Energy Use in the Kansas Agricultural Sector

Report Submitted to the Kansas Energy Council

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By

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Executive Summary

Concerns about future availability of oil have existed since the late 1800's. But, the world's remaining proven oil reserves have consistently increased over time, demonstrating that there is no meaningful measure of physical oil reserves, only an economic one. Stated another way, as oil price rises, more oil will be "found" and extracted from the earth since it will be cost effective to do so. The implication is that policy decisions should not focus on perceived physical shortages, but rather on relative prices of oil and competing alternative energy sources.

Energy independence is an often stated policy goal and U.S. energy independence has, in fact, increased during some previous periods. For example, from 1977 to 1985 the U.S. shifted from importing 47 percent of its crude oil to just 30 percent. But the increase in independence came about primarily because aggregate U.S. oil consumption declined 23 percent. The driving force behind the consumption decline was the fact that inflation adjusted oil prices more than tripled during the 1970s. Thus, changing relative prices helped achieve a policy goal.

Total energy usage in agriculture has fallen about 28 percent since the late 1970s. By 1999, agriculture was about 10 percent more efficient in terms of indirect energy usage and about 40 percent more efficient in terms of direct energy usage, both compared to 1965. However, both direct and indirect energy usage have been increasing in recent years. Yet, energy efficiency has continued to increase as well because output has been increasing even more rapidly.

During 2000-2003 about 23 percent of U.S. crop production expenses were attributable to energy costs, compared with just 6 percent for livestock production. Although energy accounts for a small percentage of direct livestock expenses, livestock operations experience higher energy costs indirectly through higher feed costs, which make up about 60 percent of all production costs. When examining energy as a share of total operating costs, wheat ranked highest among all major crops, with energy input costs accounting for 52 percent of total operating costs in 2004.

A sharp rise in input costs typically results in reduced farm profits. That likely will be the case this year as farmers face higher costs for many inputs. In particular, fertilizer prices are expected to increase about 50 percent in 2006 compared to 2005. Fuel prices represented about 11 percent of total machinery costs in 2001, but will likely total about 20 percent of machinery costs in 2006. Farmers can and do make adjustments to reduce the negative impact of rising energy costs on their farms' profitability. Farmers can alter their decisions with respect to a) crop input choice and level, b) crop selection, and c) tillage method. But farmers have little experience dealing with record high fuel and fertilizer prices, which increases the need for research and education on these topics.

Adoption of no-till technology can help mitigate the impact of rising fuel prices on farm expenses. Research conducted using Kansas Farm Management Association data indicates that fuel costs per harvested acre on no-till farms are about 67 to 75 percent of farms practicing continuous and reduced tillage. Declining glyphosphate herbicide prices, and rising diesel fuel prices, are likely to encourage more farmers to shift to no-till farming practices. Every 10 percent of Kansas crop production shifted to no-till reduces aggregate Kansas fuel consumption by about 3.5 million gallons, or about $8 million if diesel fuel is valued at $2.25 per gallon.

Increased use of soil testing could also help mitigate the impact of rising fertilizer prices. Soil testing has long been a recommended practice, yet less than 25 percent of farms rely on soil tests when making fertilizer application decisions. Research suggests that, in some situations, the benefits of soil testing could fall in a range of about $12.50 to $15.00 per acre.

Rising energy prices have hit Kansas irrigated crop producers especially hard. At current prices, the cost of water pumping per acre inch with electricity is approximately 67 percent that of natural gas and diesel (average of the two). Every 10 percent of acre-inches converted to electricity in Kansas would equate to an aggregate pumping cost savings of approximately $7 million, holding all else constant.

Adoption of organic farming systems has increased sharply since the early 1990s, but the overall adoption rate is still very low. For example, in 2003 about 0.4 percent of U.S. cropland and 0.1 percent of U.S. pasture was certified organic. Organic production has increased primarily because of consumer interest in purchasing organic production. Whether or not organic production systems reduce energy usage is debatable. Organic production systems do not rely on purchased fertilizers which helps lower their energy consumption per acre, but some research indicates yields are lower than for other farming practices. Lower yields can result in increased energy usage per unit of output. Moreover, organic production systems typically substitute tillage for herbicide usage and the cost of tillage has increased sharply relative to the cost of one of the most commonly used herbicide, glyphosphate. As a result, the recent rise in energy prices could actually discourage a shift toward organic production.

Interest in renewable energy sources is strong. Ethanol and biodiesel production have both been growing rapidly in recent years, but output is still small compared to U.S. fuel usage. For example, during 2005 U.S. ethanol production totaled 4 billion gallons, equivalent to just 2.9 percent of U.S. gasoline consumption. Continued dramatic production growth is expected over the next several years for both of these products. Most of the U.S. ethanol production capacity is located in the Upper Midwest, in part because of corn prices that are low relative to the rest of the nation. Currently there are seven ethanol plants operating in Kansas with an estimated total capacity of 170 million gallons. Kansas ethanol production accounted for approximately 4.3 percent of U.S. ethanol production during 2005. Ethanol production is expected to expand rapidly over the next several years. But the rise in energy prices, if it is long lived, could encourage plants to market their byproducts as wet distillers grains (WDGS), instead of dried distillers grains. If the net benefits associated with marketing WDGS in close proximity to ethanol plants exceed the cost of shipping in dry corn from major corn producing regions, it will encourage construction of ethanol plants in the High Plains region where large numbers of cattle are concentrated. Biodiesel production was examined in some detail. Estimates indicate that larger scale plants (10 million gallons per year) are more cost competitive than small scale plants and that biodiesel production reliant on soybean oil as a feedstock is likely to be the most cost competitive.

Cellulosic biomass for use in ethanol production was also examined. Although this technology is still immature, it could become commercially viable within the next decade. Available estimates indicate that supplies of various biomass inputs are limited at lower price levels ($25 to $30 per ton), but are relatively large at higher price levels ($50 per ton). Feasibility analysis for ethanol production from cellulosic biomass should account for the fact that acquiring biomass in sufficient quantities to run an ethanol plant will likely require compensation to farmers at higher price levels.

Several policy considerations were discussed. Policy makers should consider policies that encourage no-till production, more soil testing, and facilitate converting irrigation pumping to electricity. Additional research on cellulosic ethanol production and grain based ethanol is likely warranted to more completely assess the likelihood of future growth in Kansas.

Background

Recent sharp increases in energy prices have focused attention economy wide on improving energy efficiency. Agriculture, a typically resilient sector, could be hard hit by the recent increase in energy prices. For example, high natural gas prices have already contributed to a substantial reduction in U.S. nitrogen fertilizer production capacity. Hence, it is important to understand current energy use in agriculture in order to understand the impacts of rising energy prices on this sector. In January 2006 the Kansas Energy Council put forth a research funding proposal requesting information and analysis related to the impact of increasing energy costs on Kansas agriculture. A Kansas State University research team was assembled to answer that call. This is the team's report, which is written to aid the Council in guiding Kansas policy decisions related to energy as it is associated with agriculture.

Business activities generally are thought to be guided by market forces as businesses attempt to increase profits. Occasionally, national and state governments implement policies designed to supplement or nudge markets in particular directions. Such policies generally take the form of a carrot (e.g., tax abatements, subsidies) or a stick (e.g., regulations, increased taxes, fines). We believe that such policies are most effective when they encourage or boost existing economic trends. Policies that try to buck underlying economic forces are costly and are an inefficient use of taxpayers' funds. Hence, to encourage efficient policy making, this report identifies a number of the underlying economic forces and the associated trends with respect to energy in agriculture.

Brief historical perspective

Recent energy price increases bring to the forefront a number of political fears. For example, physically "running out" of oil is one such fear. Similarly, and partly because of oil-related events in the 1970s, it is natural to fear U.S. dependency on foreign energy sources. This section attempts to put such fears in perspective so that the underlying economic forces can guide energy policy, rather than the, sometimes unsubstantiated, fears themselves.

Drake discovered oil in Pennsylvania in 1859. Only 20 years later, partly due to a fear of oil shortages, the United States Geological Survey (USGS) was formed to measure U.S. mineral resources. Subsequently, the first of many warnings about impending oil shortages was issued by the USGS in 1906. In 1920, the USGS asserted that only 20 years of domestic petroleum supplies remained in the U.S. However, reliable foreign sources of oil soon became available and helped alleviate any potential domestic shortages. Moreover, the world's supply of oil continued to grow to meet the world's demand. By 1950, the American Petroleum Institute pegged the world's proven oil reserves at 100 billion (B) barrels (bbl). However, as with prior estimates of remaining world oil supplies, that estimate proved to be short-lived. Subsequent estimates increased the world's remaining proven oil reserves to 648B bbl in 1980, to 999B bbl in 1993, and to 1,016B bbl in 2000.

The preceding discussion is provided to illustrate that there is no meaningful measure of physical oil reserves, only an economic one. As demand for oil increases (a willingness to pay more per bbl), proven oil reserves rise. More to the point, as oil price rises, more oil will be "found" and extracted from the earth since it will be cost-effective to do so. So, policy decisions should not focus on perceived physical shortages, but rather on relative prices of oil and competing alternative energy sources. It may be that government has a role to play in helping smooth energy prices over time, but it should not be taken as a foregone conclusion that such attempts at price smoothing are more efficient than simply "letting energy markets work." Similarly, whether it is more efficient to spend taxpayer dollars on traditional energy sources, such as petroleum, or on alternative sources, such as ethanol, should be given serious consideration. After all, history is replete with beliefs that alternative energy sources would soon transplant traditional ones. For example, Henry Ford asserted in 1906 that "There's enough alcohol in an acre of potatoes to drive the machinery necessary to cultivate the field for a hundred years." Moreover, a 10 percent ethanol blend of gasoline was offered by a Lincoln, Nebraska gas station over 70 years ago, in 1933, and the first government-financed ethanol plant was established in Atchison, Kansas in 1938 (http://www.radford.edu/~wkovarik/envhist/RenHist/1.biofuels.html).

Energy independence is an often stated policy goal. There is more than one way, however, to increase "energy independence." Information from the Energy Information Administration (EIA) illustrated in figure 1 demonstrates that the U.S. can move a significant distance towards energy independence in a short time. The U.S. shifted from importing 47 percent of its crude oil to just 30 percent from 1977 to 1985. However, that increase in energy independence came about largely because aggregate U.S. oil consumption fell from 6.64B bbl to 5.14B bbl, a 23 percent decline, during the same time period. Furthermore, the reduction in aggregate consumption understates the decline in per capita consumption since the U.S. population was growing.

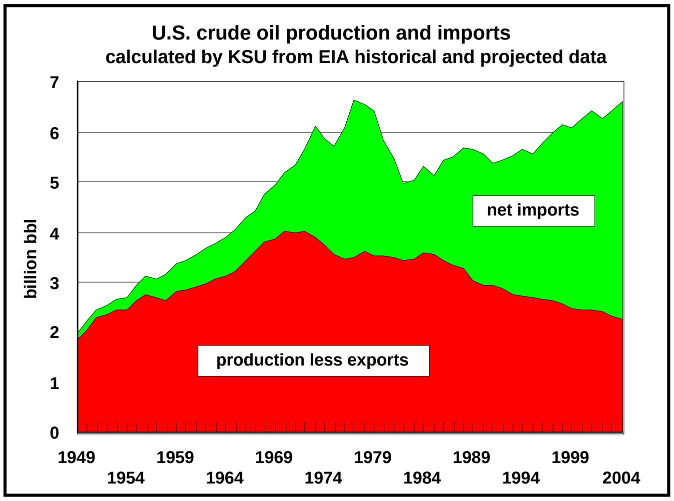


Figure 1

What led to the large drop in oil consumption? Part of the decline was likely due to strong political resolve at the time, which led to various tax incentives for reducing energy consumption, along with regulations that helped reduce fuel consumption, especially in motorized vehicles. But the driving force behind reduced consumption was a dramatic increase in oil prices. For example, figure 2 reveals that inflation adjusted domestic crude oil prices more than tripled during the 1970s (EIA).

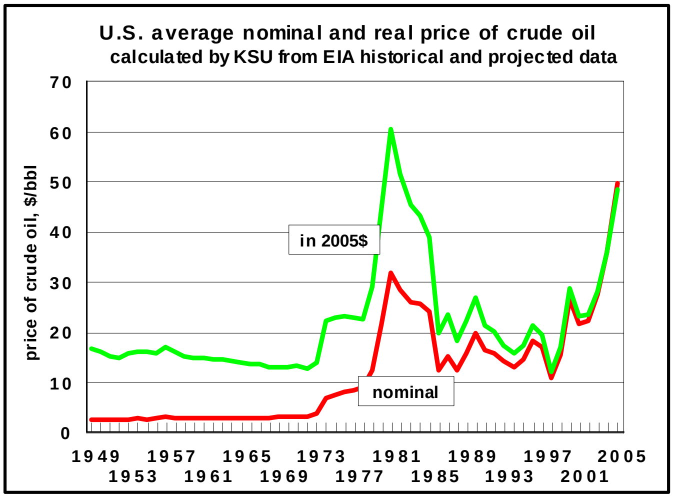


Figure 2

Two additional points regarding U.S. oil consumption and oil prices are noteworthy. First, U.S. ethanol production in 2006 likely will be around 5 billion gallons. On a contained energy (British thermal units, or BTUs) basis, 5 billion gallons of ethanol would replace around 0.066 billion barrels of crude oil. Even if this quantity is doubled, which might occur if 25 to 30 percent of the nation's corn crop is converted into ethanol, it would result in less than 2 percent of recent (2004) crude oil imports being replaced by a renewable energy source. So, greatly reducing dependency on foreign energy sources likely will not come about very quickly, nor easily, which brings us to the second point. Market price is the most important driver of change in energy source and consumption. Current (mid-2006) crude oil prices are at record high levels. Given past experience, high prices alone may sharply curtail energy consumption, leading to reduced reliance on foreign sources of energy. But, figure 1 shows that, though oil consumption was curtailed for many years (2004 U.S. consumption was still below its 1977 peak), reliance on imported oil did not stay down. For example, the U.S. was again importing nearly half of its oil needs by 1990. This likely happened because relatively low oil prices prevailed after the mid-1980s, which led to greatly reduced investment in U.S. oil exploration and production. So, to the extent that policy makers at the time wish to take credit for reduced oil consumption wrought by policies that encouraged investment in energy saving technologies, they also should be willing to bear the consequence of increased dependency on foreign energy. The point is that policies can have unintended consequences and market forces generally prevail in the end.

