farmers each year to grow a specified amount of industrial hemp.[4] As long as there are higher profits from growing industrial hemp than from growing other crops, farmers are expected to underbid each other in order to win a contract with processors. Farmers will

[4] Regulation of the industrial hemp industry is expected to require that industrial hemp processing facilities will purchase by contract. This would make it easier to monitor industrial hemp cultivation.

continue to underbid each other until the bid price drops sufficiently low. More precisely, underbidding will continue until the prices paid for industrial hemp straw and grain have fallen sufficiently so that the returns to farmers from growing industrial hemp are in line with the returns from growing other crops.[5] This point is particularly true for growing certified seed. The very high returns in Table 3 cannot be sustained. The price for certified seed will be bid down.

Such a decline in certified seed costs is expected to lead to a further decline in prices of industrial hemp crops. The prices paid for industrial hemp certified seeds is a large part of growing costs, particularly when growing industrial hemp for straw or grain and straw. The cost of cultivating industrial hemp will fall as these seed prices fall. This will mean that the price that farmers will need to receive for industrial hemp grain or straw while still making a sufficient profit will fall as well. Prices for certified industrial hemp seed may fall to as low as $1.40 per pound, the current price in France (van der Werf, 1994).

The prices paid for industrial hemp also should fall in the long run due to rising yields. Experimentation with seed varieties and cultivation practices should increase the yields of straw and grain from growing industrial hemp. This means that farmers will be able to sell industrial hemp grain and straw for lower prices while still earning a return similar to those from cultivating other crops. Yields should rise by at least 40 percent. To see this, consider that Kentucky yield growth as reported in Kentucky Agricultural Statistics publications from 1966 to 1996 indicate that the average yield growth for alfalfa hay, all hay, corn, and wheat was 69 percent in the last 30 years, 39 percent in the last 20 years, and 25 percent in the last 10 years. This yield growth occurred for crops that had already been cultivated in Kentucky for over a century. Even faster rates of yield growth over ten years should be possible for a crop like industrial hemp that is being cultivated in the state for the first time in decades, particularly as seeds are bred specifically for Kentucky growing conditions.

Finally, the prices paid for industrial hemp will likely need to fall in the long run for the industrial hemp industry to reach its potential. As is discussed below, to sell industrial hemp in larger markets such as that for paper, the prices of hurd and fiber may need to fall. Thus, the price that farmers receive for industrial hemp straw and grain must fall in the long run as the size of the industrial hemp industry continues to grow.

All of these factors lead to the conclusion that the expected yields will increase while prices for industrial hemp should fall in the long run. To see empirical evidence of this, recall that France is one of the few western European countries where the cultivation of industrial hemp has remained legal throughout the last 50 years. Prices paid for hemp in France reflect long-term prices. Industrial hemp farmers in France receive roughly $90 per ton for industrial hemp straw and $0.20 per pound for industrial hemp grain (Van der Werf, 1994).

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[5] To see why seed costs cannot remain so high, consider the reasons that growing costs are so much higher for tobacco. First, a substantial share of these high returns go to pay for a tobacco allotment. Another part of the higher returns is that farmers must spend more time in management with tobacco than with other crops. Thus, the farmer may get a higher return per acre from tobacco, but that return falls once the value of the allotment is paid (or, for farmers who own the allotment, it could be sold). Further, the remaining return falls further still when the extra labor hours of a tobacco farmer are considered.

A few examples may be used to show how far prices should fall for industrial hemp straw and grain once certified seed prices fall, yields rise, and market forces push farmer profits down in line with the profits from growing most other crops. Table 5 shows the growing costs under these conditions. It is clear from these conditions that the profits would be highest for growing certified seed ($340 per acre) and would be roughly equal for growing for straw only ($130 per acre), or a combination of straw and grain ($110 per acre). Growing industrial hemp for grain only would appear to be unprofitable ($5 per acre). Essentially, the lower cost of growing grain when it is cultivated in tandem with straw pushes the grain price low enough that it makes growing industrial hemp for grain alone unprofitable. This all assumes that industrial hemp straw can be profitably processed and marketed in the United States on a large volume, which unlike with hemp grain, has not yet been conclusively demonstrated, although it is expected.

Thus, another interesting scenario is one in which industrial hemp is grown for grain alone in the United States. Assuming the same 40 percent yield increase as in Table 5, prices could fall only to $0.25 per pound if industrial hemp is grown only for grain in the U.S., as is shown in Table 6. However, it should be noted that Wirtshafter (1998) argues that new industrial hemp grain varieties have been developed that would be planted at a density of 25 pounds of certified seed per acre and yield 2,000 to 3,000 pounds of grain per acre. The price of industrial grain could fall to $0.20 per pound if the yield is 2,000 pounds per acre, and $0.13 per pound if the yield is 3,000 pounds per acre.

Industrial Hemp Prices in the United States and Europe

The analysis presented above indicated that in the long-run industrial hemp could be grown in Kentucky at a price similar to the prices farmers receive for hemp in Europe. This result may be somewhat surprising given that European farmers receive a substantial subsidy for cultivating industrial hemp, but no subsidy was assumed in the growing cost figures presented in Tables 3, 5, and 6. How could the U.S. farmers grow the crop at a similar price without receiving the large subsidy of around $400 per acre (Roulac, 1997) that European farmers receive for cultivating industrial hemp?

The answer lies in productivity. U.S. farmers are able to grow a crop without a subsidy at the same price as European farmers who receive a subsidy because U.S. farmers are more productive. Indeed, there are many crops that sell at a lower price in the United States than in Europe even though European farmers receive a much larger subsidy than American farmers. A simple example for a common crop illustrates this. The United States Department of Agriculture's Foreign Agricultural Service (1998a) provided information on the market prices for a metric ton of wheat in France and the United States for the last five years, along with information about how much subsidy French and U.S. farmers received per metric ton produced. This information was combined with information about production of wheat per acre in France and the United States (United Nations Food and Agriculture Organization, 1998) to calculate the subsidy per acre for wheat farmers in the United States and France. The calculation indicated that French farmers received an average subsidy of $166 per acre over the last five years, compared to an average subsidy of $29 per acre in the United States. Despite this subsidy, U.S. farmers produced wheat for $10 less per metric ton than French farmers (United States Department of Agriculture, 1998a). While the size of the European subsidy in this example was less than $400 per acre, the example does illustrate that U.S. farmers can grow agricultural commodities at as low a price as European farmers even when the European farmers receive a large subsidy.

TABLE 5: Growing Costs and Returns for Industrial Hemp using Future Technology, Yields, and Prices

Variable Costs		Straw $/acre		Grain $/acre		Seed Certified $/acre		Straw & Grain $/acre
Seed (lbs.)	(50)	$70.00	(10)	$14.00	(10)	$14.00	(50)	$70.00
Fertilizer		45.01		45.01		45.01		45.01
Herbicides		0.00		10.95		10.95		0.00
Lime (tons)	(1)	12.12	(1)	12.12	(1)	12.12	(1)	12.12
Fuel, Oil (hrs)	(4.5)	18.43	(2.2)	14.06	(2.2)	14.06	(2.2)	22.25
Repair		16.14		30.38		30.38		23.12
Interest		6.56		4.82		4.82		7.00
Storage		5.00		5.00		5.00		5.00
Transport to Processor		40.00		9.60		8.00		32.00
Total Variable Costs		$213.26		$145.94		$144.34		$216.50
Fixed Costs *		$50.27		$45.00		$70.73		$75.05
Operator Labor (8)	(8)	$56.00	(8)	$56.00	(10)	$70.00	(9)	$63.00
Total Enterprise Costs		**$319.53**		**$246.94**		**$285.07**		**$354.55**
Stalk Yield		5.0 t / acre		0.5 t / acre		0.5 t / acre		3.5 t / acre
Price per Ton		$90 / t		$54 / t		$54 / t		$90 / t
Total Stalk Revenue		$450 / t		$27 / t		$27 / t		$315 / t
Seed Yield				1,500 lbs. / acre		1,000 lbs. / acre		1,000 lbs. / acre
Price per Pound				$0.15 / lb		$0.60 / lb		$0.15 / lb
Total Seed Revenue				$225.00		$600.00		$150.00
Profit		**$130.47**		**$5.06**		**$341.93**		**$110.45**

* Figures are updated to 1997 and based on estimates by Dave Spalding published in the Report to the *Governor's Hemp and Related Fiber Crops Task Force.* Several additional adjustments to Spalding's estimates are included in the text.

Herbicide, storage, and transport to processor costs are added onto Spalding's estimates. Spalding's estimates for repair were increased by 50%. 50lbs of hemp seed per acre were assumed for cultivating hemp for fiber rather than 40lbs as in the report cited above. Although, it should be noted that Hempline of Ontario, Canada, a processor which is focusing on industrial hemp fiber for textiles, is recommending that its growers use 60 to 65 pounds of certified seed per acre (Kime, 1998).

TABLE 6: Growing Costs and Returns for Industrial Hemp for Grain

Variable Costs		Grain $/acre
Seed (lbs.)	(10)	$14.00
Fertilizer		45.01
Herbicides		10.95
Lime (tons)	(1)	12.12
Fuel, Oil (hrs)	(2.2)	14.06
Repair		30.38
Interest		4.82
Storage		5.00
Transport to Processor		9.60
Total Variable Costs		$145.94
Fixed Costs *		$45.00
Operator Labor (8)	(8)	$56.00
Total Enterprise Costs		**$246.94**
Stalk Yield		0.5 t / acre
Price per Ton		$0 / t
Total Stalk Revenue		$0 / t
Seed Yield		1,500 lbs. / acre
Price per Pound		$0.25 / lb
Total Seed Revenue		$375.00
Profit		**$128.06**

* Figures are updated to 1997 and based on estimates by Dave Spalding published in the Report to the *Governor's Hemp and Related Fiber Crops Task Force*. Several additional adjustments to Spalding's estimates are included in the text. Herbicide, storage, and transport to processor costs are added onto Spalding's estimates. Spalding's estimates for repair were increased by 50%. 50lbs of hemp seed per acre were assumed for cultivating hemp for fiber rather than 40lbs as in the report cited above.

NATIONAL MARKET FOR INDUSTRIAL HEMP

The exact size of the U.S. industrial hemp industry in the future is difficult to determine. This section is an attempt to provide a rough estimate for the size of that potential market. The approximate magnitude of the estimate that is provided should be of more interest than its exact value. This section examines the size of the potential market for industrial hemp grain, hurds, and fiber.

Scenarios are presented to develop a rough estimate of the amount of industrial hemp that could be utilized by a select group of industries. These industries were selected for presentation because each appeared to be the most encouraging prospects for the expansion of the use of industrial hemp in American industry. It should be noted that the industries discussed below for the most part are industries for which hemp is currently being used in Europe. Most industries also were identified as the commercially viable sectors for Germany (Karus, 1997; nova Institute, 1996). It is not clear, however, that these alternative scenarios will occur, nor is it unlikely that industrial hemp could become widely used for other industrial applications. Finally, it should be noted throughout the following sections that industrial hemp, in addition to competing with cotton, wood, and synthetic products, competes with other non-cotton natural fiber crops, such as kenaf, and particularly, flax.

Industrial Hemp Grain in Existing Markets

As was discussed above, 1,300 tons of industrial hemp grain are presently demanded in North America each year. This is the level of cultivation given the current price for grain. The level of cultivation would likely grow as market forces pushed the price of industrial hemp grain lower.

In particular, as these forces drive down the price of hemp grain, it is expected that there would be an increase in the quantity demanded. Falling prices may be a key to the success of industrial hemp for some of the additional uses for industrial hemp that are discussed below. In addition, falling prices should lead to an increased quantity of industrial hemp grain demanded for existing uses such as cooking oil, other food products, nutrition supplements, cosmetics, and animal meal. It is the demand in these existing uses that is examined in this section.

The increase in the quantity demanded due to a particular price decline can be difficult to estimate. However, economic research has estimated these relationships using the concept of an "own-price elasticity." An own-price elasticity is the percentage increase in the quantity of a product demanded for a given percentage decline in its price. Thus, an own-price elasticity for industrial hemp grain would indicate how much the quantity of grain demanded would rise in response to a decline in the price of industrial hemp grain.

There are no known modern estimates of the elasticity of demand for industrial hemp grain, or for that matter, industrial hemp oil. There are estimates of the elasticity of demand for other oils, however. These estimates could be applied to the hemp oil and hemp meal that is made with industrial hemp seed. Resulting changes in the demand for hemp oil could be taken as the percentage change in demand for industrial hemp grain. In particular, based on the average of the price elasticity for corn oil and soy oil in Goddard and Glance (1989), an own-price elasticity of -0.55 can be used.[6] This price elasticity implies that the quantity of oil demanded is expected to increase by 0.55 percent for each one percent decline in the price of oil. It is further assumed that the quantity of industrial hemp grain demanded will increase by 0.55 percent for each one percent decline in the price of oil.

It is expected that the price of industrial hemp oil will decline by 50 percent as competition between domestic growers of industrial hemp grain drive down the price of hemp grain. As shown in Tables 3 and 5, the price of un-sterilized hemp grain is expected to fall 62 percent, from $0.39 per pound to $0.15 per pound. The price decline will probably be even greater since costly sterilization is currently required, while it is unlikely to be necessary once industrial hemp is cultivated domestically. On the other hand, the costs for processing industrial hemp grain into oil and meal are unlikely to drop substantially. Taken together, all of this suggests a roughly 50 percent decline in the price of industrial hemp oil. Given an elasticity of -0.55, this suggests that the quantity of industrial hemp grain demanded in current markets will rise by 28 percent to 1,660 tons. This represents an increase of 360 tons.

Another way in which the demand for industrial hemp should expand as the price falls is in the birdseed market. In the recent past, industrial hemp has been utilized in birdseed mix in the United States. As late as 1990, demand for industrial hemp grain for use in birdseed was roughly 60 tons per year. Since the mid-1980s, however, interest in using industrial hemp grain in bird seed has dwindled, perhaps due to changing preferences by the industry and its customers, or perhaps due to regulatory concerns with importing industrial hemp. The current scenario assumes that demand for industrial hemp grain in birdseed could again rise to its 1990 level if cultivation of industrial hemp is legalized. This would occur for two reasons. First, the legalization of industrial hemp for cultivation would signal fewer regulatory concerns regarding the use of industrial hemp grain. And second, domestic cultivation of industrial hemp seed in time would lead to lower prices for grain. A lower price would increase the appeal of industrial hemp grain as a component of birdseed mix.

In summary, this suggests a total future demand for industrial hemp grain of 1,720 tons in existing markets and birdseed after the price of hemp seed falls. This suggests sufficient grain demand for cultivating 3,440 acres of industrial hemp for both straw and grain given the yield information in Table 5.

In addition to price changes, it is possible that quality changes in industrial hemp grain could allow it to obtain even more rapid growth in existing markets. These quality changes

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[6] This elasticity was estimated based on demand responses to price for the established commodities of corn and soybeans. It might be argued that these elasticity values are not appropriate for a niche commodity that currently has a prohibitively high cost for many industrial uses and a price that is expected to fall sharply in the future. Elasticity estimates are not available for this special situation, however. Further, analysis later in this report does consider cases where the price of industrial hemp grain falls far enough to be adopted for new industrial uses.

could occur as seed selection and engineering change the characteristics of the oils in industrial hemp grain. For example, at 3 percent, industrial hemp grain has a relatively high share of gamma linolenic acid. This high share is part of what makes industrial hemp an attractive component in nutritional supplements. If seed engineering causes this 3 percent share of gamma linolenic acid to double or more, then industrial hemp grain may become a much better source for gamma linolenic acid than the existing preferred sources such as Evening Primrose.

Industrial Hemp Grain in New Markets

The largest potential area for growth in the use of oils made from industrial hemp grain, however, may not be in its existing uses. The largest potential may be in using industrial hemp grain to make industrial oils. There also should be substantial room for expansion of the use of animal meal made from industrial hemp grain. The potential for industrial hemp grain in each of these industries is explored below.

In the case of oils, industrial hemp grain oil can enter new markets in the present by re-entering markets in which it was historically important. Historically, industrial hemp oil was used in industrial applications such as paints, wood and concrete sealants, and printing inks (Wirtshafter, 1994). Industrial hemp grain can re-enter the high quality segment of these markets by gaining some of the market share currently held by linseed oil.

While linseed oil made from flax has seen its market share decline over the long run as it has been replaced by petroleum-based products, a substantial level of linseed oil continues to be produced for industrial use. Further, demand for linseed oil has risen in the last few years (Carter, 1998). Linseed oil continues to be used in high-value paints, sealants, inks, and lubricating oils. Linseed oil's advantage in the production of high-value paints and sealants is that it is composed of 60 percent linolenic acid. This acid has strong drying properties that lead to high quality. There were 86,000 tons of linseed oil produced in the United States in 1996.

Industrial hemp oil should be able to capture a portion of this industrial market for linseed oil. At 20 percent, industrial hemp oil has the second-highest percentage of linolenic acid, substantially more than in soy oil or canola oil. The main advantage of hemp oil, however, is that it greatly improves the ability of paints, sealants, and inks to penetrate surfaces. This implies a demand for hemp oil when mixed with other oils at a 5 to 10 percent share in order to improve their penetration into surfaces. If price competitive within linseed oil, hemp seed oil also may be able to compete with linseed in markets such as lubricants, where strong drying properties are less important.

In the case of animal meal, meal made from industrial hemp grain also should be able to compete for a share of the market currently held by flax. Flax meal currently holds a market niche within the animal feed market. This niche market exists because many individual animal owners still prefer to use flax meal as a supplement in horse or other animal feeds, as they have done historically. The share of flax meal in the market has steadily fallen, however, as animal feed companies have switched to the higher protein soy meal. Still, there were 159,000 tons of flax meal produced in the United States in 1996.

Hemp grain meal may be able to capture a share of the flax meal market – if it is price-competitive -- especially since it has a slightly higher protein content than flax meal. Furthermore, the oils in hemp meal improve a horse's muscle tone (Coulter, 1998) and hoofs and coat (Coulter, 1998 and Billings, 1998). Because of this potential for hemp oil and meal in the flax market, the market for hemp grain depends on the size of the market for flaxseed. The larger the flaxseed market, the larger the potential for hemp grain. According to U.S. Department of Agriculture (1998b), there were 1,960,000 bushels of flaxseed produced in the United States in 1996. There was also a substantial volume of flaxseed imported into the United States for processing. Imports have risen steadily as cultivation of flax for linseed oil has shifted over time from the upper Midwest region of the United States into Canada. According to the U.S. Department of Agriculture, there were 6,971,000 bushels of flaxseed imported from Canada in 1996. When combined with domestic production, these imports imply that nearly 9 million bushels of flaxseed were processed into oil and meal in the United States in 1996.

The ability of industrial hemp grain to capture a share of this relatively large market depends on price. Assuming that crushing costs are similar, comparing the price of industrial hemp oil with linseed oil can be accomplished by comparing the price of hemp grain with the price of flaxseed. This is true because the oil content of the two seeds is roughly the same, in the 30 to 40 percent range. Industrial hemp grain might be expected to capture a significant share of the linseed oil market if the price of hemp grain can equal or fall below the price of flaxseed. However, the share of the market going to hemp grain might be relatively small if hemp seed is more expensive than flaxseed.

According to the U.S. Department of Agriculture (1998b), the average price per pound of flaxseed is approximately $0.10. This is well below the current average price per pound estimated for industrial hemp grain. As is seen in Table 5, however, it is expected that the price for industrial hemp grain can fall dramatically over time to $0.15 per pound as yields rise, the costs of production inputs fall, and competition among farmers drives down profit levels.[7] At $0.15 per pound rather than $0.10 per pound, it is anticipated that industrial hemp grain can capture only a minority share of the market for flaxseed for oil, especially given the lower concentration of linolenic acid in hemp grain. It is estimated that the share going to industrial hemp seed could go as high as 10 percent.

A 10 percent share of the crushed linseed market in the United States would amount to about 50 million pounds. At future yields of 1,000 pounds per acre when hemp is grown for straw and grain (see Table 5), this implies up to 50,000 acres of industrial hemp cultivated for both straw and grain. When the 3,500 acres cultivated for hemp grain for existing markets is added to this figure, it yields a demand for industrial hemp grain of up to 53,500 acres grown for both straw and grain.

In addition to capturing part of the flax oil and meal market, industrial hemp oil and meal may be able to capture a portion of other markets. In particular, industrial firms in the

[7] At lower prices for hemp grain, farmers would be losing more from lost sales of hemp straw than would be gained from sales of hemp grain, particularly after the additional cost of combining hemp seed is considered. This price is just below the price at which hemp grain is typically sold in France.

future may need to substitute natural oils such as industrial hemp oil for petroleum in the manufacturing of inks, watercraft oil, and other petroleum-based products to meet environmental regulations on air and water pollution. Future research and development will be necessary in order for hemp natural oils to enter these large markets, if possible. For example, Ashland Oil Company, which has experimented with natural oils for use as a component in boat motor oil and other purposes, was not successful in research to date due to problems with polymerization (Dotson, 1998). This problem can be corrected, however, so for the long run the research is inconclusive about the potential to use industrial hemp oil and other natural oils as a component in boat motor oil.

There also may be a large potential market for industrial hemp meal as a supplement to cattle feed. Industrial hemp grain does have sterogenic compounds that can promote cattle growth, but this has not been scientifically tested (Johns, 1998). However, several trials by commercial farmers have shown that using hemp meal as a supplement did enhance cattle growth. An Alabama farmer who raises rodeo bulls indicated that hemp meal improved the strength and appearance of the 12 bulls in his experiment, and at a lower cost and with fewer side effects than the vitamin shots that would be used instead to build strength (Harrell, 1998).

Another study by a Kentucky cattle farmer found that using industrial hemp as a feed supplement increased the weight, and thus, the market value of cattle by $13 per head (Patton, 1998a). The cattle were each fed three ounces of industrial hemp meal per day for 112 days, which amounts to 21 pounds of hemp meal. Hay consumption by cattle that were fed the industrial hemp meal was also somewhat less (Coulter, 1998). But, even assuming that hay costs were the same for the cattle fed hemp, these figures suggest that supplementing cattle feed with hemp meal could be profitable for farmers if hemp meal is available for less than $0.60 per pound. This $0.60 per pound price is substantially more than the expected long-run price of hemp meal. Linseed meal cost $0.07 per pound in 1995 (U. S. Department of Agriculture, 1998b). In the long run, hemp meal should be priced only slightly higher than $0.07 per pound since flax seed costs $0.10 per pound, and the price of industrial hemp grain is expected to fall to around $0.15 per pound over time (see Table 5). Thus, the cost to farmers from using hemp meal should be far less than $0.60 per pound, even after adding in any retail mark-up and extra work necessary by the farmer.

These preliminary results suggest that there is economic potential for using industrial hemp meal as a supplement to cattle feed. This also is a large potential market given that there were 101 million head of cattle on U.S. farms in 1997 (U.S. Department of Commerce, 1998). Additional and larger field tests need to be conducted to determine whether, and by how much, supplementing cattle feed with industrial hemp enhances the sale price per head of cattle, and whether the difference is large enough to cover the costs of industrial hemp feed. Finally, preliminary research also shows that farmed catfish also will consume hemp meal (Patton, 1998b). But research has not yet addressed whether industrial hemp meal is commercially feasible as a fish food.