How important is agriculture to the energy picture?

Energy's relative importance varies by industry and industries vary in terms of their importance to the overall economy. Moreover, intentionally or unintentionally, government policies tend to impact industries differently. This report concerns the interaction of energy with agriculture, and specifically Kansas agriculture. So, it is important to recognize the importance of agriculture in general, and Kansas agriculture in particular, to the underlying economy and to the overall energy use in that economy.

A Congressional Research Service (CRS) report, *Energy Use in Agriculture: Background and Issues* (Schnepf), provides background information on the relationship between energy and agriculture in the United States. Agriculture consumes energy both directly as fuel or electricity to power farm activities, and indirectly in the fertilizers and chemicals produced off farm. Of the estimated 1.7 quadrillion BTUs of total energy used by the U.S. agricultural sector in 2002, 65% was consumed as direct energy and 35% was consumed as indirect energy. Both direct and indirect energy use by agriculture have decreased over time. Since the late 1970s, total agricultural use of energy has fallen by about 28%. Composition of energy use in agriculture has also shifted over time. Gasoline and direct use of natural gas have declined substantially. In contrast, the use of diesel fuel and electricity has increased over time. Following fertilizer, diesel and electricity had the largest use in agriculture in 2002. In terms of end-use, other than fertilizer and chemicals, nationwide, the largest on-farm energy uses include motors (with irrigation being the largest motor application), lighting, and onsite transportation (Brown and Elliott, March 2005).

At the farm level, energy cost is a significant component of total production cost, although agriculture as a share of total U.S. energy use is small. During the 2000-2003 time period, energy expenses accounted for nearly 15% total production expenses, about 5.2% direct and 9.3% indirect. The relative importance of energy costs varies greatly by production activity. In terms of energy's share of costs within each major production activity, 23% of crop production expenses were attributable to energy costs, compared with only 6% for livestock production outlays. The energy use of several major activities is described as following.

During 2002, "major field crops" were the largest agricultural energy user and accounted for 27% of production costs and 29% of the total energy costs expended by U.S. agriculture. Fertilizer and chemicals are the two leading energy sources for these field crops. Irrigation is another important energy consumption activity. In terms of direct-use energy, gasoline and diesel are the two most import energy sources and motors, machinery, and onsite transport are the main end-use types.

For three of the four most extensively planted field crops in the United States – corn, wheat, and cotton – energy costs represented 22% to 27% of total production costs. But only 14% of total production expenses of soybeans were attributable to energy. In terms of energy as a share of total operating cost, wheat ranked highest among all major crops, with energy input costs accounting for 52 percent of total operating costs in 2004. In contrast, energy input costs for soybeans and cotton made up less than 22% of the total operating costs.

In contrast to the crop sector, direct energy costs made up a small share of total operating costs on livestock operations, comprising just 3-7 percent of the operating costs for hogs, dairy, and cow-calf operations in 2004. However, livestock operations experience higher energy costs indirectly through higher feed costs. Feed costs make up roughly 60 percent of total livestock production costs (Shoemaker et al.).

Beef Cattle Ranching

Energy costs accounted for about 12% of total beef cattle ranching expenses in 2002. Despite its low share of total production costs, cattle ranching accounts for a substantial share (nearly 12%) of national agriculture-related energy consumption — including over 15% of fuel expenses and 10% of fertilizer costs used by U.S. agriculture in 2002.

Cattle Feedlots

The direct energy use in cattle feedlots is small as indirect energy uses, traceable to feed production and transportation, account for most of feedlots' energy consumption. Feedlot operations use energy to furnish feed and water to animals, to manage animal waste, and to market animals to packing plants and other slaughter houses. Feedlots' direct energy expenses accounted for less than 3% of total production costs as purchasing feeder stock and feedstuffs dominated cost outlays.

Based on the CRS study, figure 3 shows that, in 2002, direct energy use by agriculture comprised only 1.1 of the approximately 98 quadrillion (quads; a quad is 1,000 trillion) BTUs total direct energy consumed by the U.S. (about 1.1 percent). Additionally, U.S. agriculture uses about 0.6 quads of indirect energy. So, it is clear that energy policy specific to agriculture will not have a great impact on the overall U.S. energy system.

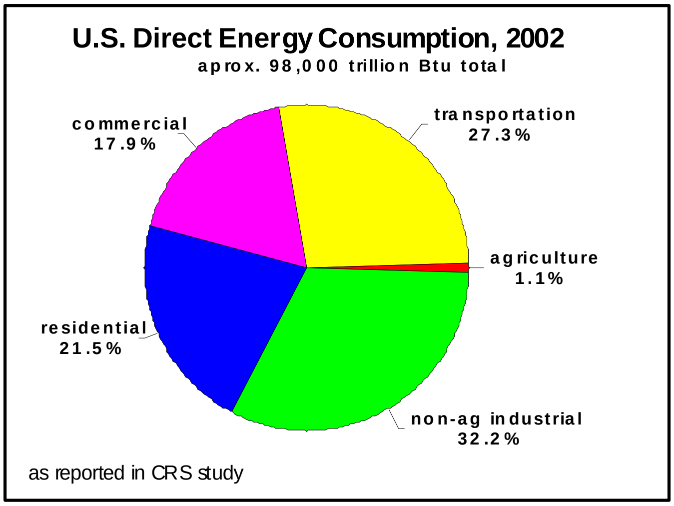


Figure 3

A Kansas State University report to Kansas Inc. in 2006, entitled "Agricultural

Commodities Future: Assess Competitive Threats to the Kansas Economy," reported on the relative importance of agriculture to Kansas (Mintert et al.). Figures 4 and 5 report this information based on 2003 data for two basic measures of importance, value-added income and number of jobs.

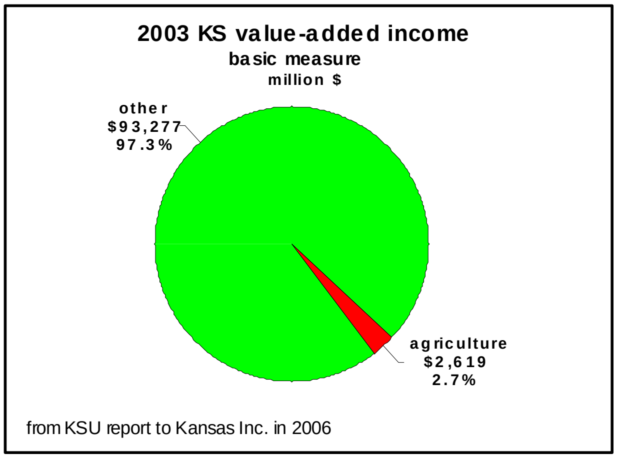


Figure 4

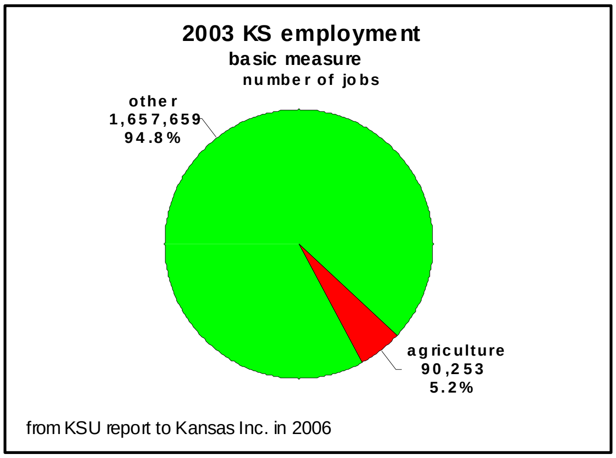


Figure 5

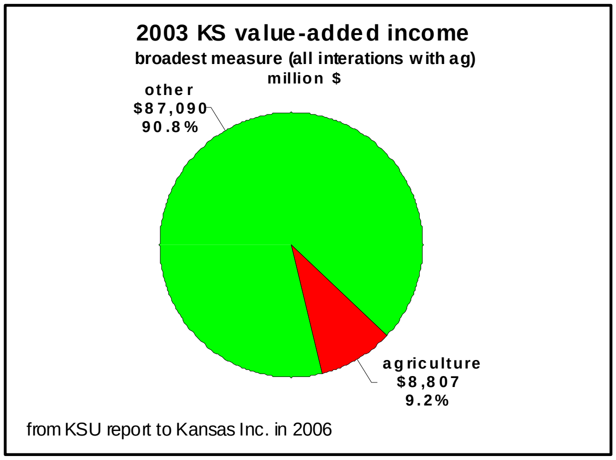


Figure 6

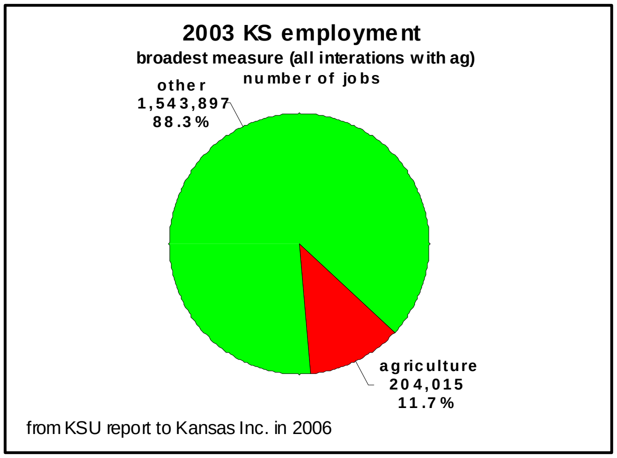


Figure 7

Figures 6 and 7 report the same information as figures 4 and 5, only now agriculture is measured in the broadest possible context. For example, the latter figures consider all employment and income in Kansas' meat packing industry, which is an important value-added activity, but it is debatable regarding whether it should be referred to as Kansas' *agriculture*. Regardless of whether Kansas agriculture is considered in the narrow or broad economic sense, the figures make it clear that most of Kansas' economy is not directly tied to agriculture. Consequently, Kansas policy makers should keep this in mind as they consider energy policy with respect to agriculture.

Changes in energy prices can have significant implications for the profitability of U.S. agriculture as well as the mix of output and management practices. Results reported in an American Council for an Energy Efficient Economy (ACEEE) report, *Potential Energy Efficiency Savings in the Agriculture Sector* (Brown and Elliot, April 2005), indicate that there are significant energy cost savings available to the agricultural sector from improved energy efficiency. The authors indicate that nationwide savings equivalent to about 10 percent of total direct energy usage in agriculture might be attainable, with the largest gains possible in irrigation pumping, transportation, and lighting. Disaggregated analysis in the report suggests that Kansas producers might be able to generate direct energy savings of as much as 29 million dollars from more efficient energy usage.

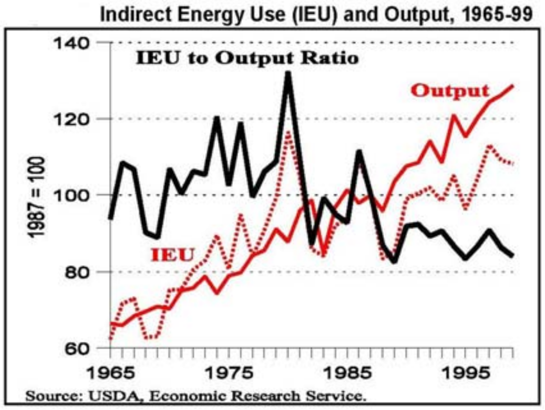


Figure 8

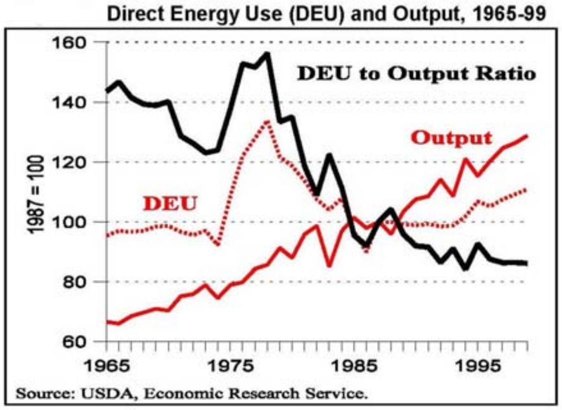


Figure 9

The CRS study discussed earlier reported information provided by the Economic Research Service (ERS) of the U.S. Department of Agriculture (USDA) regarding change in energy efficiency over time for agriculture. In particular, agricultural output generally has been rising faster over time than has agricultural energy use. Hence, the energy use to output ratio has been declining over time. The end result is that U.S. agriculture in 1999 was about 10 percent more efficient in terms of indirect energy usage than it was in 1965 (figure 8), and about 40 percent more efficient in terms of direct energy usage (figure 9). Of course, much of that improved energy efficiency likely is due to technology-based investments related to crop yields (e.g., more bushels (bu) per acre of corn with the same fertilizer inputs) and improved machinery operational efficiency (e.g., more horsepower-hours per unit of diesel fuel). It is likely that such investments were made more because of relative price issues around profit seeking than because of energy policy. So, once again, markets have a way of “fixing” their own problems over time and policy makers always should question the wisdom of interfering with such market forces.