Animal Bedding

Many of the scenarios for the growth of the industrial hemp industry that will be discussed below involve the sale of industrial hemp fiber for a variety of industrial uses. These types of fiber sales are often the focus of discussions about the development of the industrial hemp industry in Kentucky and the United States. It is important to remember that even industrial hemp plants bred for fiber content rarely produce hemp straw with more than a 30 percent fiber content (de Meijer, 1994). The remainder of the stem is composed of the hurds, or the inner woody core of the plant. This material also can be sold for a variety of uses, although it is sold at a much lower price per ton than the industrial hemp fiber. Even with a lower market price, however, the large portion of stem occupied by hurds makes the sale of hurds an important factor in the development of the industrial hemp industry. Indeed, the successful sale of hemp hurds may be the difference between a profitable and unprofitable industrial hemp industry in Kentucky. The successful establishment of an industrial hemp industry may rely on the sale of the whole plant -- fiber and hurds.

Industrial hemp hurds have been used or proposed for a variety of industrial purposes, including for use in construction materials, paper, and plastics. Under current market conditions and technologies, however, the most economically feasible use for industrial hemp hurds may be in agriculture. This use is as animal bedding. Industrial hemp hurds appear to be price-competitive with wood chips, fine wheat straw, and other types of bedding used for valuable thoroughbred or breeding horses, or used by horse and other pet owners willing to spend more on their animals. These materials are favored over cheaper alternatives since they are more absorbent, and thus, reduce illness.

The market for high-value animal bedding is quite large. In England, a country with an population about one-fifth as large as the United States, the market for high-value animal bedding is approximately 250,000 tons per year (Lowe, 1998). Industrial hemp hurds have been demonstrated to be competitive in these markets. The sale of hemp hurds for animal bedding has been the primary use for hemp hurds in both England (Lowe, 1998) and France (Van der Werf, 1994). Hemp hurds also have been used to make medium-density fiber board. However, Lloyd (1998) expects that hurds would command a low price of only about $40/ton if used for this purpose.

Hemp hurds are price-competitive with alternative high-value animal bedding such as wood chips and fine wheat straw. Compressed bags of chipped wood for horse bedding cost roughly $0.12 per pound retail (Gluck Equine Research Center, 1998), while fine wheat straw for use as horse bedding is sold for roughly $0.09 per pound retail. These figures translate into a retail price of $180 to $240 per ton of raw material for horse bedding. Given these prices, it appears that industrial hemp hurds could be sold at $180 per ton at the retail level and still be a low-cost producer in these markets.[8] This implies a return to hemp hurds of $100 per ton to the

[8] Lloyd (1997) also suggests that hemp hurds can be competitively sold for roughly $0.10 per pound, or $200 a ton. Hemcore in England currently sells hemp hurds for animal bedding at a price of $0.20 per pound or $400 a ton (Lowe, 1998). England, however, does not currently have the competitive market for hemp hurds animal bedding that is envisioned in the estimates above.

processor, given that it costs roughly $30 per ton to clean, pelletize, and bale hemp hurds for sale as animal bedding (Lloyd, 1998), and assuming a retail mark-up of around 40 percent.

As seen in Table 2, this price for industrial hemp hurds is consistent with the $90 a ton return for hemp straw used in Table 5. In addition to being price-competitive, industrial hemp hurds have an additional advantage over fine wheat straw and chipped wood because these other types of bedding are more difficult to clean than industrial hemp hurds. Industrial hemp hurds, because they are highly degradable, also pose significantly less of a disposal problem than chipped wood. Rather than piling up in compost heaps, used hemp hurds can be spread on fields.

This suggests an economically feasible potential market for industrial hemp hurds in the United States. This is not surprising given that, as was mentioned earlier, most of the hurds marketed in France, England, and The Netherlands are marketed for sale as horse or other animal bedding, rather than for other uses (Lowe, 1998; Van der Werf, 1994). It also suggests that being able to sell hemp hurds for animal bedding rather than for medium-density fiber boards at $40 a ton (Lloyd, 1998) would be a substantial advantage for an industrial hemp processing plant.

As a result, processing plants located near large markets for horse and animal bedding may have an advantage in the industrial hemp industry. In particular, an industrial hemp decorticating plant located near an area where many race or thoroughbred horses are located might be most successful, since transportation costs in this case would not significantly reduce profitability even though transportation costs for animal bedding would be much less than for raw industrial hemp straw since processing would have made the animal bedding much less bulky. This suggests an advantage for locating an industrial hemp processing facility in Kentucky. Location near the farms or racetracks where race horses and thoroughbreds are housed is important because these horses' owners potentially are primary customers for industrial hemp hurds. The owners of these types of horses most frequently use the chipped wood or fine wheat straw animal bedding that industrial hemp hurds strongly compete with on price.

The extent of the market for high-value animal bedding in Kentucky and the United States can be roughly estimated in part based on the number of valuable thoroughbreds therein. While the precise number of thoroughbreds in Kentucky or the nation is not known, major horse associations do track the number of thoroughbred foals signed with breeder registries each year. This information can be used to estimate the number of thoroughbred horses in Kentucky and the United States.

The Jockey Club, based in Lexington, Kentucky, identified a crop of roughly 32,000 thoroughbred racing breed foals registered in the United States in 1995, with 7,700 registered in Kentucky (Jockey Club, 1998a). There were a total of 9,700 thoroughbred racing breed foals born in Kentucky and the adjoining states of Ohio, West Virginia, Tennessee, Indiana, Illinois, and Missouri. This crop was one of the lowest since 1980. Crops have been as high as 47,000 in 1986. Based on 32,000 foals each year, and a 20-year average life span for thoroughbred horses, it is estimated that there are 640,000 thoroughbred horses residing in the United States in any given year. Based on 7,700 foals each year in Kentucky, a 20-year life span, and an expectation that 50 percent of thoroughbreds born in Kentucky are sold out-of-state, it is estimated that 77,000 thoroughbreds reside in Kentucky in any given year. This expectation that 50% of thoroughbreds born in Kentucky are sold out-of-state is based on interviews with the Jockey Club (Jockey Club, 1998b). Based on a 20-year life span, and 9,700 foals born in Kentucky and surrounding states, it is estimated that there were 117,000 thoroughbreds residing in Kentucky and surrounding states in any given year.

Each horse would use about 180 pounds of industrial hemp hurds per week, based on two stall changes per week and three 30 pound bags per stall change (Gluck Equine Research Center, 1998). This translates into 9,360 pounds or 4.7 tons of industrial hemp hurds per horse per year. Given 640,000 such horses, this would translate into 2,995,000 tons of industrial hemp hurds sold nationally, if all such horses were switched to hemp hurds for bedding. Given 77,000 horses in Kentucky, this would translates into 360,000 tons of industrial hemp hurds sold in Kentucky, and 550,000 tons of industrial hemp hurds sold in Kentucky and adjoining states. However, it is clear that not all thoroughbred horses would be switched to industrial hemp hurds bedding.

Even though industrial hemp hurds appear to be a lower cost and more convenient alternative than chipped wood and fine wheat straw, the assumption that all thoroughbred horses would switch to industrial hemp hurds is not reasonable. For example, many thoroughbred horses may use low-cost straw. A more reasonable assumption is that some percentage of horse owners over time would switch to industrial hemp hurds. At a 10 percent switching rate, this translates into 300,000 tons of industrial hemp hurds sold in the United States per year, 36,000 tons sold each year in Kentucky, and 55,000 tons sold in Kentucky and adjoining states. At a yield of 2.9 tons of hemp hurds per acre, this suggests a potential market for 103,000 acres of industrial hemp a year in the United States. It suggests 12,000 acres of industrial hemp a year just to satisfy the demand for hurds in Kentucky, and 19,000 acres per year for Kentucky and adjoining states. The figure of 2.9 tons of hurds per acre is based on an average yield of 4.25 tons of straw per acre and straw that is 68 percent hurds.

These estimates show that the potential demand for industrial hemp hurds from thoroughbreds alone is substantial. Thoroughbreds account for only a small share of horses, however. Among all registered breeds, there were 250,000 foals born a year compared to 32,000 thoroughbred foals (American Horse Council, 1998). Based on a 20-year life span, this would translate into an estimate of 4,400,000 registered horses besides thoroughbreds housed in the United States. The share of these horses using expensive bedding such as fine wheat straw or wood chip may not be as large as with thoroughbreds, but these breeds would certainly support some sales for industrial hemp hurds. If only one percent of these horses used industrial hemp hurds as bedding, this would mean a demand for hurds that would require an additional 71,000 acres of industrial hemp production.

Finally, the preceeding analysis may be somewhat of an underestimate of the potential market for industrial hemp hurds as animal bedding because it did not consider that hemp hurds could be used as bedding for animals besides horses. In particular, hemp hurds may be used by owners of smaller animals such as rabbits, hamsters, and cats simply for the comfort of their pet. For example, the hurds of kenaf, another crop composed of hurds in the interior and longer fibers near the exterior, are sold for approximately $300 per ton (delivered) in the Memphis area as bedding for lizards (Fuller, 1997).

Animal bedding is a large market for industrial hemp hurds. However, scientists and businesses in Austria are examining another large potential market for hemp hurds in the plastics industries. Hemp hurds cellulose would be used as a feed stock for plastics under this approach. This use for hemp hurds could lead to a substantial expansion in the market for hemp hurds if hurd-based plastics can be cost-competitive with petroleum-based plastics.

Paper

Paper is an important potential market for industrial hemp fiber. Like other non-wood fibers, the advantage of paper made with industrial hemp fiber is its strength and length. The extent of the paper market where industrial hemp paper can be economically competitive is somewhat limited, though. Currently, paper made with industrial hemp fiber is significantly more expensive than paper made with wood. Hemp paper pulp can cost up to $2,000 a ton versus $500 a ton for wood paper pulp. Still, there are a handful of economically feasible uses for industrial hemp paper, particularly because it would probably be feasible to produce hemp pulp at a cost well below $2,000 a ton. These uses are specialty papers and non-wood papers (Byrd, 1998a).

The first general use for industrial hemp fiber is for specialty papers that require a stronger fiber than is available from wood, and in some cases, a fiber that is stronger when wet. These specialty papers include parchment quality papers, teabags and coffee filters, other filters, and cigarette papers. It is important to note that non-wood fibers such as flax, jute, abaca, and industrial hemp are the lowest cost ways to produce these products. Consumers are not being asked to pay more simply because these papers are made with non-wood fiber.

The role of industrial hemp fiber in the specialty market is a function of both its price and the technical requirements of each paper. Technical requirements refer to length of fibers, ratio of length to fiber width, the wet strength of fibers, and other characteristics that make fibers appropriate for certain specialty papers. For example, the especially high level of wet strength and shorter fibers of abaca make it most effective in teabags (Riccio, 1998). Industrial hemp fiber is closest in strength and fiber length to flax fiber (Van der Werf, 1994). This is fortunate since flax fiber is the largest component of the specialty fiber market. Riccio (1998) estimates that the specialty fiber market in North America requires roughly 125,000 tons of fiber per year. Roughly 500,000 acres of flax fiber are harvested from fields grown for flax seed in Canada and North Dakota (Carter, 1988). At 1,000 pounds of straw per acre and straw that is 30 percent fiber, this translates into 75,000 tons of flax fiber produced each year in North America. The market for flax paper is for Bible paper, other parchment and archival papers, and cigarette papers.

The ability of industrial hemp fiber to capture a share of this flax market depends on relative price. Industrial hemp fiber is expected to be more expensive. As calculated in Table 6, industrial hemp straw delivered to a decorticating plant in the long run is expected to cost roughly $90/ton. Flax straw from flax grown for seed costs roughly $40/ton delivered. This low price is possible because in the United States and Canada flax straw is a byproduct of plants grown exclusively based on the sale of flaxseed (Carter, 1998).[9] Given that only about 2,000,000 acres are cultivated for flaxseed in the United States and Canada each year,[10] and about one-quarter already is used in specialty paper production, there is a limit to the supply of low-price flax straw. Once the remaining supply is exhausted, the price of flax straw could rise, quite probably above the cost of industrial hemp straw. Still, under current conditions, given that both straws are approximately 30 percent fiber and have similar decorticating costs and uses for hurds, this suggests a higher price for hemp fiber. Once decorticating and pulping costs are added, industrial hemp pulp would be about 10 to 15 percent more expensive than flax pulp. This higher price for industrial hemp suggests that hemp will have difficulty capturing a large share of the flax market.

It is expected that industrial hemp fiber can capture up to 20 percent of the 75,000 tons of flax fiber used for specialty papers. This percentage is also the lower bound suggested by Lloyd (1998). This translates into a demand for 15,000 tons of industrial hemp fiber. Given an average yield of approximately 1.2 tons of fiber per acre, this translates into a demand for 12,500 acres of industrial hemp. This estimate of 1.2 tons of fiber per acre is based on an average yield of 4.25 tons of hemp straw per acre and straw that is 28 percent fiber. The average yield of 4.25 tons per acre is an average of the five tons per acre expected in Table 5 when industrial hemp is grown for straw only and the 3.5 tons per acre when it is grown for straw and grain. About 50 percent of farmers are expected to choose each growing plan since the returns from growing for straw and growing for both straw and grain are roughly equal.

The potential use for industrial hemp in specialty paper-making is verified by activity in Europe. Industrial hemp fiber producers in France supply industrial hemp fiber to specialty paper mills in a number of European countries. Indeed, the vast majority of the 12,000 acres of industrial hemp grown and processed in France in the early 1990s was utilized to manufacture paper pulp (Van der Werf, 1994).[11] Industrial hemp fiber grown in other European countries such as the United Kingdom and Spain also is used in specialty paper production.

The demand for tree free paper made from industrial hemp is expected to be even higher than the demand for industrial hemp-based specialty papers. The current demand for tree-free paper is estimated to be roughly 10,000 tons per year. That demand should grow rapidly due to an anticipated drop in price. Currently, industrial hemp pulp costs more than twice as much as pulp made from virgin wood fiber. However, new pulping plants are expected to be built that can produce paper pulp from industrial hemp at a price that is only 10% to 30% higher than the price of pulp made from virgin wood (Byrd, 1998b), assuming that the price of industrial hemp straw falls in the long-run to near $90/ton, as in Table 5. As

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[9] Flax straw is simply burned rather than collected for industrial purposes on many of the acres where flaxseed is grown (Carter, 1998).
[10] This figure is based on 1997 data. Canadian acreage was taken from Statistics Canada (1998). U.S. acreage was not yet available but was estimated based on discussions with Carter (1998). Canadian production accounted for roughly 90 percent of the total.
[11] Recall that the expected long-run price for industrial hemp straw in the United States is similar to that in France, so the hemp fiber would enjoy no relative price advantage in France, despite the price subsidy for hemp cultivation in Europe.

industrial hemp pulp is substituted for virgin wood pulp in recycled paper, this in turn should allow the production of tree-free paper that is only 10% to 20% more expensive than recycled paper. Virgin rather than recycled wood pulp often accounts for a majority of pulp in recycled paper.

It is expected that newly constructed pulping facilities, if built, would be able to use a combination of the "tornado" pulping technology and a standard chemical pulping facility to produce industrial hemp pulp at these prices.[12] The tornado pulping equipment would be able to use the whole hemp stalk, and would serve to shorten hemp fibers down to a size similar to those of wood fibers. Shortening the fibers would mean that equipment in a standard chemical pulping facility could be used to complete the pulping process. Use of whole stalk as the raw material rather than industrial hemp fiber, as with specialty paper, would be key in reducing hemp pulp costs. As indicated in Tables 2 and 5 of this report, whole stalk would cost roughly $90 per ton in the long-run while industrial hemp fiber would cost from $400 to $600 per ton. Pulp yields from industrial hemp would be expected to reach 55 percent, about 10 percent higher than the yields from virgin wood (Byrd, 1998b). Given that the tornado pulping equipment would use the whole industrial hemp stalk, sufficient industrial hemp stalk would need to be grown close to the location of the plant, as is the case with decortication facilities.

A drop in price that allows tree-free paper to enter the recycled market should allow for a rapid expansion in sales. After all, the annual use of recycled paper for making new paper, rather than paperboard boxes, numbers just above 10 million tons (Finchem, 1998). Given this market size, even if paper pulp made with whole stalk industrial hemp could capture 1% of this market, it would amount to over 100,000 tons of production. This level of production is roughly consistent with the estimate of Byrd (1998b), who felt that the market could support up to a six pulping plants each with a capacity to produce approximately 40,000 tons of pulp annually.

Rather than assuming a half don pulping plants, assume 2 with an annual capacity of 40,000 tons of pulp. Given a 55 percent pulping yield, a demand for 80,000 tons of industrial hemp pulp would translate into a demand for 145,000 tons of industrial hemp stalk. This amount of stalk could be produced on 34,000 acres, assuming that 4.25 tons of industrial hemp stalk would be grown per acre. When this figure is combined with the figure from the specialty market, it suggests a requirement of up to 46,500 acres of industrial hemp cultivated for use in paper production in North America. Although, it should again be pointed out that while production using the whole stalk technology has been tested recently by Byrd (1998b), no such pulping facility is yet built and operating in North America.

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[12] There are several reasons why pulp made from whole stalk industrial hemp would cost more to produce than pulp made from virgin wood (Byrd, 1998c). These reasons include: the smaller size of industrial hemp pulping plants, the higher capital and operating costs of the rotating digesters needed in a hemp pulp plant versus stationary digesters in a wood pulp plant; the $5 to $10/ton cost of operating a tornado pulper, and slightly higher raw material costs (virgin wood costs roughly $80 per dry ton, while the price of whole stalk industrial hemp is anticipated to fall to about $90/ton). There are also several reasons why producing industrial hemp pulp might be less expensive than producing virgin wood pulp. These reasons include: less need for chemicals when bleaching and cooking industrial hemp pulp; pulp yields of 55% from whole stalk industrial hemp versus 45% pulp yields from virgin wood; and the costs of debarking and chipping wood logs.

These acreage estimates for industrial hemp grown for paper may be far too low depending on current and potential new technologies. In particular, tree-free paper made with industrial hemp may gain a larger share of the recycled paper market if new whole stalk pulping facilities using a tornado pulper are able to produce paper pulp at the price of virgin wood pulp. Naturally, this would also make it possible for 100 percent industrial hemp paper to enter the much larger 100 percent virgin wood paper market. In addition, other whole stalk pulping methods may be developed that can compete with virgin wood pulp on price. Krotov (1997) has developed machinery for producing paper pulp from the whole stalk of hemp, or other bast plants or agricultural waste fibers. Rather than preparing hemp stalk for processing in standard pulping plants like the tornado pulper, Krotov's machinery is a self-contained pulping process that does not release effluent into the environment, but instead produces fertilizer for agriculture as a by-product of the pulping process. At present, however, it is not clear that Krotov's machinery can be used to produce pulp that is competitive on price with virgin wood pulp.

Finally, paper pulp made with industrial hemp or other non-wood fibers could become more competitive with virgin wood pulp if the federal government ended implicit subsidies of timber production in national forests. These implicit subsidies occur through U.S. Forest Service activities such as forest road construction and maintenance and timber sales management. Fees paid by loggers to the Forest Service do not fully cover the cost of these activities, which is the source of the implicit subsidy. The value of these subsidies was estimated to be $791 million in 1996 (Hanson, 1998).

Automobile Parts

Another potential use for industrial hemp fiber is in selected automobile parts. Vehicle headliners, rear window shelving, door panels, matting under carpets, air bag parts, and trunk liners are examples of automobile parts that can be manufactured using industrial hemp. Industrial hemp fiber already has been used in trunk liners and press-molded air bag parts in several models of BMW cars (nova Institute, 1997). In North America, KENEX, Inc. has developed prototype molded automobile parts (Laprise, 1998). Used transit buses are currently being retrofitted in Florida with molded hemp parts for use in Orlando, Florida, and potentially other cities (Zeller International, 1998). Using industrial hemp may appeal to automobile manufacturers because industrial hemp parts are lighter and more recyclable than the parts they replace, and are fire resistant in crash situations (nova Institute, 1997). While it was not possible to determine the exact relative price of automobile parts made from industrial hemp versus parts made from existing materials, the use of industrial hemp in automobile parts in Germany provides some evidence that the parts made from industrial hemp fiber can be cost competitive.

The best potential for North American production appears to be in vehicle headliners, rear window shelving, and trunk liners. Based on discussions with Laprise (1998), it was estimated that the typical vehicle headliner would use 2.5 kilograms of industrial hemp. This would lead to a substantial demand for industrial hemp if even 20 percent of the 12 million new cars and light trucks manufactured in the United States each year (U.S. Department of

Commerce, 1998) were to use industrial hemp headliners. This would create demand sufficient for 6,600 tons of industrial hemp.

As for rear window shelving, the typical panel for rear window shelving would use 2 kg of industrial hemp (Laprise 1998). As a result, it would require 5,300 tons of industrial hemp fiber for rear window shelving if only 20 percent of new automobiles and light trucks used shelving constructed from industrial hemp. As for trunk liners, it is estimated that roughly 2.5 kg of industrial hemp would be required per trunk liner. This suggests a need for another 6,600 tons of industrial hemp fiber for use in trunk liners if 20 percent of trunk liners are made with industrial hemp.

Together, these cases suggest that 18,500 tons of industrial hemp fiber would be required if only 20 percent of vehicles produced in the United States used headliners, rear window shelving, and trunk liners made with industrial hemp. In turn, a requirement of 18,500 tons of industrial hemp fiber suggests a demand for 15,500 acres cultivated for industrial hemp straw or straw and grain based on a yield of 1.2 tons of fiber per acre.

Fiberglass Alternative

Hemp products also could be used as a replacement for fiberglass. So-called "hempmat" has been touted as a safer and more desirable alternative to fiberglass. Many concerns have recently been raised about the health dangers of fiberglass, such as potential airborne glass particles that may cause respiratory problems. In addition, Hemcore of England reports that they have found hempmat to be cheaper than fiberglass. Any offcuts created from molds used to form the hempmat can be recycled to produce additional hempmat, whereas fiberglass cannot. Hemp fiber products in general also are less hazardous to recycle than fiber glass, for which there are concerns about worker health in recycling. Finally, hempmat is very lightweight and gives a better surface finish than glass. Hemcore also reports, however, that hempmat is not as strong as fiberglass for impact strength, although new technologies are being developed to improve this impact strength (Hobson, 1998).

Although hemp may be able to replace fiberglass in many applications, it will not be able to replace the entire market. Based upon conversations with Lloyd (1998), hemp and other natural fibers can only compete with fiberglass for certain applications. First, natural fibers can only compete with so-called "chopped" fiberglass, in which the synthetic materials used in fiberglass have been cut into small strands rather than being used from one continuous strand. Hemp and other natural fibers have a naturally short length compared to synthetic fibers that can be made of very long lengths. And second, because of its highly absorbent qualities, hempmat cannot be used in exterior applications where moisture may be a problem.