Figures 8 and 9 make it clear that agriculture’s energy efficiency has been improving over time. Thus, it seems reasonable to assert that energy policy that enhances this temporal trend could be both acceptable and accomplished at reasonable cost. However, it also should be remembered that improving energy efficiency typically means lowering the relative price of energy (energy becomes less important per unit of output) and economics suggests that lower relative prices mean that the quantity demanded will increase. Furthermore, the figures clearly show that total energy usage in agriculture has been increasing. Yet, society generally has been better off despite the increased energy usage – because output per unit has risen even faster, which serves to lower the price of food and other agricultural outputs to the U.S. population. More to the point, policy makers should not focus on absolute reduction in energy usage, but rather on changing relative prices over time so that society can be made better off along the way.

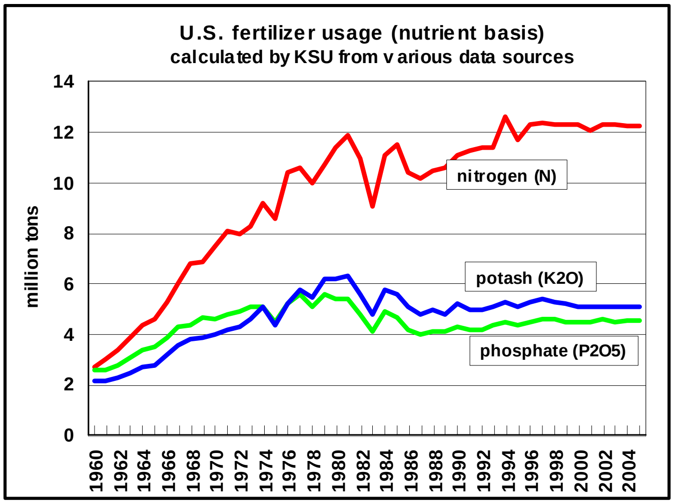


Figure 10

The fact that it is relative prices that matter is demonstrated further in figure 10, which reports U.S. fertilizer usage based on data calculated from various sources (but mostly from USDA's Economic Research Service) by the research team. Nitrogen (N) fertilizer price is highly dependent on energy prices since it is manufactured from natural gas. Note in the figure that N usage rose dramatically throughout the 1970s. This was despite the fact that energy prices also increased dramatically during the same time period (see figure 2). This is worth noting for the following reason. Well-intentioned policy makers determined to reduce energy consumption at the time might have suggested a tax on N fertilizer to reduce its usage and hence the usage of natural gas. But, such a policy likely would have been ineffective – since the underlying economic forces (rising grain prices and improvements in technology) at the time were causing the demand curve for N fertilizer to shift out and to the right.

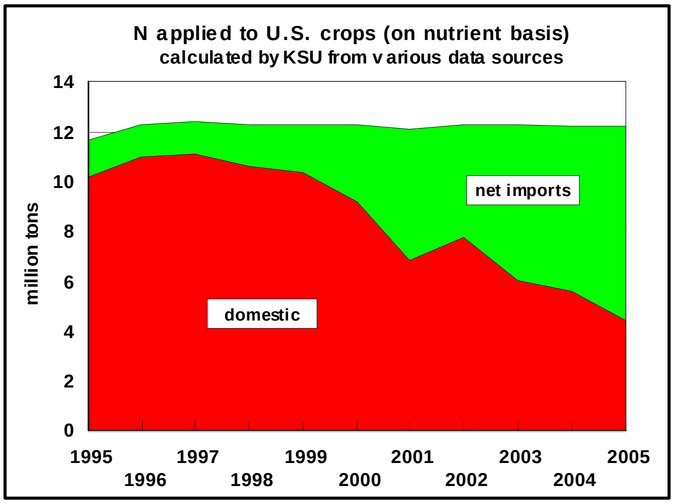


Figure 11

A more recent N fertilizer trend is seen in figure 11. Clearly, agriculture's use of N in the U.S. has become much more dependent on foreign sources of N since the late 1990s. Hence, a policy focused on enhancing domestic N use might see little impact on that goal – current economic forces are simply too strong. In particular, natural gas currently (2006) is much cheaper in many places around the world than in the U.S. Consequently, a policy that seeks to capitalize on that fact, say by reducing the cost of imported N, likely will do a better job of promoting agricultural and taxpayer welfare – despite the fact that it would make the U.S. more reliant on imported N fertilizer.

Energy-related price trends relevant to farmers

Figure 12 shows two farm-level (i.e., non-taxable) diesel price series over time. One (SW KS) is from a southwestern Kansas fuel provider and the other is from the EIA. Forecasts from the SW KS series are generated from a model using commodity futures prices and are based on futures prices observed at the end of May 2006 whereas the EIA forecast was generated by the EIA. The figure clearly shows why farmers have been concerned with fuel prices recently. Actual diesel prices spiked to an historical high in late 2005 and are forecast to remain high relative to historical prices throughout 2006 and 2007. To provide further clarity, figure 13 shows selected numerical information from the graphical figure 12. It focuses on recent and future comparisons with the more “normal” times associated with the 2000-2004 time period. Figures 14 and 15 show similar information regarding natural gas, an especially important fuel for Kansas irrigated crop producers.

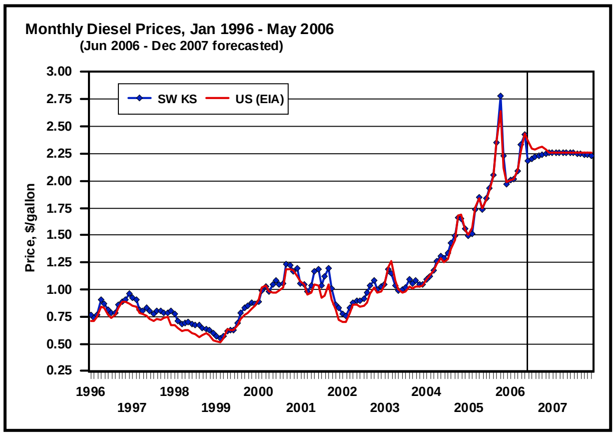


Figure 12

Diesel Fuel Prices

	Mar-Oct Diesel Price			Year-to-year percent change		
Year	SW KS	US (EIA)	Average	SW KS	US (EIA)	Average
2000	$1.09	$1.04	$1.07	-----	-----	-----
2001	$1.09	$0.98	$1.04	0.6%	-6.1%	-2.7%
2002	$0.94	$0.88	$0.91	-14.1%	-10.0%	-12.1%
2003	$1.05	$1.05	$1.05	12.1%	18.6%	15.3%
2004	$1.37	$1.34	$1.36	30.0%	28.4%	29.2%
2005	$2.04	$2.02	$2.03	48.5%	49.9%	49.2%
2006 (F)	$2.24	$2.30	$2.27	10.2%	14.0%	12.1%
2007 (F)	$2.25	$2.21	$2.23	0.6%	-3.7%	-1.6%
06 - Avg(00-04)	$1.13	$1.24	$1.19	102.1%	116.8%	109.3%
07 - Avg(00-04)	$1.15	$1.15	$1.15	103.3%	108.8%	106.0%

$1.08
“normal”
times

F = forecast

Figure 13

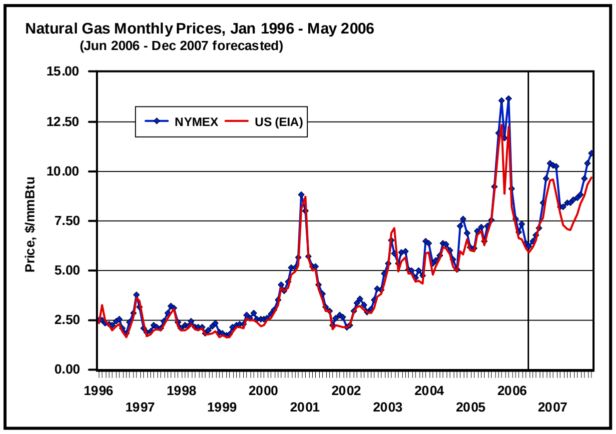


Figure 14

Natural Gas Prices

	Mar-Sep Natural Gas Price			Year-to-year percent change		
Year	NYMEX	US (EIA)	Average	NYMEX	US (EIA)	Average
2000	$3.89	$3.69	$3.79	-----	-----	-----
2001	$3.85	$3.66	$3.76	-1.0%	-0.7%	-0.9%
2002	$3.25	$3.03	$3.14	-15.5%	-17.2%	-16.3%
2003	$5.40	$5.35	$5.37	66.0%	76.3%	71.0%
2004	$5.81	$5.58	$5.70	7.6%	4.5%	6.0%
2005	$8.09	$7.81	$7.95	39.2%	39.8%	39.5%
2006 (F)	$6.76	$6.47	$6.61	-16.5%	-17.2%	-16.8%
2007 (F)	$8.47	$7.57	$8.02	25.3%	17.1%	21.3%
06 - Avg(00-04)	$2.32	$2.21	$2.26	52.2%	51.7%	52.0%
07 - Avg(00-04)	$4.03	$3.31	$3.67	90.7%	77.6%	84.3%

$4.35
“normal”
times

F = forecast

Figure 15

Based on proprietary information from a private source, figure 16 reveals price information associated with the three major sources of N fertilizer; the gaseous N product anhydrous ammonia (chemically NH_3, but simply called NH3), the liquid N product urea ammonium nitrate (UAN), and the dry N product of urea. Forecasts of NH3 are based on a model of the historical relationship between NH3 price and natural gas futures prices (observed futures prices from late May 2006). UAN and urea forecasts are based on the NH3 forecast. To ease comparison, prices are expressed per lb of N. That N prices are at historical highs nearly goes without saying.

Figure 17 extracts numerical information from the graphical figure 16 associated with N prices. In addition, price information associated with phosphate (referred to here simply as P, but which actually is P_2O_5) and potash (referred to here simply as K, but which actually is K_2O). Forecasts of P and K are based on forecasts of NH3 and a model of the associated historical price relationships. A weighted average of the various fertilizer prices is generated to depict a relevant “basket” of fertilizers representative of what farmers typically use. The figure shows that fertilizer prices are expected to be almost 50 percent higher in 2006 relative to the more normal 2000-2004 time period, and will be down only slightly in 2007. As with the fuel price figures earlier, which imply an increase in direct energy costs for farms, these figures show that indirect energy costs (i.e., fertilizers) also are expected to be higher than normal. Consequently, it is not surprising that farmers interested in energy policy focus their attention primarily on fuel and fertilizer prices. So, state-level policy makers should be aware of impacts their policies might have on these prices.

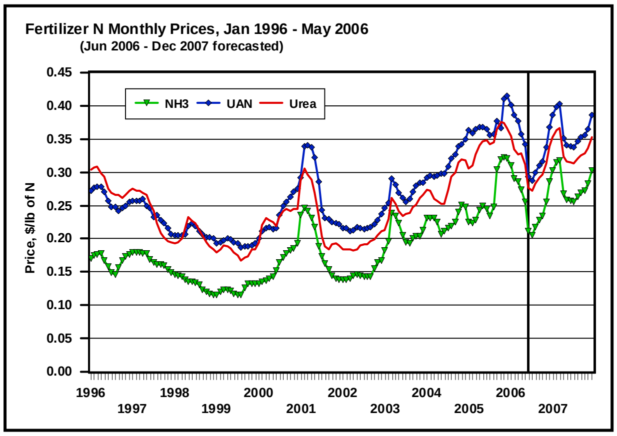
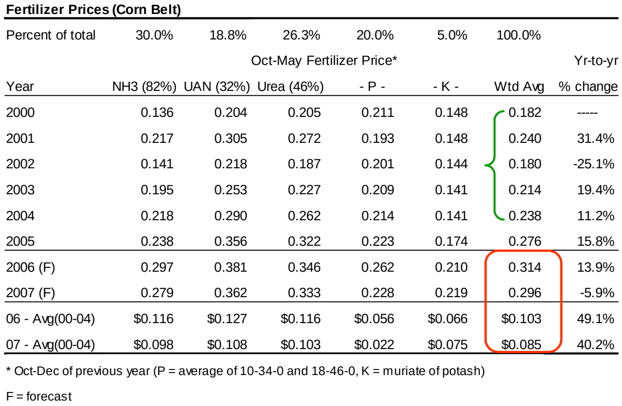


Figure 16



Fertilizer Prices (Corn Belt)

Percent of total	30.0%	18.8%	26.3%	20.0%	5.0%	100.0%	
			Oct-May Fertilizer Price*				Yr-to-yr
Year	NH3 (82%)	UAN (32%)	Urea (46%)	- P -	- K -	Wtd Avg	% change
2000	0.136	0.204	0.205	0.211	0.148	0.182	-----
2001	0.217	0.305	0.272	0.193	0.148	0.240	31.4%
2002	0.141	0.218	0.187	0.201	0.144	0.180	-25.1%
2003	0.195	0.253	0.227	0.209	0.141	0.214	19.4%
2004	0.218	0.290	0.262	0.214	0.141	0.238	11.2%
2005	0.238	0.356	0.322	0.223	0.174	0.276	15.8%
2006 (F)	0.297	0.381	0.346	0.262	0.210	0.314	13.9%
2007 (F)	0.279	0.362	0.333	0.228	0.219	0.296	-5.9%
06 - Avg(00-04)	$0.116	$0.127	$0.116	$0.056	$0.066	$0.103	49.1%
07 - Avg(00-04)	$0.098	$0.108	$0.103	$0.022	$0.075	$0.085	40.2%

* Oct-Dec of previous year (P = average of 10-34-0 and 18-46-0, K = muriate of potash)

F = forecast

Figure 17

Though energy-related input prices for farmers are at historically high levels, short-term flexibility to respond to these changing price relationships is somewhat limited. For example, there is little flexibility regarding the quantity of diesel fuel required for planting and harvesting of crops. Similarly, not planting a crop or not fertilizing a crop typically are not in a farmer's feasible choice set because such decisions would cause profits to fall even more. Moreover, unlike say, the trucking industry, which regularly depends on fuel surcharges in transportation contracts to mitigate the impacts of higher fuel prices, farmers generally have not been able to "pass on" short run cost increases. So, a sharp rise in input (such as energy) costs typically results in reduced farm profits.