According to Lloyd, the total staple fiber U.S. non-woven production is approximately 293,500 tons. Using the assumption that fiberglass currently represents approximately 60 percent of that figure, current fiberglass production would be approximately 176,100 tons. Using the further assumption that natural fibers could capture 20 percent of the current fiberglass market (due to the limitations discussed above and because other fibers may still be cheaper than hemp in some areas), this means that natural fibers would represent 35,220 tons of the total fiberglass market. Finally, we assume that hemp would capture 20 percent of this market because of competition from other natural fibers, leaving hemp with 7,044 tons of the overall fiberglass market.

Using the assumption that 1.2 tons of hemp fiber would be produced per acre of hemp grown, this translates into 5,870 additional acres of hemp that could be planted to support hemp as a replacement for fiberglass in the U.S. It will take time before this level of acreage is cultivated for fiberglass replacement, however. Existing fiberglass manufacturers may find it difficult to retool their machines to accommodate hemp fiber, even given its cheaper cost than glass. Some years will need to pass before existing manufacturers or new manufacturers come online with the appropriate technology required to process hemp into an alternative to fiberglass.

Textiles and Apparel

The sales of clothing, as well as sofa covers and other textiles made with industrial hemp, have grown rapidly over the last few years. This has brought opportunity and success to many importers and retailers of industrial hemp textiles and apparel. Fashion has contributed to this success. While industrial hemp textile and apparel products are more expensive than their counterparts made with cotton or synthetic materials, fashionable clothing can be sold at a higher price. Some consumers will be willing to pay more for apparel items such as clothing, hats, and bags made with non-cotton natural fibers in general, or industrial hemp in particular. This has helped the industrial hemp apparel industry to grow. On the other hand, some consumers will not be willing to pay a price premium for natural fiber such as industrial hemp, or at least not a large premium, so price will be a key issue in the further expansion of the industrial hemp market.

There are two reasons why apparel products made with industrial hemp are more expensive than cotton or synthetic products. These reasons are higher raw material costs and higher processing costs. Domestic production of industrial hemp would reduce hemp's price disadvantage in terms of raw material cost. Higher processing costs, however, may be more difficult to alleviate. Processing costs with industrial hemp are higher because industrial hemp fibers often do not meet specifications such as fiber length or diameter required for the equipment used in most textile mills and apparel factories. As a result, industrial hemp must be processed on more expensive specialty machinery, which leads to much higher processing costs.

This type of problem is most acute when using industrial hemp fiber to produce textiles for apparel. Industrial hemp fibers are inherently too long for use in machines that spin cotton, or the synthetic fibers in common use. Efforts to convert industrial hemp fibers to the proper specification, a process known as "cottonization," are still under development.

This problem is less acute for household interior coverings such as carpets and furniture covering than for apparel. This is because industrial hemp fibers, when properly grown and processed, can be used to produce yarns that match the specifications on fiber length, diameter, stiffness, and color of existing state-of-the-art canvas and rug weaving machinery (Kime, 1998).[13]

Meeting these specifications, however, requires an exacting decortication process, and precision when cultivating industrial hemp stalk for fiber. To encourage that specifications are met, Hempline, Inc., is leading the formation of a grading system for industrial hemp fiber similar to the system for wool or cotton according to the specifications listed above (Kime, 1998). This should help carpet and furniture covering makers purchase hemp fiber with confidence that the fibers will meet their specifications.

Given that industrial hemp furniture coverings can meet the design specifications for industry machinery, it is anticipated that industrial hemp coverings can capture a share of the high-value portion of this market. Industrial hemp furniture coverings would be more expensive than cotton upholstery due to the higher cost of industrial hemp fiber and yarn. However, industrial hemp furniture coverings would fit in with the growing aesthetic interest in natural materials in home interiors. Industrial hemp furniture coverings are also very long-lasting due to a resistance to wear and tear and sunlight.

Given a place in the high value portion of the upholstery market, industrial hemp might be able to capture a small percentage of the national upholstery market. If industrial hemp could capture one percent of the market for upholstery, this would amount to 5.5 million square yards of industrial hemp canvas produced each year (U.S. Department of Commerce, 1997a). At an estimate of 11 ounces of industrial hemp yarn per square yard of canvas for furnishings (Goldstein, 1998a), this amounts to a demand for 1,900 tons of industrial hemp yarn. The yield for processing industrial hemp fiber into yarn is estimated to vary between 50 and 85 percent, depending on the application (Goldstein, 1998a).

Using a yield of 75%, there would be a need for 2,500 tons of industrial fiber to meet the demand. It is anticipated that each acre of industrial hemp cultivated for textile fiber could in time reach a yield of 1.5 tons of textile-quality fiber per acre. This estimate is based on the long-term yield of five tons an acre on acreage cultivated for straw only (see Table 5). Industrial hemp cultivated for straw only must be used to obtain fiber that can meet the specifications of textile producers. Thus, roughly 1,700 acres of industrial hemp straw would need to be cultivated to supply enough fiber for industrial hemp furniture coverings to capture one percent of the market for upholstery. The potential for industrial hemp fiber in the carpet market is covered in a separate section.

As for industrial hemp apparel, the market for apparel in the United States is expected to continue to grow. Total consumption of industrial hemp yarn for hemp apparel production in the United States will likely be limited by price, as was discussed above. As a result, the fiber needed to supply the industrial hemp apparel industry probably could be grown on hundreds rather than thousands of acres. To see this, consider that a recent study indicated that $23.3 million in industrial hemp merchandise was sold in the United States in 1996 (Bordenaro, 1997). This level of sales translates into an estimated demand for roughly 820,000 square meters of

[13] The percent lignification and percent pectin are also key specifications.

industrial hemp cloth in the United States in 1996.[14] This cloth would be in the form of either finished apparel products or raw cloth imported into the United States for making apparel products. Note that this level of demand is consistent with U.S. Trade Administration data in Table 1 showing the import of 435,000 square meters of industrial hemp cloth into the United States in 1996, given that some finished apparel products would be imported in addition to cloth.

A need for 820,000 square meters of industrial hemp cloth would create a demand for 308,000 pounds, or 154 tons, of industrial hemp yarn, based on cloth that weighs roughly six ounces per square meter (Goldstein, 1998a). Using the same yield and cultivation information as was used for hemp furniture coverings, this level of demand could be met with 140 acres of industrial hemp production.

This 1996 figure is almost certainly an underestimate of demand in future years. Recall that in Table 1 imports of industrial hemp cloth grew by 62 percent between 1996 and 1997. However, even if growth continued at this very rapid pace, it would take more than four years for the demand for fiber from apparel sold in the United States to be large enough to require 1,000 acres of industrial hemp cultivation.

While the potential for using industrial hemp in apparel products may not be as great as in some of the products discussed above, at least given current technologies, there is activity in this sector. There is substantial retail activity, as discussed by Bordenaro (1997), and many firms are manufacturing industrial hemp apparel from imported cloth. In addition, there is at least one company now producing industrial hemp cloth in the United States, using imported fiber or yarn. American Hemp Mills is producing cloth that it believes will offer higher quality, better colors, and more intricate patterns than imported cloth (Goldstein, 1998b).

Finally, this potential under current technologies, however, may vastly underestimate the potential for using industrial hemp to make apparel products under a new fiber separation process under development. This process is the “cottonization” or steam explosion process. Using steam explosion to process hemp fibers may provide better results than traditional mechanical processing. Traditional processing equipment for natural fibers such as hemp and flax can result in low yields of high-value fiber. This occurs because the traditional equipment is unable to account for variability in the quality of the fiber being processed.

Some researchers have shown that steam explosion may produce a better quality fiber and enable hemp fibers to be used in a wider range of applications (Kessler, 1996). The major advantage is that this type of treatment can be more easily adjusted to accommodate variations in fiber quality that are inevitable in the processing of industrial hemp. It has been shown that this treatment can yield up to 95 percent good fiber, and the fibers made using this are much

[14] This estimate was made as follows: Assume that 90 percent of industrial hemp sales by value was in clothing (70 percent) and backpacks (20 percent), the principal apparel items. Given an average price of $63 per clothing item and $37 per backpack, this would translate into sales of roughly 410,000 items a year. This would translate into a demand for 820,000 square meters of industrial hemp cloth, assuming two square meters of industrial hemp cloth per clothing item or backpack.

finer than those made with mechanical treatments. A yield of 95 percent helps to reduce fiber costs.

This type of treatment holds some promise for the use of industrial hemp and other natural fibers in a variety of applications. The textile industry is perhaps best suited to exploit the advantages of this processing. Using steam explosion can generate bast fibers with properties that make them more easily usable on traditional cotton or wool equipment than fibers processed by traditional mechanical methods. Moreover, the textile industry is more prepared than more highly technical industries to use natural, heterogeneous materials. The fiber demand from apparel would be substantially higher than the estimates presented above if this steam explosion or “cottonization” process is developed into a cost-competitive technology.

Carpet

Industrial hemp may also have potential for use in the carpet industry. A blend of industrial hemp and wool fibers can produce a carpet that retains the durability of wool carpet, but produces an even softer and more health promoting carpet than a pure wool carpet (Stinett, 1998a). The hemp wool blend of carpet also should become cheaper than all wool carpeting once cultivating and processing of industrial hemp straw is legalized in the United States. Industrial hemp fiber is currently being used by a Georgia company in the carpet industry, Earthweave, to produce a hemp and wool blend carpet (Stinett, 1998a).

An examination of the wool carpet industry is necessary to estimate the potential demand for industrial hemp fiber in a hemp and wool blend market. One important factor to consider is that wool carpet production represents a minor share of the carpet industry. There were approximately four million square yards of woven wool carpet shipped in the United States in 1993, the last year that wool carpet shipments were reported. These data were not reported in later reports about the carpet industry in order to ensure the privacy of the factories producing wool carpet. The production of tufted wool carpets is unknown. However, four million square yards is a conservative estimate given that tufted carpets account for more than 90 percent of carpet production, compared to only 10 percent for non-tufted carpets. This results in an estimate that wool carpet shipments account for at least eight million square yards of carpet production per year.

When hemp and wool are used in a 50 percent blend, as is currently the case at the existing producer, then approximately 1.3 pounds of industrial hemp yarn is used per square yard of residential carpet (Stinnet, 1998a). This information makes it possible to estimate the amount of industrial hemp that will be required as a hemp wool blend captures a share of the wool carpet market. For example, 1,000 square yards of 50 percent hemp and wool blend carpet would require 0.65 tons of industrial hemp yarn. This implies that if the hemp and wool blend is able to capture 10 percent of the wool carpet market, 520 tons of industrial hemp yarn would be required for production. Roughly 2,600 tons of industrial hemp yarn would be required if a hemp and wool blend was able to capture 50 percent of the wool carpet market. An expectation that the hemp and wool blend could capture 50 percent of the carpet market is reasonable. While imported industrial hemp yarn currently costs more than wool yarn (Stinnett, 1998a), the price of industrial hemp yarn should fall below the cost of wool once it is produced domestically.

The yield for processing suitable industrial hemp fiber into yarn is estimated to vary between 50 and 85 percent, depending on the application (Goldstein, 1998a). Using a yield of 75 percent, there would be a need for 3,500 tons of industrial fiber to meet the demand for 2,600 tons of industrial hemp yarn. This tonnage of industrial hemp yarn suggests a need for roughly 2,300 acres of industrial hemp straw cultivation based on an average yield of five tons of industrial hemp straw per acre, and industrial hemp straw that is 30 percent fiber. An estimate of five tons of straw per acre is used since only industrial hemp cultivated for straw only will produce fibers of sufficient quality to meet the specifications of carpet makers.

This estimate, however, does not account for the possibility that industrial hemp carpeting may compete outside the wool segment of the carpet industry. For example, Interface, a major U.S. carpet maker based in Georgia, is developing a 100 percent industrial hemp carpet to compete in both the office and residential carpet markets. This 100 percent hemp carpet should have several advantages in the marketplace. First, 100 percent industrial hemp carpeting would be a natural carpet that could match a main selling point of higher quality synthetic filament carpet. This is because, like higher quality synthetic filament carpet, industrial hemp carpet does not shed of fuzz (Stinnett, 1998b). Second, industrial hemp carpet is very resistant to decomposition, due to the strength of industrial hemp fibers (Berard, 1998). Third, it may be possible to recycle industrial hemp carpet, or, at least, compost it (Berard, 1998). Thus, industrial hemp carpet would be a high quality carpet that also had an environmental appeal that would influence some consumers. But industrial hemp carpet would be more expensive due to higher yarn costs and a somewhat higher processing cost, since carpet-making machinery must run more slowly when processing natural rather than synthetic fiber (Stinnett, 1998b).

The higher price of industrial hemp carpet suggests that hemp will be able to capture a share of the high value segment of the carpet industry. In particular, industrial hemp may be able to compete for a share of the high quality nylon carpet segment, rather than the very inexpensive polypropylene carpet segment. Given a place in the high value portion of the nylon carpet segment of the market, industrial hemp might be able to capture a few percent of the nylon carpet segment. If industrial hemp could capture one percent of the market for nylon carpet, this would amount to 9.8 million square yards of carpeting (United States Department of Commerce, 1997b). The yarn requirement for 100 percent industrial hemp carpet averaged for the residential and office market segments would be 2.2 pounds per square meter (Stinnett, 1998a). This would translate into a need for 10,700 tons of yarn for carpeting. The fiber needed to make that much yarn could be grown on 9,500 acres of industrial hemp cultivated for straw alone, based on the ratios calculated above for wool carpets. This acreage, when combined with the acreage required in the wool carpet market segment, suggests a potential need for up to 12,000 acres of industrial hemp cultivated for use in carpet making.

Summary

This analysis of the national market for industrial hemp products yielded a rough estimate that there may be demand for up to 100,000 tons of industrial hemp fiber each year. This tonnage suggests that there would be a need to cultivate up to 82,000 acres of industrial hemp for straw or straw and grain each year. Given that the returns to farmers from growing industrial hemp for straw and for straw and grain are very similar, it is assumed that roughly one-half of that acreage would be devoted to growing straw only and one-half to growing grain and straw. Analysis further indicates that there should be sufficient demand for the industrial hemp grain and hurds grown on these 82,000 acres.

This said, it should be pointed out that this estimated acreage is a rough estimate. It is most appropriate to focus on the rough magnitude of this acreage estimate rather than its exact value. This rough magnitude suggests tens of thousands of acres of cultivation or perhaps a few hundred thousand acres. This is substantial acreage for a niche agricultural crop. The rough magnitude does not suggest a need for millions of acres of industrial hemp cultivation, at least given current technologies and uses for industrial hemp. Finally, it should be noted that this acreage estimate is consistent with the acreage currently cultivated in Europe. There were 52,000 acres of industrial hemp cultivated in Western Europe in 1997 (Bosca and Karos, 1998), and the size of the Western European economies together is roughly equal to the size of the U.S. economy.

ECONOMIC IMPACT IN KENTUCKY

The preceding analysis examined the potential acreage for the industrial hemp industry in the United States if the cultivation of industrial hemp is legalized. This analysis produced a rough estimate that the industrial hemp industry could reach up to 82,000 acres of agricultural production given existing uses and technologies if cultivation is legalized. The magnitude of these national figures, however, does not easily lead to an estimate of the size of the industry in Kentucky. In particular, it is unclear how many acres of production would occur in Kentucky.

There are three reasons why Kentucky might gain a significant share of the industrial hemp industry. The first reason is that Kentucky may be a location where industrial hemp processors could expect to receive a high price for hemp hurds, which is a key to profitability in the industrial hemp processing industry. High quality animal bedding, and particularly, horse bedding, currently appears to be the highest value use for hemp hurds. The high concentration of valuable horses in Kentucky may mean that a substantial amount of hurds can be sold at a high price locally, before transportation costs erode profits. The second reason why Kentucky may be active in the industrial hemp industry is the state's advantage in the certified seed market, that is, the market for growing seeds for use in sowing the crop elsewhere. Kentucky's longer growing season and appropriate soil made the state the major source for certified seed up through the World War II period.[15] This historical relationship may return if cultivation of industrial hemp is legalized.

The last way that Kentucky may gain an advantage in the industrial hemp industry is to be the first state, or one of the first states, to legalize the cultivation of industrial hemp. An industrial hemp industry of the size discussed above will be large enough to support only a limited number of industrial hemp decorticating plants, and the surrounding fields cultivating industrial hemp. It may be that those states that legalize industrial hemp cultivation first will capture early investments in the industry. This will build a level of local expertise in processing and farming the crop that may create a local comparative advantage that will supercede lower growing costs that may exist in other areas of the country.

These three reasons lead to an expectation that Kentucky will have some role in an industrial hemp industry that, given current technology and uses, may have national agricultural production of up to around 80,000 acres. It is difficult to be precise about the exact share of the industry that Kentucky can expect to capture, however. This uncertainty makes it difficult to estimate precisely the economic impact that the industrial hemp industry would have on Kentucky. Kentucky may gain only a share of the certified seed production segment of the industry. But Kentucky might also capture one or two decorticating facilities and the corresponding agricultural production of hemp straw and grain. For example, if the national industrial hemp industry reaches 34,000 acres of straw production for whole stalk paper pulp plants, and 48,000 acres for decortication, this would be enough production nationally to require five large decorticating plants. It is feasible that Kentucky might capture one or two of these plants.

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[15] Some cultivation continued past the end of World War II. For example, Kentucky sources continued to supply Wisconsin farmers with industrial hemp seed for planting through 1958.

A range of potential economic impacts for the industrial hemp industry will be reported below to correspond with the estimated size of the industry nationally and potential share of the industry located in Kentucky. Specifically, the economic impact will be estimated under five different scenarios. The first scenario is that straw processing for hurds and fiber fails as a business in the United States and industrial hemp is only grown for its grain. The second scenario is that straw processing reaches 82,000 acres in the United States but Kentucky receives no decorticating plants, but does grow one-half of the certified seed required in the United States. The third scenario is that Kentucky captures one-half of the certified seed market and one decorticating facility. This implies a substantial number of acres of industrial hemp grown in Kentucky, most likely for both straw alone and grain and straw. The fourth scenario is that Kentucky captures one-half of the certified seed market and two decorticating facilities. The fifth scenario is that Kentucky captures one of the certified seed market, one decortication facility, and one industrial hemp paper pulp plant.

These economic impact estimates include an estimate of the acres of production of industrial hemp in Kentucky. However, the key outcome of the economic impact analysis will be an estimate of employment and worker earnings due to the industrial hemp industry in Kentucky.

The economic impact is calculated by applying economic multipliers to the purchases and profits associated with farm production of industrial hemp, and the operation of hemp straw decorticating processing facilities. These multipliers capture both the direct jobs and earnings of industrial hemp farmers and employees at processing plants and the additional jobs and earnings in the community and state as industrial hemp farmers purchase supplies at the local feed store or equipment retailer. It also includes the additional economic impact that occurs as farm workers and workers at industrial hemp processing facilities spend their income, or farm operators spend their profits during their daily life at grocery stores, food stores, or on insurance premiums, to give a few examples. This additional spending, and the jobs and worker income it supports, must also be included in calculations of the economic impact of an industry. The economic impact multipliers that are used are state multipliers for Kentucky calculated using the Micro IMPLAN model (MIG, 1996). This model, originally developed by the United States Forest Service and the University of Minnesota, is widely used throughout the United States to calculate both state and county economic multipliers.

Finally, it is important to remember that the economic *impacts* on Kentucky discussed below are not equivalent to economic *benefits.* Economic impact calculations only reflect the impact of the growth of a particular industry or project on the economy but do not consider any loss of economic activity that may occur in other industries as a result. Yet, such a simultaneous loss is clear for industrial hemp cultivation. In particular, any time that industrial hemp is grown on agricultural land, that land cannot be used to grow other crops during that season, or be used for forage or forestry. This will mean a loss of economic impact in these industries, which will mean that the net benefit to Kentucky from cultivating industrial hemp will be less than the economic impact.[16] Similarly, any workers at an industrial hemp processing plant will

[16] The overall net economic benefit will be positive, however. Farmers would not switch to cultivating industrial hemp unless it added greater value to the land than alternative uses.

not be available to work at other Kentucky businesses, unless the plant happens to be located in a region of the state experiencing a spell of high unemployment. Nonetheless, it is still worthwhile to consider the economic impact. Most reports detailing how particular industries will affect a state or local economy report the industry's economic impact rather than net economic benefit. Thus, economic impacts are presented here for comparison purposes.

Industrial Hemp Grain Production Only

The first economic impact estimate that is calculated is a scenario under which industrial hemp grain continues to be processed in the United States but the processing of industrial hemp straw for hurds and fiber fails. Recall that there are currently 1,300 tons of industrial hemp grain imported into the United States or slated for production in Canada. Recall further that the price of industrial hemp grain could be expected to fall to roughly $0.25 per pound if industrial hemp is grown for grain only (see Table 6). Given the elasticity of demand for oils, sales of industrial hemp grain for existing products would rise to 1,500 tons of industrial hemp grain at a price of $0.25 per pound rather than $0.15 per pound. At a price of $0.25 per pound, industrial hemp grain also could be expected to capture about five percent of the current sales of flaxseed. This implies an additional 12,500 tons of industrial hemp grain sold. All of this totals to 14,000 tons of industrial hemp grain sold.

Assuming that Kentucky farmers could capture 20 percent of this market, this would imply 4,000 acres of production of industrial hemp grain in Kentucky. This rather large share is based on the assumption that Kentucky legalizes the production of industrial hemp before most other states, so that Kentucky farmers are able to cultivate industrial hemp first if cultivation is legalized by the federal government. In any case, Kentucky would have an advantage in growing industrial hemp for grain over more northern states due to Kentucky's longer growing season. Under this scenario, it is assumed that most of the hemp straw harvested from acreage grown for hemp seed cannot be sold since there is no decorticating plant in Kentucky.

The economic impact under this scenario would be approximately $1,100,000 in worker earnings or farmer income coming from 59 full-time equivalent jobs. Recall that the term full-time equivalent means jobs with enough hours to be equivalent to a full-time job. One full-time job is one full-time equivalent job, but so are two half-time jobs, or four quarter-time jobs. This implies that many more than 59 farmers could be involved in growing hemp as part of their acreage. It is just that industrial hemp cultivation is not their full-time job. Similarly, no single store clerk at a feed store will have his or her entire job devoted to supplying industrial hemp farmers, but many clerks will spend a few hours, perhaps enough hours between all affected clerks to sum up to a full-time job. Finally, recall that these economic impacts are based on the assumption that Kentucky farmers could capture 20 percent of the demand for industrial hemp grain. Economic impacts would be smaller if Kentucky farmers capture a smaller share.

Certified Seed Only

This scenario assumes that a processing industry for industrial hemp straw develops in the United States but that Kentucky is not able to capture an industrial hemp straw decorticating plant or paper pulp plant. As was true historically, however, Kentucky is assumed to capture roughly one-half of the national production of certified seeds for planting. In particular, Kentucky is assumed to produce enough certified industrial hemp seed to plant 41,000 acres of industrial hemp for straw.

As illustrated in Table 5 above, 50 pounds of certified seed is required per acre of industrial hemp grown for straw alone, or grown for both straw and grain. This suggests a demand for 1,025 tons of certified industrial hemp seed on 41,000 acres. This suggests a need for cultivating 2,050 acres of industrial hemp certified seed, given the average yield of 1,000 pounds of certified seed per acre utilized (see Table 5). Based on this method, the economic impact of the industrial hemp industry would be 69 full-time equivalent jobs and $1,300,000 in worker earnings.