Despite farmers generally being unable to pass on the impact of higher crop input costs, there are more subtle decisions they can make to reduce the negative impacts to their bottom lines wrought by higher energy prices. The most important decisions they are able to make are related to a) crop input choice and level (e.g., how much fertilizer to apply), b) crop selection (which crop to plant), and c) tillage method (conventional mechanical tillage, or more herbicide-dependent reduced or no-tillage). Finally, if high energy prices prevail for several years, farmers eventually do pass on some of the cost increase by renegotiating rental contracts with landowners to lower rental payments. However, land-owning farmers generally are not afforded this option; they merely have to absorb the reduced net worth associated with lower land values caused by lower returns (rents) to agricultural land.

Each decision (noted above) that farmers can make to help mitigate the impacts of higher energy prices can be impacted by increased management awareness and education. That is because farmers have little experience dealing with such things as record high fertilizer and fuel prices. More importantly, the research and understanding around such decisions often is unavailable to farmers simply because it has not yet been undertaken. So, policy makers concerned with the impact of high energy prices on farms and farmers should recognize the potential need for increased research and education around such issues. What follows is a discussion of energy-related decisions at the farm level. Such information should enhance the awareness level of policy makers concerned with preserving or enhancing the profitability of farms in the face of higher energy-related input prices.

Impact of high diesel fuel prices on farm machinery costs

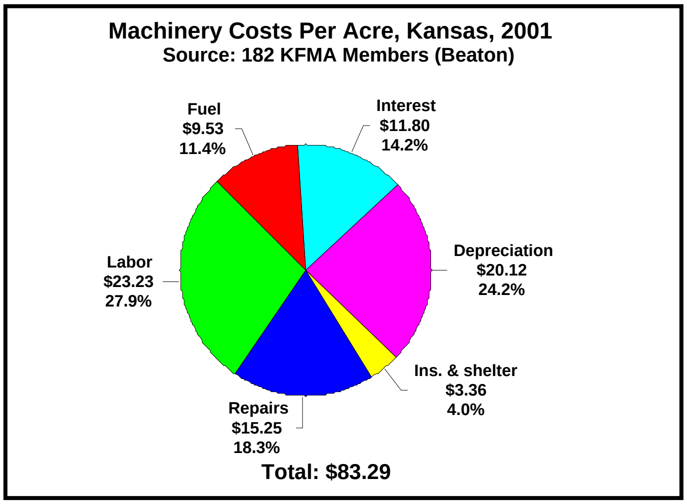
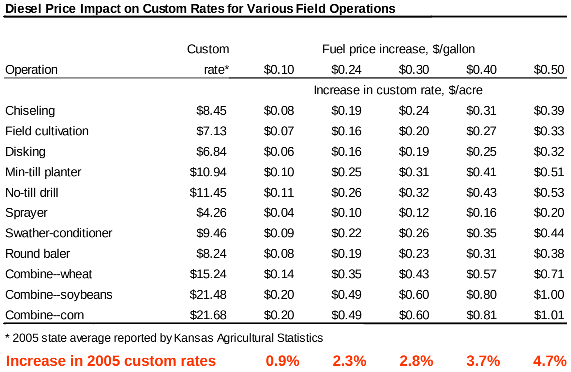


Figure 18

Typically, farm machinery cost comprises around half of all non-land costs in crop production. Importantly, machinery cost usually is the most important management category whereby farms are able to differentiate themselves from others and thereby acquire positive profits. Machinery cost is comprised of a number of sub-cost categories as depicted in figure 18, which is based on financial and survey information of Kansas farms enrolled in Kansas Farm Management Associations (KFMA) in 2001. The direct energy cost category shown in the figure is fuel and in 2001 represented 11.4 percent of the total machinery cost. Though significant in overall machinery costs, small changes in fuel prices generally would not be expected to have large impacts on overall machinery costs. But, though the study behind figure 18 has not been repeated, we would expect that fuel costs are now a substantially larger component of machinery costs. That is, figure 13 revealed a 113 percent increase in diesel prices from 2001 to 2006. Assuming two percent inflation annually for the non-fuel categories in figure 18 and the 2001-to-2006 fuel price increase (113%) implies that fuel costs in 2006 will be around 20 percent of total machinery costs. So, fuel price clearly is becoming more important to Kansas farms.



Diesel Price Impact on Custom Rates for Various Field Operations

	Custom	Fuel price increase, $/gallon				
Operation	rate*	$0.10	$0.24	$0.30	$0.40	$0.50
		Increase in custom rate, $/acre				
Chiseling	$8.45	$0.08	$0.19	$0.24	$0.31	$0.39
Field cultivation	$7.13	$0.07	$0.16	$0.20	$0.27	$0.33
Disking	$6.84	$0.06	$0.16	$0.19	$0.25	$0.32
Min-till planter	$10.94	$0.10	$0.25	$0.31	$0.41	$0.51
No-till drill	$11.45	$0.11	$0.26	$0.32	$0.43	$0.53
Sprayer	$4.26	$0.04	$0.10	$0.12	$0.16	$0.20
Swather-conditioner	$9.46	$0.09	$0.22	$0.26	$0.35	$0.44
Round baler	$8.24	$0.08	$0.19	$0.23	$0.31	$0.38
Combine--wheat	$15.24	$0.14	$0.35	$0.43	$0.57	$0.71
Combine--soybeans	$21.48	$0.20	$0.49	$0.60	$0.80	$1.00
Combine--corn	$21.68	$0.20	$0.49	$0.60	$0.81	$1.01
Increase in 2005 custom rates		**0.9%**	**2.3%**	**2.8%**	**3.7%**	**4.7%**

* 2005 state average reported by Kansas Agricultural Statistics

Figure 19

Custom machinery operators provide machinery services for farmers. Kansas Agricultural Statistics annually conducts a survey of such charges to serve as a market guide. Moreover, as a part of machinery cost management, some Kansas farmers routinely perform custom machinery work for others. Presumably, custom machinery rates do not immediately reflect changes in fuel price. So, it is sometimes recommended that farmers, as a response to higher fuel prices, hire custom machinery services rather than perform such services with their own machinery. Obviously, the degree to which such actions achieve their goal of holding down farm-related energy costs is a function of speed of custom rate change over time. Figure 19 displays Kansas Custom Rates in 2005 for various field operations and also helps illustrate the impact of energy prices on field operation costs by reporting rate increases needed to accommodate categorical fuel price changes.

Respectively, figures 20-23 show custom rates for wheat, soybean, and grain sorghum harvesting in Kansas over time. Note the substantial increase in 2005 over 2004. Given a 50 percent increase in diesel price from 2004 to 2005 (see figure 13), assuming that fuel represents around 15 percent of total harvesting machinery cost and that no other costs changed, we would expect an increase in custom harvesting rates of around 7.5 percent from 2004 to 2005. Interestingly, wheat rate increases (figure 20) were less than this amount, but soybean and grain sorghum rate increases were very close to it (figures 21 and 22). Likely, this is because fuel prices climbed during the year and were considerably higher in the fall, when soybeans and grain sorghum were harvested, than in the early summer, when wheat was harvested. Figure 23 generally shows more modest rate increases for non-harvesting machinery operations from 2004 to 2005 (percentages at right of figure). This probably is because such machinery services markets are less well developed than with custom grain harvesting. Regardless, it does appear that custom machinery operators were able to effectively pass on the higher costs associated with increased diesel prices in 2005. It follows that farmers were not able to greatly mitigate the impacts of higher energy prices during the time by simply hiring machinery operations performed.

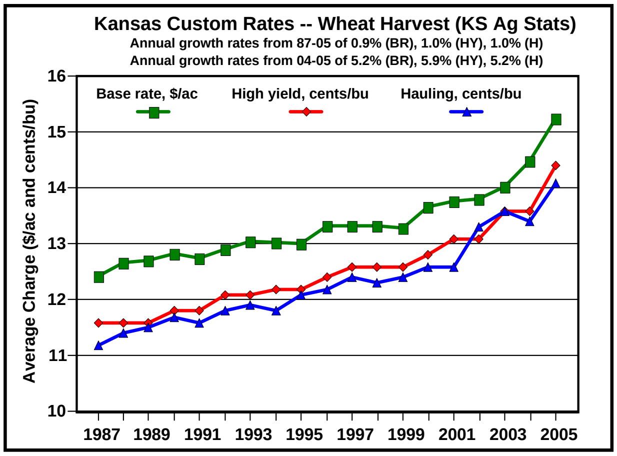


Figure 20

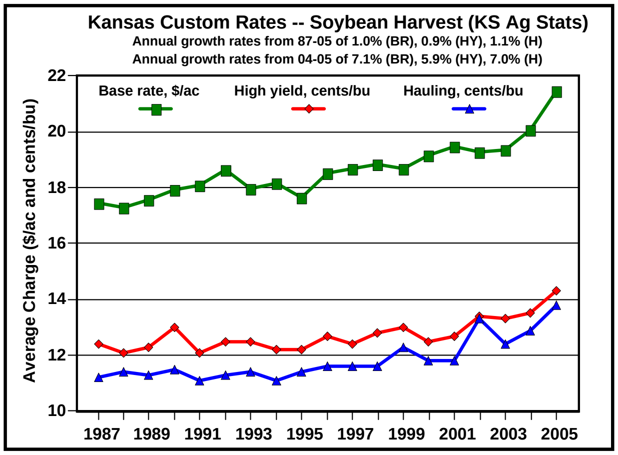


Figure 21

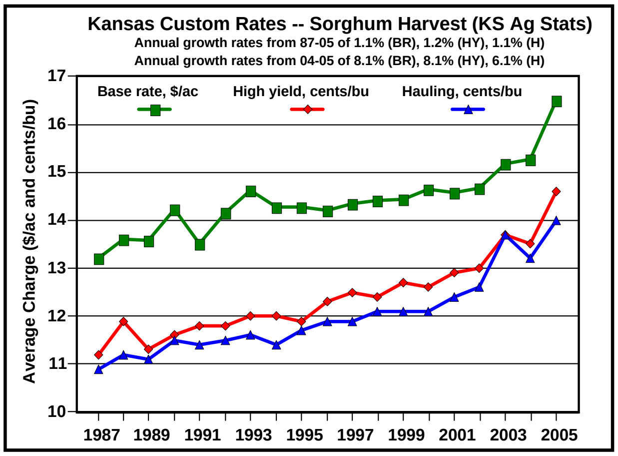


Figure 22

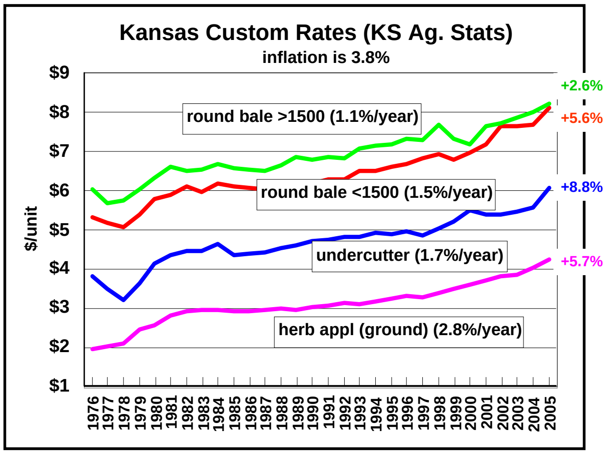


Figure 23

It has been noted that it may be difficult for farmers to pass on cost increases associated with energy. This is examined numerically in figure 24, which depicts fuel and oil costs for KFMA non-irrigated crop farms against diesel price. At the time of this writing (June 2006), both 2005 and 2006 numbers are still estimates. These estimates are based on the relationship between diesel prices ($/gallon) and fuel costs ($/acre) over the 2000-2004 time period. The correlation between farm fuel costs and diesel price from 2000 to 2004, at 0.975, is very high. This indicates that farm fuel costs are tied closely to diesel price and that farmers generally are unable to substantially reduce fuel consumption in times of higher energy prices, at least in the short run.