One Decortication Plant and Certified Seed

The third scenario examined assumes that Kentucky is able to capture one industrial hemp straw decorticating facility and to supply certified seed to 41,000 acres of industrial hemp for straw. The decorticating facility assumed is the facility described in Appendix 1. The facility processes 36,300 tons of industrial hemp straw into hurds and fiber in a given year. Given the high costs of transporting industrial hemp straw, a facility of this size will require the cultivation of the required hemp straw nearby, probably within a 50-mile radius. This need for 36,300 tons of industrial hemp straw will necessitate the cultivation of 8,500 acres of industrial hemp straw in Kentucky. This calculation is based on the assumption that one-half of this acreage would be grown for hemp straw alone and one-half for straw and grain. Recall that in Table 6 it is expected that the yield on acreage cultivated for straw only would be five tons of straw per acre, while the yield of straw would be 3.5 tons per acre on acreage cultivated for both straw and grain.

The economic impact of operating one decorticating facility and cultivating 8,500 acres for straw or straw and grain and 2,050 acres for certified seed can be calculated based on the production expenses and operator profits listed in Table 5 along with economic multipliers from the Micro IMPLAN model. Production expenses and operator profits for the decorticating facility operator and farmers would represent the sales revenues flowing into Kentucky as hurds, fiber grain, and certified seed are sold to customers throughout North America. The economic multipliers convert these sales revenues into an estimate of the employment and worker earnings that would result in Kentucky. Based on this method, the economic impact would be 303 full-time equivalent jobs, and $6,700,000 in worker earnings.

Two Decortication Plants and Certified Seed

The fourth scenario examined assumes that Kentucky is able to capture two industrial hemp straw processing facilities and to supply certified seed to 41,000 acres of industrial hemp cultivated for straw or for straw and grain. The decorticating facility assumed is the facility described in Appendix 1. Two facilities would process 72,600 tons of industrial hemp straw into hurds and fiber in a given year. Given the high costs of transporting industrial hemp straw, a facility of this size will require the cultivation of the required hemp straw nearby, probably within a 50-mile radius. This need for 72,600 tons of industrial hemp straw will necessitate the cultivation of 17,000 acres of industrial hemp straw in Kentucky. This calculation is based on the assumption that one-half of this acreage would be grown for hemp straw alone and one-half for straw and grain.

The economic impact of operating two decorticating facilities and cultivating 17,000 acres for straw or straw and grain and 2,050 acres for certified seed can be calculated based on the production expenses and operators profits listed in Table 5 along with economic multipliers from the Micro IMPLAN model. Production expenses and operators profits for the decorticating facility operator and farmers would represent the sales revenues flowing into Kentucky as hurds, fiber grain, and certified seed are sold to customers throughout North America. The economic multipliers convert these sales revenues into an estimate of the employment and worker earnings that would result in Kentucky. Based on this method, the economic impact would be 537 full-time equivalent jobs, and $12,100,000 in worker earnings.

One Decortication Plant, One Paper Pulp Plant and Certified Seed

The last scenario examined assumes that Kentucky is able to capture one industrial hemp paper pulp plant and one industrial hemp straw processing facility as well as supply certified seed to 41,000 acres of industrial hemp cultivated for straw or for straw and grain. The decorticating facility assumed is the facility described in Appendix 1. The decortication facility would process 36,300 tons of industrial hemp straw into hurds and fiber in a given year. The pulp paper plant would process 72,500 tons of industrial hemp straw each year. Given the high costs of transporting industrial hemp straw, these facilities will require the cultivation of the required hemp straw nearby, probably within a 50-mile radius. This need for 108,800 tons of industrial hemp straw will necessitate the cultivation of 25,600 acres of industrial hemp straw in Kentucky. This calculation is based on the assumption that one-half of this acreage would be grown for hemp straw alone and one-half for straw and grain.

The economic impact of operating one decorticating facility, one industrial hemp paper pulp plant, and cultivating 25,600 acres for straw or straw and grain and 2,050 acres for certified seed can be calculated based on the production expenses and operator profits listed in Table 5 along with economic multipliers from the Micro IMPLAN model. Production expenses and operators profits for the decorticating facility operator and farmers would represent the sales revenues flowing into Kentucky as hurds, fiber, grain, and certified seed are sold to customers throughout North America. The economic multipliers convert these sales revenues into an estimate of the employment and worker earnings that would result in Kentucky. Based on this method, the economic impact would be 771 full-time equivalent jobs, and $17,600,000 in worker earnings.

Impact on Crop Yields

The previous section examined the economic impact due to industrial hemp production. It covered the jobs and earnings related to industrial hemp. It did not consider the benefits that can occur when industrial hemp is used as a rotation crop, that is, the benefits that occur when hemp production is rotated from year to year with the production of other crops such as corn or soybeans. These benefits occur because industrial hemp can reduce weeds and raise yields for the suceeding crops in the rotation, which can lead to higher net incomes for farmers. These benefits can also be counted as an impact of industrial hemp, at least to the extent that the benefits are unique to industrial hemp and cannot be obtained from other rotation crops.

Several agronomic studies indicate that growing industrial hemp in rotation reduces the growth of certain types of weeds. In a European study, planting industrial hemp before corn was found to reduce the growth of the common weed *Cyperus esculentus* for several years of corn cultivation (Lotz, *et. al*, 1991). Cultivating industrial hemp before corn was found to be much more effective at reducing growth of this weed than planting barley or rye. In Canada, Laprise (1998) reported that cultivating industrial hemp for one year reduced soybean nematode cysts by more than 80 percent. This reduction in soybean nematodes was greater than with corn, another crop that is helpful in reducing soybean nematodes. Such a large reduction occurred because industrial hemp is not a host for nematodes, and the population is greatly diminished in a year without a host. This implies that cultivating industrial hemp before soybeans would probably raise soybean yields, especially since herbicides are ineffective against soybean nematodes (Laprise, 1998).

Industrial hemp in rotation also improves yields for suceeding crops by improving soil ventilation and water balance (Bosca and Karus, 1998). The improved soil ventilation and water balance allows suceeding crops to be planted earlier in the season, allowing for greater yields. The impact on yields occurs in a number of crops. Farmers in The Netherlands reported a 10 percent increase in winter wheat yields when planted after industrial hemp cultivated for fiber due to improved soil structure (Bosca and Karus, 1998).

Such improved yields can be significant for the net return to farmers in the years after industrial hemp is grown in rotation. Take the above example of a 10 percent increase in winter wheat yields. In Kentucky, the yield for winter wheat in 1996 was 53 bushels an acre (Kentucky Agricultural Statistical Service, 1996). A 10 percent yield increase would mean an additional 5.3 bushels per acre. This implies an additional $23 in net returns per acre for the farmer since the average price paid for a bushel of winter wheat was $4.30 in 1996 (Kentucky Agricultural Statistical Service, 1996).

Such benefits from growing industrial hemp may be especially great for organic farmers. A farmer that cannot use herbicides may benefit substantially from cultivating a crop that itself does not use herbicides, and is especially potent in reducing weed growth affecting succeeding crops.

Environmental Impact

There also is an environmental benefit from growing industrial hemp versus other fiber crops. Cultivation of industrial hemp does not require pesticides (Bosca and Karus, 1998; nova Institute, 1996; see Tables 3,5, and 6). The production of other fiber crops such as flax or cotton often uses large quantities of pesticides (Bosca and Karus, 1998). This implies that a reduction in pesticide use will occur in society anytime that industrial hemp fiber or grain is substituted for flax fiber or seed in paper, oils, animal feed, animal bedding, and the like. Similarly, it implies a reduction in pesticide use any time industrial hemp fiber is substituted for cotton fiber in clothing, paper, or carpets.

Such a reduction in pesticide use could bring a benefit to society. This is because flax and cotton farmers do not pay the full social cost of their pesticide use when they purchase these inputs. This full social cost includes the health costs of ground water contamination resulting from pesticide use as well as the cost of manufacturing the pesticides. This cost, however, is not added to the normal price of pesticides through taxation or some other method. The fact that these costs are not included means that more pesticides are used than is socially optimal. If the cost were added, there would be a reduction in the use of pesticides when growing cotton or flax, and a resulting decline in yields as well.

Because such a tax scheme to reduce the use of pesticides in flax and cotton cultivation does not exist, a social cost is avoided whenever industrial hemp is cultivated rather than flax or cotton. Calculating the exact value of the excess ground water contamination that is avoided if industrial hemp is substituted for flax or cotton is beyond the scope of this report, however.

CONCLUSION

This report has examined the economic feasibility of establishing an industrial hemp industry in the United States, and more specifically, the state of Kentucky. To conduct this analysis, the report has focused on the general economic feasibility of cultivating and processing the crop in the United States given existing technologies and uses for industrial hemp. The report also has discussed some comparative advantages present in Kentucky for cultivating industrial hemp. Such a comparative advantage for Kentucky, naturally, would be important to ensuring that part of the industry would locate in Kentucky versus other parts of the country. The prospect for establishing industrial hemp processing facilities in Kentucky is also examined. Finally, this report examines the potential economic impact of the industry in Kentucky given existing technology and uses for industrial hemp.

The primary finding regarding economic feasibility was that industrial hemp appears to be a potentially profitable crop for farmers as well as a profitable input into a number of high value added products in the United States. Industrial hemp appears to be useful for higher value products in industries ranging from health supplements, nutraneuticals, food products, animal feed, and animal bedding to paper, carpets, and automobile parts. The list identified was quite similar to a list identified for Germany in a report from the nova Institute (1996). Products made with industrial hemp were expected to capture a share of the higher end of these markets where consumers were willing to pay a higher price in order to receive a higher quality product, a product for some specialized use, or out of environmental concern. Given current technologies and uses for industrial hemp, sales of hemp products in these industries were estimated to support the cultivation of up to 82,000 acres of industrial hemp for fiber and grain, or fiber alone. This number appears reasonable given that 52,000 acres of industrial hemp were cultivated in western Europe in 1997 (Bosca and Karos, 1998), and the size of the western European economies together is roughly equal to the size of the U.S. economy.

Kentucky is expected to have a comparative advantage in several components of the hemp industry. First, Kentucky historically has enjoyed an advantage as an area for producing certified seed for replanting due to a long growing season and appropriate climate and soil. This advantage made Kentucky the primary area in North America for growing industrial hemp certified seed in the earlier portion of the century and should make it a favored location again. Second, Kentucky may enjoy an advantage as a location for growing industrial hemp straw due to nearby, high-value markets for hemp hurds. Sales of industrial hemp hurds for horse bedding is one of the highest value uses for the hurds, and Kentucky has a high concentration of thoroughbred horses and race horses both at its breeding farms and racetracks. Third, Kentucky might create a comparative advantage by becoming the first or one of the first states to legalize the cultivation of industrial hemp. In this way, Kentucky might gain early investments in the industry that will allow local farmers, workers, and plant operators to develop expertise in the industry. This advantage in expertise may allow Kentucky producers to compete favorably for quite some time with processors located near potentially more productive land.

Given the estimated size of the industry in the United States, and Kentucky's comparative advantage, it is estimated that Kentucky could grow certified seed to supply up to 41,000 acres of industrial hemp planted for straw alone, or straw and grain. Under this assumption, Kentucky would produce 2,050 acres of industrial hemp for certified seed. This production would have an economic impact of 69 full-time equivalent jobs and $1,300,000 in worker earnings. Kentucky also may supply certified seed to industrial hemp farmers in Ontario, Canada, as was the case historically.