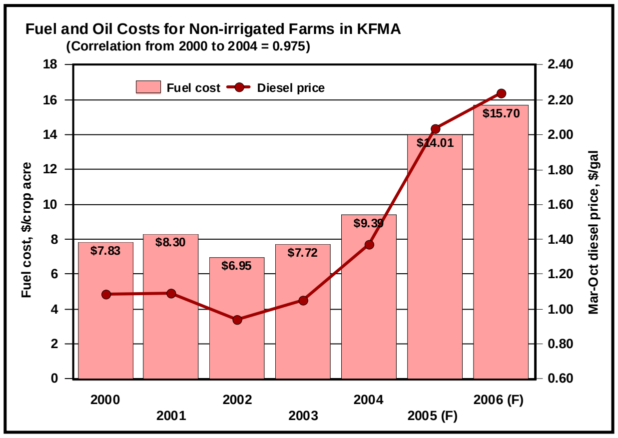
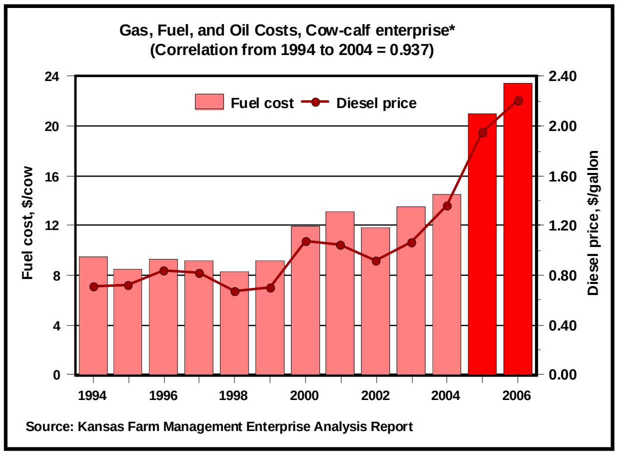


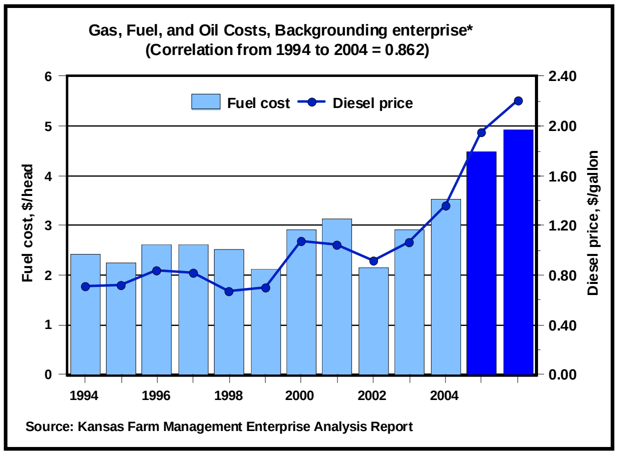
Figure 24

Livestock farming operations also are impacted by energy prices. Figure 25 shows information comparable to figure 24, only for KFMA cow-calf livestock operations. Similarly, figure 26 relates to KFMA backgrounding (cattle growing as opposed to fattening) livestock operations. The high correlations shown in the figures confirm that livestock producers, like their crop producing counterparts, are not able to pass on higher energy prices in the short run.



Source: Kansas Farm Management Enterprise Analysis Report

Figure 25



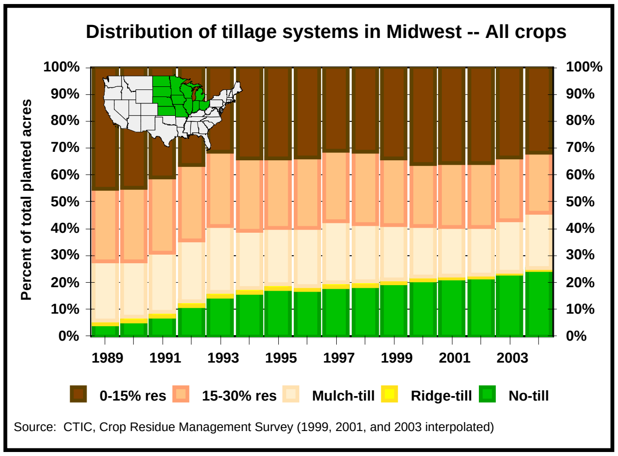
Source: Kansas Farm Management Enterprise Analysis Report

Figure 26

The tillage decision, with an emphasis on no-till

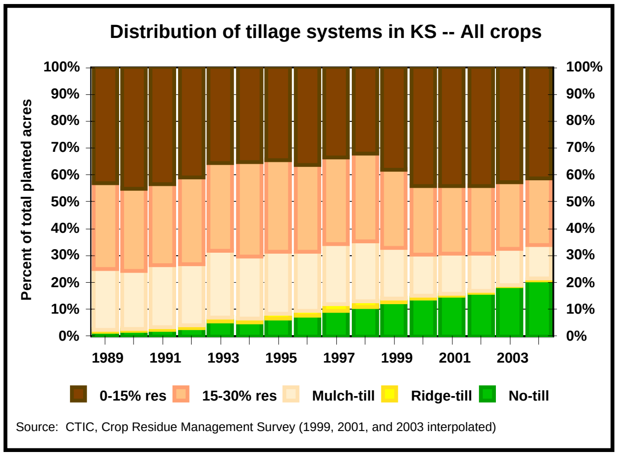
As in the U.S. in general, Kansas farms routinely consider the adoption of reduced-tillage farming practices, in particular no-till. Such reduced tillage practices substitute herbicides for tillage in order to kill weeds, which could lead to reduced energy costs. Over the years, farms have adopted no-till for a variety of reasons, but rarely with the most important purpose being that of reducing fuel costs. Granted, farmers note that they expect to reduce machinery costs with no-till (and fuel is one part of machinery cost), but they recognize that reducing machinery costs may not of itself lead to higher profit with no-till since increased herbicide costs might more than offset machinery-related cost reductions. Moreover, they recognize that a large portion of machinery operations, for example planting and harvesting, cannot be avoided by adopting no-till. More typically, farms have adopted no-till because it allows them to manage more land without hiring additional labor, thereby taking advantage of economies of size in crop production. Plus, no-till might allow for increased cropping intensity (e.g., double-cropped soybeans where two crops can be harvested on the same acre in a year), as well as increased yields associated with better water management, especially in western Kansas where moisture conservation is particularly important.

Respectively, figures 27 and 28 depict the adoption rate of various tillage practices across the broader Midwest region of the U.S. and Kansas. Information is based primarily on survey work by the Conservation Technology Information Center (CTIC). Though no-till adoption is on the rise, the pace has not been particularly fast. Moreover, despite having a much drier climate, and hence expecting crop yield increasing benefits associated with no-till production, Kansas farmers have not adopted no-till any faster than in the Midwest. Moreover, a large portion of crop acreage is still farmed with a substantial amount of tillage. In that regard, if no-till becomes more advantageous due to higher energy prices, there certainly is significant potential for Kansas' no-till acreage to increase.



Source: CTIC, Crop Residue Management Survey (1999, 2001, and 2003 interpolated)

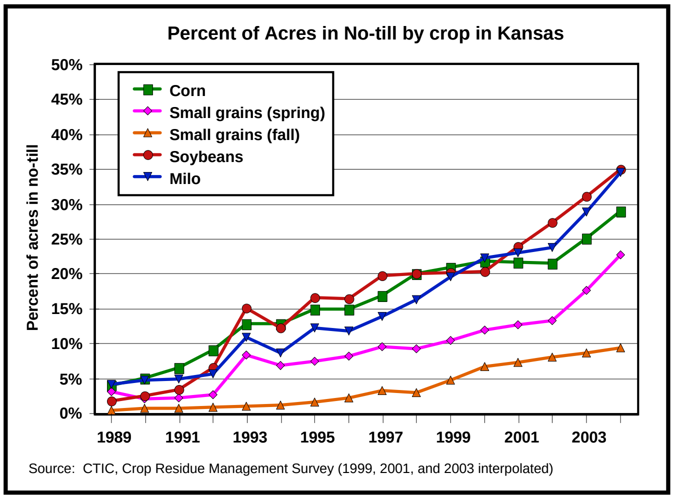
Figure 27



Source: CTIC, Crop Residue Management Survey (1999, 2001, and 2003 interpolated)

Figure 28

Some crops intrinsically respond better to no-till farming practices than others. In particular, crops reliant on a summer, especially late summer, growing season are more adaptable to no-till. The reason is that evaporation is typically highest in the summer. Hence the crop residue-based evaporation reduction associated with no-till production generally provides the greatest benefit to spring planted crops. Kansas no-till adoption rates by crop, as seen in figure 29, confirm this assertion. Since climate conditions in much of the Great Plains still economically favor wheat production over spring planted crops, it is not surprising that no-till adoption rates in Kansas are comparable to the Midwest.



Source: CTIC, Crop Residue Management Survey (1999, 2001, and 2003 interpolated)

Figure 29

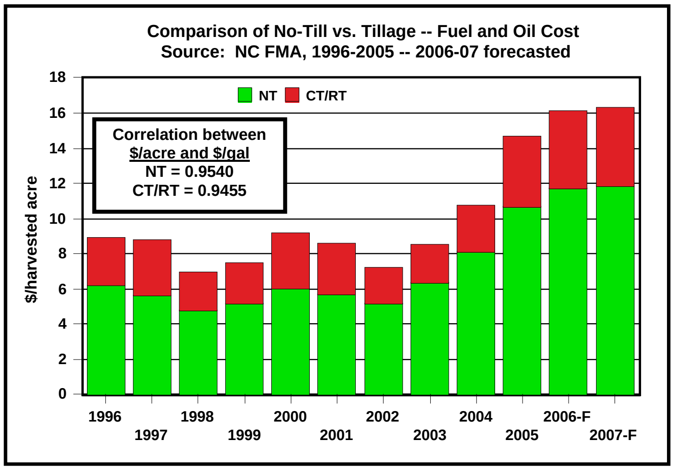


Figure 30

Do no-till farming practices save fuel? That question can be answered by examining figure 30, which compares fuel costs across tillage practices and time for a sample of KFMA farms in north-central Kansas. The sample compares pure no-tillers (NT), who essentially operate their farms with virtually no tillage, with farms that likely use a mixture of conventional tillage (CT) and reduced tillage (RT), hence CT/RT. The bottom part of the bars in the figure represents the fuel costs for the NT farmers, and the total height of the bars the fuel cost for the CT/RT farmers. Essentially, the figure shows that NT fuel costs are about 2/3 to 3/4 that of the CT/RT farms, representing about $4/acre fuel savings for NT at current and forecasted fuel prices. Also, note that the correlations between fuel price and fuel cost, as with previous figures, is quite high for both CT/RT farms and NT farms. Thus, though NT farms have consistently lower fuel costs, they are no more able to pass on higher energy prices than CT/RT farms.

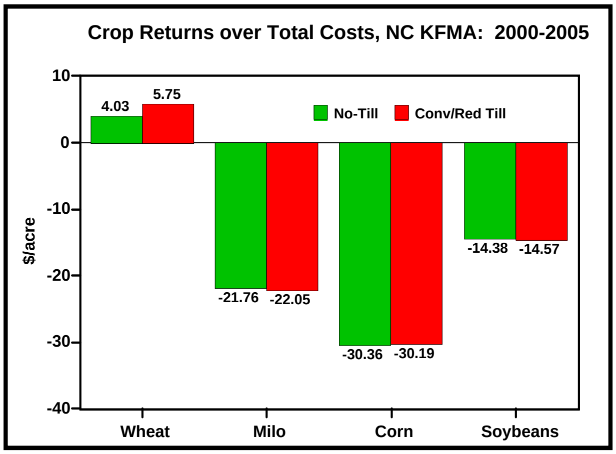


Figure 31

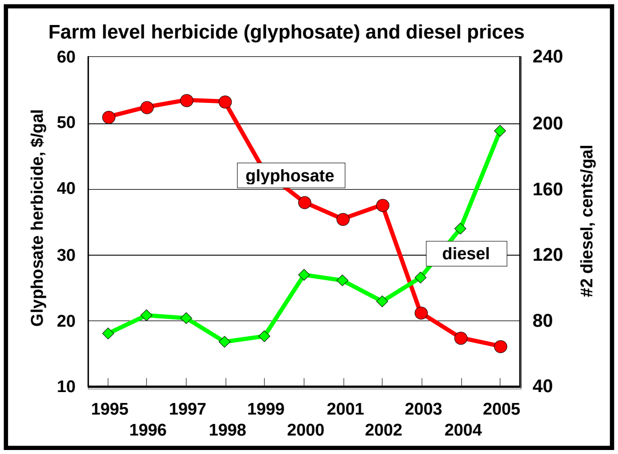


Figure 32

As suggested earlier, the fact that fuel costs are lower with NT does not necessarily indicate that profit is greater. Where information was available, figure 31 examines the relative profit associated with the farms underlying figure 30. Within short time periods, weather and crop price can greatly impact farm profits. So, the relevant comparisons in figure 31 are the side-by-side bars for each crop. As already hinted at earlier, CT/RT wheat is slightly more profitable than NT wheat. For the other three crops, profit differences across tillage practices are nearly zero. Unfortunately from a NT standpoint, this region and all regions of Kansas depend heavily on wheat because wheat has been the economically preferred crop regardless of tillage practice. Still, evidence that differences in tillage-related profits are small for wheat and nearly zero for other crops suggests that small increases in fuel prices will lead to faster no-till adoption. This possibility is made abundantly clear in figure 32, which compares diesel fuel price to that of glyphosate, which is by far the most dominant herbicide used in no-till. If it is sustained for an extended period of time, the rise in the ratio of diesel to glyphosphate price implied in the chart will encourage a shift to no-till farming. Given current trends and diesel-to-herbicide price relationships, policies that encourage crop producers to reduce tillage might be successful in conserving energy and enhancing producer profitability. However, a potential unintended consequence of more producers converting to no-till would be increasing the speed of consolidation as no-till farms tend to be larger due to higher labor efficiencies.

The aggregate value of fuel savings at various rates of no-till adoption and diesel fuel prices are reported in Table 1 assuming fuel consumption decreases by two gallons per acre with NT compared to CT/RT (approximate average for data in figure 30). At diesel fuel prices of $2.25/gallon, every 10% of acres converted to no-till yields a savings of a little under 3.5 million gallons of fuel and almost $8 million to Kansas producers.

Table 1. Total Value of Fuel Savings from Converting Crop Production to No-till in Kansas[1]

Diesel price	Percent Acres Converted				
$/gal	10%	20%	30%	40%	50%
$1.50	$5,240,400	$10,480,800	$15,721,200	$20,961,600	$26,202,000
$1.75	$6,113,800	$12,227,600	$18,341,400	$24,455,200	$30,569,000
$2.00	$6,987,200	$13,974,400	$20,961,600	$27,948,800	$34,936,000
$2.25	$7,860,600	$15,721,200	$23,581,800	$31,442,400	$39,303,000
$2.50	$8,734,000	$17,468,000	$26,202,000	$34,936,000	$43,670,000
$2.75	$9,607,400	$19,214,800	$28,822,200	$38,429,600	$48,037,000
$3.00	$10,480,800	$20,961,600	$31,442,400	$41,923,200	$52,404,000

[1] Based on fuel savings of 2.0 gallons/acre and 2001-2005 average acres of corn, grain sorghum, soybeans, and wheat (irrigated and dryland).

What can farms do about high fertilizer prices?

Earlier in this report we showed that N fertilizer prices are at record levels. Though we suggested that farmers may not be able to do a great deal to mitigate the economic impacts of higher fertilizer prices, we also hinted that they may be able to do a little. In particular, they might be able to cut back on fertilizer rates to alleviate some of the economic pain associated with higher N prices.

Traditionally, university and private providers of fertilizer rate recommendations have not allowed fertilizer price to impact what they considered to be the optimal fertilizer rate. That may have been appropriate in times when fertilizer prices fluctuated little, but it is certainly not appropriate today. Consequently, some universities, including some researchers at Kansas State University (KSU), have attempted to incorporate fertilizer and crop prices into recommended fertilizer rates (Kastens et al.). The authors assumed that KSU's official non-price-responsive fertilizer rate recommendations (referred to here as KSU N rec) actually were based on implied long run prices for crops and fertilizer. In particular, the following prices were assumed: wheat $3.20/bu, corn $2.35/bu, grain sorghum $2.05/bu, sunflowers $0.10/lb, fertilizer N $0.22/lb N, fertilizer P $0.25/lb P_2O_5. In addition to the paper, the authors developed an Excel spreadsheet decision tool (KSU-CropBudgets2006.xls) that is available to farmers and crop consultants at

KSU's Department of Agricultural Economics www.AgManager.info website in order to expedite their understanding and decision making.

Nitrogen Recommendations for Wheat					
Yield goal, bu/ac	40	50	60	70	80
KSU N rec, lbs/ac	66	90	114	138	162
N price	Price adjusted N rec, lbs/ac				
$0.25	67	91	116	140	164
$0.30	65	89	113	137	161
$0.35	64	87	111	134	158
$0.40	62	85	108	132	155
$0.45	61	83	106	129	151
N price	Price adjusted N rec reduction				
$0.25	-1.6%	-1.5%	-1.4%	-1.4%	-1.3%
$0.30	0.8%	0.7%	0.7%	0.6%	0.6%
$0.35	3.2%	2.9%	2.8%	2.7%	2.6%
$0.40	5.6%	5.1%	4.9%	4.7%	4.6%
$0.45	8.0%	7.3%	7.0%	6.7%	6.5%

SOM=2.0; STN=10; Wheat price=$4.33

Figure 33

Nitrogen Recommendations for Corn					
Yield goal, bu/ac	60	90	120	150	180
KSU N rec, lbs/ac	46	94	142	190	238
N price	Price adjusted N rec, lbs/ac				
$0.25	44	91	138	185	232
$0.30	42	88	134	180	226
$0.35	40	85	130	175	220
$0.40	38	82	126	170	213
$0.45	36	79	122	164	207
N price	Price adjusted N rec reduction				
$0.25	4.6%	3.3%	3.0%	2.8%	2.6%
$0.30	9.0%	6.6%	5.8%	5.4%	5.2%
$0.35	13.4%	9.8%	8.7%	8.1%	7.8%
$0.40	17.8%	13.1%	11.5%	10.8%	10.3%
$0.45	22.2%	16.3%	14.4%	13.5%	12.9%

SOM=2.0; STN=10; Corn price=$2.22

Figure 34

Two non-irrigated crop examples, wheat and corn, in figures 33 and 34 show the impact on optimal fertilizer N rates associated with different N prices, as determined by the Excel decision tool noted. Consistent with crop prices observed in the spring of 2006, wheat price is held fixed at $4.33/bu and corn at $2.22/bu, soil organic matter (SOM) is assumed to be 2.0 percent, and soil test N (STN) is assumed to be 10 lb of N per acre.

In general, for most non-irrigated crops, and as seen in figures 33 and 34, differences in economically optimal fertilizer rates across different fertilizer N prices are small. Yet, as always, it is important that farms take whatever actions are necessary to preserve even small economic comparative advantages over their neighbors. So, just as with no-till, education will be key to helping farm managers preserve profitability in times of high energy prices. Also, appropriately responding to market signals is critical to ensure markets adjust over time. In the particular case of high fertilizer N prices, reduced usage of N will eventually help lead to lower N prices, which will improve farm profitability. Use of appropriate fertilizer decision tools helps that occur.

As an interesting sidebar to the wheat example depicted in figure 33, note that the recommended N rates for all yield goals, and all N prices, are higher than the KSU N rec, which did not account for price. This is despite the fact that all N prices considered ($0.25 to $0.45) were greater than that assumed to underlie the KSU N rec (i.e., $0.22/lb N). This is because the $4.33/bu projected wheat price is considerably higher than that assumed in the long run (i.e., $3.20/bu). Two points are relevant here. First, though it generally is true that higher fertilizer prices should lead to reduced fertilizer usage, that underlying economic force might be offset by an increase in crop prices. Therefore, it is possible for fertilizer usage to actually rise in the face of higher N prices. Second, reduced farm profits associated with higher energy prices might be offset by higher crop prices, at least for farms that are not part of the much larger group whose weather-caused crop failures are the cause of the higher wheat prices in the first place.

Soil testing has long been a recommended practice for Kansas farms and critically underlies fertilizer rate recommendations. Yet, probably less than 25 percent of farms regularly use soil testing. As a part of the research that considered the impact of fertilizer price on optimal fertilizer rates, we also examined the economic benefit associated with soil testing. Figure 35 displays the results around a farm that has wheat and corn yield goals of 50 and 85 bu/acre, respectively, a soil test N level of 40 lb N/acre, a soil organic matter of 1.6 percent, and a fertilizer N cost of $0.40/lb. Clearly, economic benefits to soil testing are large. Equally important, in this situation, the soil testing farmer would have applied 50 lb/acre of N fertilizer whereas the non-tester applying a uniform rate across all fields on his farm would have applied 70 lb/acre.

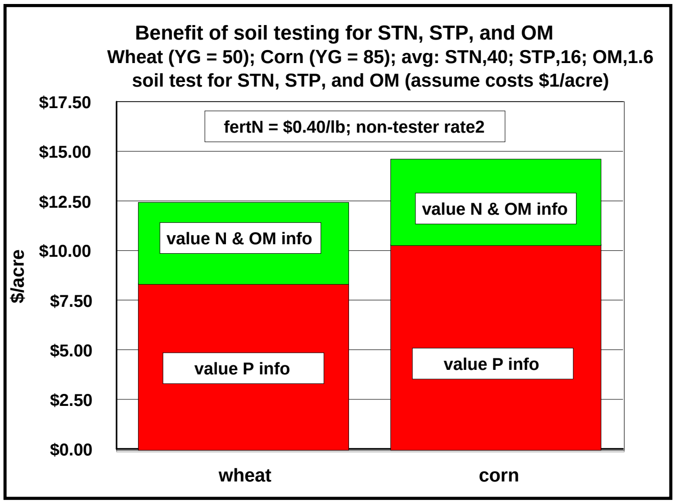


Figure 35

The impact of higher fertilizer prices on irrigated farms deserves special consideration. That is because irrigated farmers depend not only on increased N to obtain higher crop yields, but also on a higher rate of water application. The cost of irrigation water delivered to crops is highly dependent on energy prices, and especially so when groundwater wells are deep. As indicated previously, the price of fertilizer also depends on energy prices. So, making profit-maximizing crop input decisions in the face of changing energy prices is substantially more critical for irrigated farmers than for non-irrigated farmers. As background information and based on KSU calculations, figure 36 shows irrigation water costs ($/acre-inch) across different fuel prices and system pressures, for two different fuel sources, all associated with a pumping depth of 300 feet.

ENERGY PUMPING COST/ACRE WITH NATURAL GAS

	Pressure (PSI)						
	5.0	15.0	25.0	35.0	45.0	55.0	65.0
$/mcf	-------- Energy Cost ($/Acre) --------						
$4.00	2.57	2.76	2.95	3.14	3.33	3.52	3.71
$5.00	3.21	3.45	3.69	3.92	4.16	4.40	4.64
$6.00	3.85	4.14	4.42	4.71	4.99	5.28	5.56
$7.00	4.49	4.83	5.16	5.49	5.83	6.16	6.49
$8.00	5.13	5.52	5.90	6.28	6.66	7.04	7.42
$9.00	5.78	6.20	6.63	7.06	7.49	7.92	8.35
$10.00	6.42	6.89	7.37	7.85	8.32	8.80	9.27

Based on applying 1.0 inches/acre and a lift of 300 feet

ENERGY PUMPING COST/ACRE WITH DIESEL

	Pressure (PSI)						
	5.0	15.0	25.0	35.0	45.0	55.0	65.0
$/gal	-------- Energy Cost ($/Acre) --------						
$0.75	2.38	2.55	2.73	2.90	3.08	3.26	3.43
$1.00	3.17	3.40	3.64	3.87	4.11	4.34	4.58
$1.25	3.96	4.25	4.55	4.84	5.13	5.43	5.72
$1.50	4.75	5.10	5.46	5.81	6.16	6.51	6.87
$1.75	5.54	5.96	6.37	6.78	7.19	7.60	8.01
$2.00	6.34	6.81	7.28	7.75	8.22	8.69	9.16
$2.25	7.13	7.66	8.19	8.71	9.24	9.77	10.30

Based on applying 1.0 inches/acre and a lift of 300 feet

Figure 36

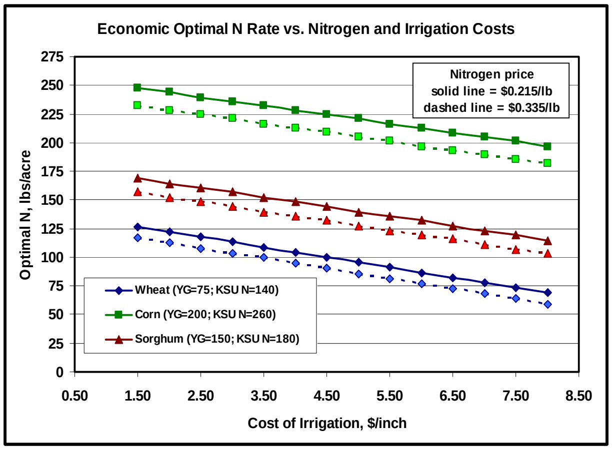


Figure 37

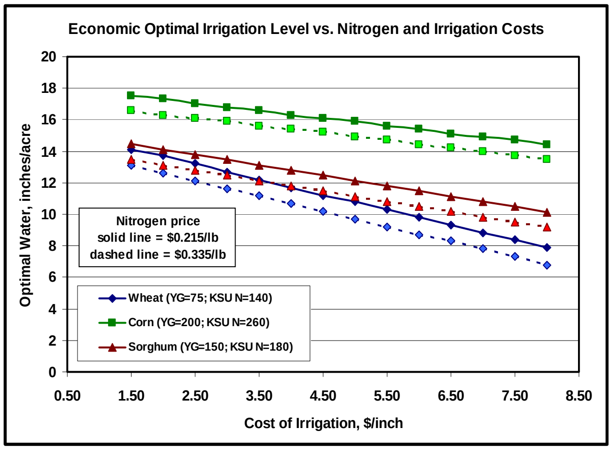


Figure 38

The decision spreadsheet available from KSU for farmers making fertilizer decisions also can be used for making irrigation water decisions. That spreadsheet is used here to identify optimal fertilizer N and irrigation rates for yield goals of 75, 200, and 150 bu/acre for irrigated wheat, corn, and grain sorghum, respectively. KSU's official non-price-responsive N rate recommendations (here, referred to as KSU) would be 140, 260, and 180 lb N per acre for wheat, corn, and grain sorghum, respectively. Figure 37 shows the optimal N rate recommendations for these crops at two N price levels (an historical price of $0.215/lb and a "current" price of $0.335/lb) and across a range of different irrigation water costs.