Kentucky may also be able to capture one or several decorticating facilities and the attendant industrial hemp acreage. The economic impact of one decortication plant and the certified seed market discussed above would lead to approximately 10,500 acres of industrial hemp production in Kentucky, and an economic impact of 303 jobs and $6,700,000 in worker earnings. If two decortication plants locate in Kentucky, cultivation would rise to 19,000 acres, and the economic impact to 537 jobs and $12,100,000 in worker earnings. If one decortication plant and one industrial hemp paper pulp plant were to locate in Kentucky, cultivation would rise to 27,600 acres of industrial hemp in Kentucky, and an economic impact of 771 jobs and $17,600,000 in worker earnings.

Finally, it should be pointed out that the current role for industrial hemp in high value or specialty markets does not preclude its future use in bulk markets. After all, there has been little research or engineering work done on industrial hemp processing given that its cultivation has been banned in most western countries for the last four or five decades. Indeed, research is now underway on how to use industrial hemp in bulk plastics, and cattle feed markets, to name some key areas. This research may prove successful, which would certainly mean a significantly larger cultivation and economic impact for industrial hemp than was discussed above.

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APPENDIX 1: HEMP DECORTICATING FACILITY

An important issue in the economic viability of industrial hemp is the processing of the plant once it has been harvested. With the important exception of whole stalk paper pulp production, very few practical applications exist that can use whole hemp stalks that have not been processed. With processing, however, hemp can be separated into the bast fiber and hurds, both of which can then be used in different applications.

To separate whole hemp stalks, decortication plants would have to be constructed. Since no hemp is currently grown in the United States, there exist no plants specifically designed to perform this separation. In addition, because of the high costs of transporting whole hemp stalks, these decortication plants would need to be located near the growing sites of hemp. This section describes in detail the various costs associated with constructing a hemp decortication plant.

Although plants of varying capacity could be constructed, a plant that can process about one ton per hour (TPH) of whole hemp stalks is the minimum size necessary (Lloyd, 1998). As with most production processes, however, relative costs savings, or economies of scale, can be realized with plants of larger capacity. For this reason, we assume that the processing plant would be constructed with a capacity of five tons per hour of whole hemp stalks. For this plant to operate effectively, it would need to operate for 22 hours in the day and for 330 days out of the year.

The costs for this processing facility can be broken down into two main categories: fixed and variable costs. Fixed costs include so-called "startup" costs that must be made before the plant can begin operation. These include purchase of the necessary land, improvements to the land, and building permits. In addition, these costs will include actual construction costs and the purchase of equipment that will decorticate the hemp. Variable costs, on the other hand, include costs such as wages and benefits paid to employees at the plant, utility costs (electric, water, gas, etc.) as well as costs for maintaining, upgrading, and renovating plant equipment and interest paid for land, buildings, and equipment.

The fixed and variable costs for constructing and operating a decortication facility will vary by the size of the plant constructed. Larger plants will have higher fixed or capital costs and higher variable costs because they employ more people and have higher maintenance costs. Using figures on the costs of constructing a large-scale (five TPH of whole stalk) processing plant, Lloyd (1998) estimates that the fixed costs of a processing facility would be approximately $2,315,000 and the variable costs to be $2,334,286 per year. Assuming that this plant could process 36,300 tons of hemp per year, this would translate into a processing cost of $100.50/ton. This figure is used in the analysis in Table 2 to help calculate the potential price that industrial hemp farmers could be paid for their hemp.

Several important considerations must be addressed when choosing a site to construct a processing facility. For a large facility capable of processing five tons per hour, approximately 11 acres of land will be necessary. Because of the heavy amounts of dust produced by processing plants, any plant will need to be located in a fairly rural area and at least 1,500 feet from any residential structures (Lloyd, 1998).

In addition to the basic decortication of the hemp plant, other levels of processing could be conducted at the plant. This additional processing, however, would in some cases require substantial additional investments. Processed hemp could be pelletized or compacted to facilitate its transportation over long distances. In addition, hemp fiber could be processed into a very fine grade suitable for use in textiles. Or finally, some type of manufacturing operation could be established at the plant whereby processed hemp would be combined with plastic to produce a composite material. For this study, we will not include the costs of these processing options. Instead, we will only include the basic decortication costs for separating hemp stalk. Experiences in other countries, however, suggests that additional processing may be necessary to put hemp into a usable form. Hemcore (1998) of England reports that the hemp hurds they use for horse bedding must be pelletized (densified) before shipping. Lloyd (1998) estimates that the additional processing required for pelletized would cost an additional $24.09/ton.

APPENDIX 2: COMPARISON OF GROWING COSTS

Another alternative set of growing expense estimates were prepared by Gordon Reichert of the Agriculture and Agri-Food Canada and reported in the article "Hemp Agronomics" by Dave Marcus (1997). These cost estimates also are reprinted in Table A2.1 below. In general, cost estimates from this source were lower than those provided by Spalding. Reichert's 1995 cost estimates called for costs of $195.71 per acre for growing hemp fiber and $173.38 for growing hemp grain. Cost estimates were in U.S. dollars. Even if updated to 1997 dollars, these cost estimates would still be lower than Spalding's. The primary reason for Reichert's lower operating costs were much lower costs for certified hemp seed for planting and for fertilizer costs. Yet, the higher seed and fertilizer costs used by Spalding were verified in actual rather than estimated production cost data for Ontario, Canada provided by Laprise (1997). Further, it is not likely that there will be a crop insurance program for industrial hemp in the United States as is used for Canada by Reichert. Reichert's approach does suggest that herbicide costs need to be added for hemp grain production.

Cost estimates from German cultivation data are also listed in Table A2.2 and A2.3. Two sets of cost estimates are included in each Table. One set is for Germany, the other is for the United States. Growing costs can be quite different in Germany and the United States. Data in the first column of Tables A2.2 and A2.3 reflect the technical requirements for production in terms of pounds of seed and fertilizer and the tasks that need to be run. German production costs are listed in the second column. German costs are converted into U.S. dollars by converted marks to dollars, kilograms to pounds, and hectares to acres. This is a process of simply converting German costs per hectare into U.S. costs per acre. It does not involve actually accounting for the difference in growing costs in the two countries. The U.S. costs in the last column reflect these differences. U.S. costs are calculated using data from a variety of sources. As in Spalding's data, the estimated cost per pound of certified seed is based on the price charged in U.S. dollars by KENEX of Ontario, Canada. This is the company supplying certified seed for cultivation in Canada. Per acre costs for harrowing, plowing, seed preparation, fertilizer application, sowing, and combining are estimated based on machinery and labor costs estimates developed for each task by agronomists at the University of Tennessee. Data from Tennessee was used because growing costs by task are not estimated by the University of Kentucky. For industrial hemp straw cultivation, U.S. growing costs estimated from the German data are roughly in line with estimates from Spalding, especially if the seed requirements per acre are equalized. German growing costs are higher but this is not unusual since German growing costs are typically higher than U.S. growing costs. For industrial hemp grain cultivation, U.S. growing cost estimates from the German data are lower than the estimates from Spalding, but again, would be similar if per acre seed requirements are equalized.

TABLE A2.1: Production Cost Estimates for Ontario in 1995 US$/Acre

Expenses		Hemp Fiber		Hemp Grain
Cash Operating Costs				
Seed (lbs.)	(50)	$45.11	(13)	$11.83
Fertilizer Total		29.20		29.20
Herbicides and Insecticides		0.00		10.95
Fuel		8.76		8.76
Repair		18.98		18.98
Custom Work and Hired Labor		5.84		5.84
Interest on Operating		5.84		5.84
Crop Insurance Premium		5.11		5.11
Revenue Insurance		3.65		3.65
Premium Utilities		1.20		1.20
Miscellaneous Overhead		1.83		1.83
Building Repair		.84		.84
Property Taxes		2.74		2.74
Total Cash Operating Costs		$129.10		$106.76
NonCash or Fixed Costs				
Machinery Depreciation		$20.99		$20.99
Building Depreciation		0.84		0.84
Machinery Investment		12.78		12.78
Building Investment		1.35		1.35
Land Cost		16.79		16.79
Operator Labor and Management		13.87		13.87
Total Non Cash Costs		$66.61		$66.61
Total Costs		$195.71		$173.37

Estimates by Gordon Reichert appear in Marcus (1997) in *Hemp Pages.* Categories from original tables were collapsed in some cases to compare with Spalding's estimates.

TABLE A2.2: Cost and Returns From Growing an Acre of Industrial Hemp Seed

Cost	Production Requirements	Germany Price	Germany Cost per Acre	Kentucky Price	Kentucky Cost per Acre
Seed Costs	2.23lbs / acre	$1.55 / lb	$3.46	$2.5 / lb	$5.58
Fertilizer Costs					
N	0.0445 t / acre	$494 / ton	$21.98	$255 / ton	$11.36
P_2O_5	0.0358 t / acre	$704 / ton	$25.22	$245 / ton	$8.77
K_2O + 6%MgO	0.0671 t / acre	$283 / ton	$18.98	$255 / ton	$17.11
CaO	0.0537 t / acre	$98 / ton	$5.25	$50 / ton	$2.68
Planting and Sowing					
Harrow	Once	$12.82 / ton	$12.82	$10.00 / acre	$10.00
Plow	Once	$34.28 / ton	$34.28	$5.17 / acre	$5.17
Seed Preparation	Once	$8.99 / acre	$8.99	$8.99 / acre	$8.99
Fertilizer (application)	Twice	$4.09 / ton	$8.18	$1.40 / acre	$2.80
Sowing	Once	$17.10 / acre	$17.10	$7.44 / acre	$7.44
Harvest					
Combining, Harvesting	Once	$66.97 / acre	$66.97	$27.10 / acre	$27.10
Seed Transport	Once	$13.63 / acre	$13.63	$13.63 / acre	$13.63
Turning	Thrice	$8.19 / acre	$24.57	$8.19 / acre	$24.57
Bailing, Bundling	Once	$31.30 / acre	$31.30	$10.05 / acre	$10.05
Fixed Costs (insurance, interest)			$60.01		$60.01
Total Costs			$336.36		$215.26

Note: This table is based on an exchange rate of 1.76 DM per US$.

TABLE A2.3: Cost and Returns From Growing an Acre of Industrial Hemp for Fiber

Cost	Production Requirements	Germany Price	Germany Cost per Acre	Kentucky Price	Kentucky Cost per Acre
Seed Costs	60lbs / acre	$1.55 / lb	$93.00	$2.50 / lb	$150.00
Fertilizer Costs					
N	0.0445 t / acre	$494 / ton	$21.98	$255 / ton	$11.36
P_2O_5	0.0358 t / acre	$704 / ton	$25.22	$245 / ton	$8.77
K_2O + 6%MgO	0.0671 t / acre	$283 / ton	$18.98	$255 / ton	$17.11
CaO	0.0537 t / acre	$98 / ton	$5.25	$50 / ton	$2.68
Planting and Sowing					
Harrow	once	$12.82 / ton	$12.82	$10.00 / acre	$10.00
Plow	once	$34.28 / ton	$34.28	$5.17 / acre	$5.17
Seed Preparation	once	$8.99 / acre	$8.99	$8.99 / acre	$8.99
Fertilizer (application)	twice	$4.09 / ton	$8.18	$1.40 / acre	$2.80
Sowing	once	$17.10 / acre	$17.10	$7.44 / acre	$7.44
Harvest					
Chopping, Cutting	once	$50.00 / acre	$50.00	$50.00 / acre	$50.00
Turning	thrice	$8.19 / acre	$24.57	$8.19 / acre	$24.57
Bailing, Bundling	once	$31.30 / acre	$31.30	$10.05 / acre	$10.05
Transportation	once	$15.40 / ton	$52.36	$8.00 / ton	$27.20
Fixed Costs (insurance, interest)			$60.01		$60.01
Total Costs			$464.04		$396.15

Note: This table is based on an exchange rate of 1.76 DM per US$.