The first noteworthy aspect of figure 37 is that, even at low water costs (i.e., $1.50/acre-inch), the price-responsive spreadsheet recommended N rates that were lower than KSU's official non-price-responsive rates. That is because KSU's official recommendations do not account for the cost of irrigation water and thus result in the same recommendation for both non-irrigated and irrigated farms with the same yield goal. The second point of note is that, regardless of N price, optimal fertilizer N rates always fall when water costs increase. Ignoring that aspect costs a producer profit.

Figure 38 presents optimal irrigation rates given otherwise the same information underlying figure 37. An interesting aspect of each figure, though not shown, is that reduced N rates and reduced irrigation water rates wrought by higher energy prices lead to greater N use efficiency and greater water use efficiency. In particular, going from $3.00/acre-inch of water and $0.215/lb N (prices consistent with energy prices prior to the last two years) to $6.00/acre-inch of water and $0.335/lb N (prices consistent with "current" energy prices) results in the following increases in N use efficiency: wheat 29.6%, corn 14.3%, and grain sorghum 21.7%. Similarly, water use efficiency increases by 28.0%, 11.2%, and 19.3% for wheat, corn, and grain sorghum, respectively. The upshot to this is twofold. First, the irrigated farmer is more profitable for having appropriately considered energy prices in his input decision making. Second, society is better off in the sense that greater output (bushels of crop) is achieved per BTU of energy expended. This is an appropriate outcome in that higher energy prices should lead to greater physical output per physical unit of energy.

To serve as a reminder to producers that they should expect lower crop yields in the face of higher energy prices, figure 39 shows the expected crop yields associated with the same information behind figures 37 and 38. Note that producers aiming for lower yields when energy prices are high, via their reduced input rate selections, are expected to be more profitable than farms that ignore that information and merely apply what “they’ve always applied.” Once again, just as with fertilizer rates and the no-till decision, these irrigation rate decisions are not intuitive to farm managers and so a substantial amount of education and awareness typically is required to induce the necessary changes in input use wrought by higher energy prices.

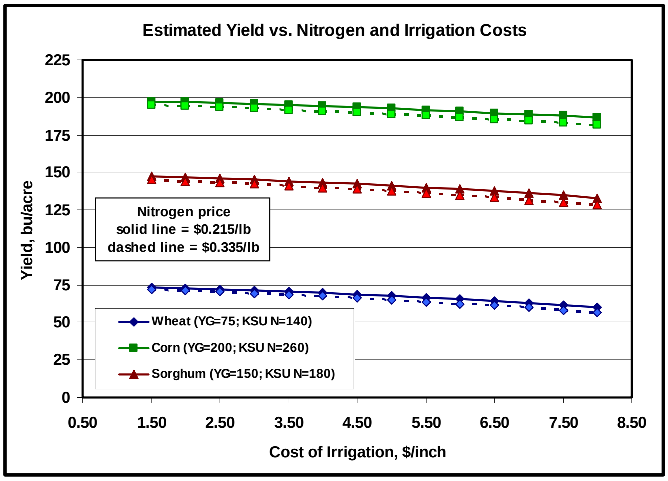


Figure 39

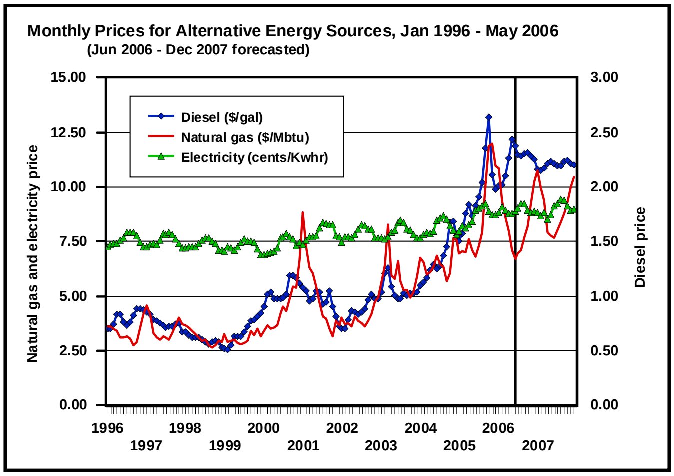


Figure 40

Another important decision that irrigators sometimes face is the choice of pumping fuel source. In 2003, a study by two KSU irrigation researchers, Lamm and Rogers, revealed that 41 percent of Kansas irrigators used natural gas, 28 percent used electricity, 26 percent used diesel, and 5 percent used propane (LP: liquefied petroleum). Figure 40 displays the cost in $/acre-inch of water for three of these energy sources over time. The historical economic advantage to natural gas and diesel over electricity is clearly apparent in the figure. But, just as apparent is the current and expected advantage for electricity. Conversion of water pumping plants from liquid fuels to electricity likely would benefit not only irrigators, but also possibly society as a whole – since electricity generally is generated by energy sources that are currently less in short supply, for example nuclear and coal. Thus, similar to the decision to substitute herbicides for diesel fuel (i.e., no-till), irrigated producers in Kansas also have the decision to substitute from one energy source to another for their irrigation wells. Given current price relationships, policies that encourage irrigated producers to convert their energy source from natural gas or diesel to electricity might be successful. However, a potential unintended consequence of such a policy would be an increase in the amount of water pumped due to the lower pumping cost.

Aggregate irrigation pumping cost savings associated with converting from natural gas or diesel to electricity were estimated for various levels of conversion and at various price relationships (Table 2). Estimates are based on pumping 37.5 million acre-inches of water per year in the state at costs of $6.75, $4.00, and $2.00 per-acre inch in western, central, and eastern Kansas, respectively. At current prices, the cost of pumping per acre inch with electricity is approximately 67% of that of natural gas and diesel (average of the two). At this price relationship, every 10% of acre-inches converted to electricity would equate to a pumping cost savings of approximately $7 million, holding all else constant. While this amount does not reflect an extremely large number for the state, it is quite significant for the irrigated producers affected.

Table 2. Total Pumping Cost Savings from Converting Irrigation to Electricity in Kansas.[1]

Electricity cost as % of diesel & gas[2]	Percent Acre-Inches Affected 10%	20%	30%	40%	50%
55%	$9,995,795	$19,991,590	$29,987,385	$39,983,180	$49,978,976
60%	$8,885,151	$17,770,302	$26,655,454	$35,540,605	$44,425,756
65%	$7,774,507	$15,549,015	$23,323,522	$31,098,029	$38,872,537
70%	$6,663,863	$13,327,727	$19,991,590	$26,655,454	$33,319,317
75%	$5,553,220	$11,106,439	$16,659,659	$22,212,878	$27,766,098
80%	$4,442,576	$8,885,151	$13,327,727	$17,770,302	$22,212,878
85%	$3,331,932	$6,663,863	$9,995,795	$13,327,727	$16,659,659

[1] Acre-inches of application and cost per acre inch are based on KSU Farm Management Guides for western Kansas and then modified for central and eastern Kansas acres.

[2] Current prices are consistent with electricity being approximately 67% of the cost of the average of diesel and natural gas.

Organic Production and Energy Use

Interest in organic farming has increased sharply since the early 1990s. Certified organic cropland for grains, fruits, vegetables and other crops more than doubled from 1992 to 1997, and doubled again for many crops between 1997 and 2003. Two organic livestock sectors – poultry and dairy – grew even faster. According to USDA organic production data, farmers in the continental 49 states dedicated 2.2 million acres of cropland and pasture to organic production systems in 2003. By 2003, producers in over 30 states were raising certified organic livestock.

While adoption of organic farming systems showed strong gains between 1992 and 2003, the overall adoption level is still low–only about 0.4 percent of all U.S. cropland and 0.1 percent of all U.S. pasture was certified organic in 2003. Furthermore, only a small percentage of the top U.S. field crops–corn (0.1 percent), soybeans (0.2 percent), and wheat (0.4 percent)–were grown under certified organic farming systems. On the other hand, some crops such as organic apples (4 percent), organic lettuce (4 percent) and other fruit and vegetable crops represented a more sizable component of total production. There are a multitude of reasons for increased interest in organic production including: a desire to lower input costs; conserve nonrenewable resources; capture high-value markets; and boost farm income.

It has been suggested that a switch to organic farming practices would reduce agriculture's energy usage. Research on this point is mixed and there is not a large body of research to draw upon. One of the problems is how energy usage is measured, per unit of input, such as acres, or per unit of output, as costs are typically measured. From the perspective of organic farming and energy use, Dalgaard, Halberg, and Porter stated that energy use was generally lower in organic production than in the conventional system, but yields also were lower. Reduced yield levels historically have been a problem in organic production systems and are one reason organic production costs per unit of output typically are higher than for conventional production. However, Refsgaard, Halberg, and Kristensen suggested that conventional yields were not sufficiently higher than organic yields to compensate for the extra energy usage compared with organic crops. One consideration in organic production is that organic crop production typically substitutes tillage for herbicide usage. As seen previously, the cost of tillage (e.g., diesel fuel) has increased sharply relative to the cost of one of the most commonly used herbicides, glyphosphate. Thus, it is possible that the recent run-up in energy prices could actually discourage a shift towards organic production.

Organic crop production generally relies upon livestock manure as the primary nutrient source. Because nutrients in livestock manure are not as concentrated as commercial fertilizers, using manure as a nutrient source often is only economical when the crop field is located close to the manure source so as to minimize hauling costs. Thus, the high cost of diesel, which impacts tillage, also increases fertility costs (i.e., hauling and spreading manure), which also could temper the trend to increased organic production in the short run.

Government efforts have been invested to boost organic production by developing national certification standards to assure consumers of consistent product quality and by streamlining interstate commerce in organically grown products. In addition, several states have begun subsidizing conversions to organic farming as a way of capturing perceived environmental benefits. Looking ahead, it is likely that organic crop and livestock production will continue to increase, but the driving force will be consumer interest in purchasing organic products and the relatively large premiums some consumers are willing to pay to obtain organically produced food products.

Renewable Energy

Producing energy and products from renewable energy resources such as biomass, wind, and solar can help reduce dependence on fossil-based resources such as coal and petroleum. Renewable energy resources such as wind, solar, and biomass have some advantages over the present sources of energy upon which we now rely. They are significantly more abundant, are virtually inexhaustible, and provide several environmental advantages - most notably they are carbon neutral; e.g., they provide a “closed-carbon” loop. Some renewable energy technologies, such as solar and wind energy, produce no direct emissions. Biomass energy crops such as agricultural crop residues can, under judicious management, be harvested for alternative energy purposes (e.g., bioethanol production) and provide adequate protection from soil erosion and needed soil tilth. Other biomass energy resources, such as herbaceous and woody energy crops, offer a wide range of environmental benefits including:

1. Reduced water and wind produced soil erosion;
2. Reduced surface and subsurface fertilizer and pesticide migration, improving surface and groundwater quality;
3. Reduced emissions of global warming gases and more extensive carbon sequestration in root systems than annual crops; and
4. Improved regional air quality by reducing SO_2 and NO_2 emissions.

In addition to the above, benefits of renewable energy resources go beyond replacement of fossil fuels and a reduction in greenhouse gas emissions. Implementation of renewable energy can provide direct benefits to local communities and counties through job creation in such areas as installing and maintaining wind turbines or solar photovoltaic equipment, or the harvesting, transportation, and processing of biomass resources such as corn stover and/or energy crops into usable energy sources. Also, implementation of renewables can help protect consumers against unforeseen costs of pollution control regulations and potential price hikes in fossil fuels.

Wind and solar energy certainly are applicable to the Kansas agriculture community and primarily are used for the production of electricity on both small and large-scales. However, small-scale wind and solar electricity production systems are, for the most part, economically infeasible at the present time whereas large-scale wind energy systems may or may not be economically feasible, depending upon a number of factors. A detailed analysis of large-scale wind energy systems is beyond the scope of this report. The remainder of this section will focus on biomass since it is the most applicable to Kansas' agriculture sector.

Biomass is defined as organic material derived from plant and animal growth. The biomass resource is diverse and includes forestry and primary and secondary wood processing wastes, oilseed crops such as soybeans and cottonseed, animal manures, wastes associated with food processing operations, energy crops such as switchgrass and poplar trees, and agricultural crop residues such as corn stover and wheat straw. Biofuels are the product derived from conversion of these resources into liquids such as ethanol or a low to medium methane gas. Table 3 presents the most predominant biomass resources either currently generated or with potential for production and conversion into alternative fuels and most applicable end-use(s).

Table 3. Biomass Resources and Potential Viable Energy End-uses.

Biomass Resource	Ethanol	Biodiesel	Heat	Electricity
Grain crops				
Corn/grain sorghum	√			
Oilseed crops				
Soybeans		√		
Cottonseed		√		
Sunflowers		√		
Canola		√		
Cellulosic biomass				
Ag Crop Residues				
Corn/grain sorghum stover	√			
Wheat straw	√			
Herbaceous				
Switchgrass	√		√	√
Short-rotation				
Woody crops			√	√
Wood wastes				
Primary (logging)			√	
Secondary (finishing)			√	
Urban (municipal wastes)			√	
Livestock manures			√	√
Landfill gas			√	√

A number of energetic, environmental, and economic issues apply to the production, development, and potential utilization of the biomass resource base as feedstocks converted into alternative energy resources. A partial list of these issues includes:

- energy production
- sustainability (maintaining acceptable soil tilth and soil productivity) of the resource base
- climate
- geography
- applicable land resource base and arable versus non-arable lands
- competing crop and/or land base revenue and competing crop uses

Following are sections that provide general background on areas of biomass production and end use that potentially are applicable to Kansas. The four areas with potential in Kansas are:

1) biodiesel
2) cellulosic ethanol
3) anaerobic digestion of animal manures
4) grain-based ethanol

Biodiesel

Background

Biodiesel is a domestic, renewable alternative diesel fuel derived from vegetable oils, animal fats, and/or waste greases and can be used in any concentration with petroleum-based diesel fuel in existing diesel engines with little or no modification. Biodiesel is produced by combining the oil or fat with alcohol and a catalyst, which yields the pure biodiesel and glycerol (a by-product). Most biodiesel today is produced from soybeans with the remainder coming from waste greases.

Advantages of biodiesel over standard #2 diesel fuel include the following: high cetane level (average >50 vs. ~41 for standard diesel), no nitrogen or aromatics, biodegradable and non-toxic, energy balance of 3.24 to 1, and life cycle CO_2 reduction of 78%. Biodiesel combustion reduces emissions of un-burnt hydrocarbons, particulate matter, and carbon monoxide. Nitrous oxide emissions from biodiesel combustion can either be higher or lower than emissions from conventional diesel, depending upon a number of factors. Disadvantages of biodiesel focus primarily on two factors. First, the energy content of a gallon of biodiesel is about 8% below that of standard diesel fuel. Second, biodiesel will gel more quickly than diesel fuel, which can be problematic in higher concentration levels in certain environments.

Current United States Production

Figure 41 presents a historical perspective concerning biodiesel production in the United States. While this market it still relatively small, it can be seen that this market has been growing rapidly over the last several years.

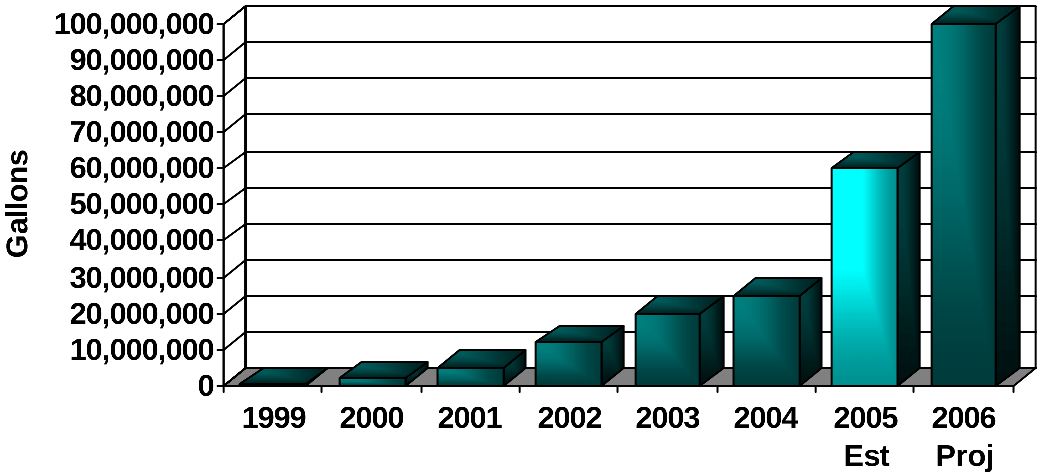


Figure 41. Historical and Expected Production of Biodiesel in the United States

Current market drivers for biodiesel which have contributed to the recent dramatic production increases include:

1) Further compliance with the Energy Policy Act of 1992 (EPACT), of which biodiesel is the lowest cost alternative fuel;
2) Passage of the 'blenders tax credit' of 1 cent per gallon per percent biodiesel blended with diesel fuel;
3) State mandates of low-blends of biodiesel in Minnesota and Washington and an Illinois sales tax waiver for blends exceeding 10% biodiesel;
4) Passage of the Renewable Fuels Standard and a possible increase in the required levels of biodiesel;
5) A desire for energy independence; and
6) Superior environmental benefits versus conventional diesel fuel.

In addition to the six reasons listed above, implementation of the Environmental Protection Agency's 2006 Ultra-Low-Sulfur-Diesel (ULSD) Rule also will lead to an increase in demand for biodiesel. The ULSD Rule mandates on-highway diesel fuel contain no more than 15 parts per million (ppm) of sulfur, which effectively eliminates the required lubricity for safe operation in compression-ignition engines. Biodiesel, in blends of 1-2%, can restore all the needed lubricity in mandated ultra-low-sulfur-diesel. It is expected that the introduction of low sulfur fuel also will be required in other sectors of the economy, such as off-road, railroads, and agriculture in the future, which could further boost demand for biodiesel. As an example of biodiesel's potential, the quantity of biodiesel needed to replace the required lubricity in all on-highway diesel fuel at a 2% blend rate would equal approximately 750 million gallons, an increase of 650% over current production. Table 4 presents average annual levels of distillate consumption in Kansas for 2000-2004, the percentage of this consumption relative to the national average, and the gallons of low-blend (2%) biodiesel required to achieve adequate lubricity.

Table 4. Average Annual Kansas Distillate Consumption and Low-blend Biodiesel Requirements, gallons.

Kansas Economic Sector	2000-2004 Annual Average Distillate Fuel Consumption	2% Biodiesel (low-blend) Blend Requirement
Residential	838,400	16,768
Commercial	25,247,000	504,940
Industrial	15,053,200	301,064
Farm	156,195,000	3,123,900
Electric Power	37,686,600	753,732
Oil Company	0	0
Railroad	57,351,600	1,147,032
Vessel Bunkering	0	0
On-Highway	389,908,000	7,798,160
Military	1,512,600	30,252
Off-Highway	19,965,800	399,316
13-All Other	7,200	144
Totals	703,765,400	14,075,308
Total Biodiesel Potential from Soybeans Produced in Kansas		120,781,440

Kansas potential for biodiesel production from various oil and fat feedstocks

Kansas' soybean production from 2000-2005 averaged approximately 84 million bushels. If all of the soy oil produced from this production were converted to biodiesel it would yield over 120 million gallons annually, however this is an unrealistic scenario since soybean oil typically has a high market value for use in the food sector. Biodiesel also can be produced from a variety of other feedstocks such as sunflowers, cottonseed, peanuts, canola, and edible and inedible tallow, all of which are currently produced, or have the potential to be produced, in Kansas.

There are a number of factors that must be considered with respect to biodiesel production and potential end-use as an alternative fuel. First, each of these oil stocks, in its present form, is an agricultural commodity and as such has one or more competing markets for its use, mainly in the food or livestock feed sectors. Second, these commodities (with the exception of tallow) will compete for acreage presently in use by other crops and their potential profitability will be measured against these competing commodities. Third, the cost of producing biodiesel from each commodity must be competitive with current and expected future diesel fuel costs. Fourth, a viable and consistent market for their end-use in biodiesel production must be established.

Economic feasibility utilizing various feedstocks

Biodiesel production cost is highly correlated with feedstock cost, as well as plant capacity (million gallons per year, MGY). Table 5 lists historical and projected feedstock costs (10 years previous and 10 years forward) for each agricultural commodity previously identified to provide a sense of the range of feedstock costs as a function of time. These are national annual average costs obtained from the commodities database of the Food and Agricultural Policy Research Institute (FAPRI) (http://www.fapri.iastate.edu/tools/outlook.aspx). Table 6 presents general biodiesel production costs (variable costs only) for each feedstocks for two potential capacity (MGY) plants; one equal to 10 million gallons per year and one less than one million gallons per year (IBFG, 2005). As in many sectors of the economy, there are scale economies present in biodiesel production, making it cheaper to produce biodiesel in larger plants.

Table 5. Costs ($/pound) for Potential Biodiesel Oil and Fat Feedstocks.

Products	Historical Low	Historical High	Projected Low	Projected High
Canola oil	$0.171	$0.330	$0.274	$0.311
Sunflower oil	$0.159	$0.334	$0.322	$0.345
Peanut oil	$0.325	$0.597	$0.483	$0.535
Cottonseed oil	$0.160	$0.378	$0.220	$0.252
Soybean oil	$0.142	$0.300	$0.209	$0.239

Table 6. Variable cost ($/gallon) of biodiesel production for six possible feedstocks and low (< 1 million gallons per year) and high (10 million gallons per year) production scenarios (costs exclude interest on capital and depreciation).

	10 million gallon per year biodiesel production facility			
	Low historical feedstock price	High historical feedstock price	Low future feedstock price	High future feedstock price
Canola oil	$1.44	$2.63	$2.21	$2.49
Sunflower oil	$1.35	$2.66	$2.57	$2.75
Peanut oil	$2.60	$4.64	$3.78	$4.17
Cottonseed oil	$1.36	$2.99	$1.80	$2.12
Soybean oil	$1.22	$2.41	$1.73	$1.95
Beef tallow	$1.07	$2.24	n/a	n/a
	Less than 1 million gallon per year biodiesel production facility			
	Low historical feedstock price	High historical feedstock price	Low future feedstock price	High future feedstock price
Canola oil	$1.55	$2.74	$2.31	$2.60
Sunflower oil	$1.46	$2.77	$2.68	$2.85
Peanut oil	$2.70	$4.74	$3.89	$4.28
Cottonseed oil	$1.46	$3.10	$1.91	$2.15
Soybean oil	$1.33	$2.51	$1.83	$2.06
Beef tallow	$1.17	$2.34	n/a	n/a

Cellulosic Biomass

Definition of Cellulosic Biomass

Cellulosic biomass is defined as the biomass resource base that would be available on a regular or recurring basis and includes dedicated energy crops and trees, wood and wood residues, plants, grasses, agricultural residues, fibers, animal wastes and other waste materials, and municipal solid waste (Energy Policy Act of 2005). Cellulosic biomass includes the following:

- Forest Residues
    - Logging Residues, Other Removals, Fuel Treatment Removals;
- Mill Residues
    - Primary Mills, Secondary Mills;
- Urban Wood Wastes
    - Residential and Non-Residential Construction, Demolition, and Renovation;
- Agricultural Crop Residues
    - Corn Stover, Grain Sorghum Stover, Wheat Straw;
- Dedicated Energy Crops
    - Perennial Grasses (Switchgrass), Short Rotation Woody Crops (Poplar, Willow).

Cellulosic biomass can be used for the production of both electricity and biofuels (bioethanol). A few electricity generating facilities in the United States have successfully utilized switchgrass as a co-firing fuel (between 1% and 10% of total heat input) with success. Ethanol produced from cellulosic materials, like those listed above, is referred to as bioethanol and has the potential to expand the total ethanol market to help meet the rising demand for motor fuels. The chief process for converting cellulosic materials such as those listed above into bioethanol is somewhat different than the process used to convert conventional grain crops into ethanol. Basically, the cellulosic conversion process involves the use of genetically modified/engineered bacteria to break down complex sugars inherent in the biomass and these sugars can then be used to produce chemicals, ethanol, and other biofuels. However, the technology for producing cellulosic ethanol is still not economically feasible on a "stand-alone" basis at this time.

Currently, nearly all ethanol produced in the United States is produced from grain crops (starch crops) such as corn and grain sorghum, which have alternate markets and potential energetic and environmental problems. Advantages in producing and utilizing cellulosic feedstocks as an alternative energy source include:

- use of marginal lands for production with potential for environmental improvement in air, soil, and water quality;
- production and utilization of a renewable resource;
- reduction in carbon loading to the atmosphere due to biomass's "closed-carbon" cycle;
- production of an energy resource located in close proximity to demand;
- potential to increase farmer/landowner income.

National Cellulosic Biomass Supply

Tables 7-9 provide national estimates of the total potential quantity (mass) and supply (quantity at particular prices) of various cellulosic biomass feedstocks in 2005 (Walsh).

Table 7. Supply (million dry tons) of Forest, Primary Mill, and Urban Wood Wastes Biomass Feedstocks at Two Price Levels.

Biomass Feedstock	$25/dry ton	$50/dry ton
Forest Residues	8.91	37.17
Primary Mill Residues	19.26	59.71
Urban Wood Wastes	15.56	34.93

Table 8. Supply (million dry tons) of Stover and Straw at Two Price Levels.

Crop Rotation and Tillage Scenario	$30/dry ton	$50/dry ton
Corn Stover, Corn-Soybean Rotation, Current Tillage Mix	0	99.8
Corn Stover, Corn-Soybean Rotation, All No-till	0	162.8
Corn Stover, Continuous Corn, Current Tillage Mix	0	115.9
Corn Stover, Continuous Corn, All No-till	0	200.1
Wheat Straw, Continuous Wheat, Current Tillage Mix	6.44	20.91
Wheat Straw, Continuous Wheat, All No-till	33.85	64.69

Table 9. Supply (million dry tons at certain price ($) settings) of Switchgrass and Short-rotation Woody Crops

	$30/dry ton	$50/dry ton
Switchgrass	57.9	193.3
Hybrid Poplar	0	0.4
Willow	0	0.02
TOTAL	57.9	193.7

National Efforts to Enhance Cellulosic Biomass Production and Utilization

Renewable Fuels Standard (RFS)

In 2005 national legislation was enacted that would effectively double the amount of renewable fuels, such as ethanol and biodiesel, by 2012. The Renewable Fuels Standard (RFS) mandates at least 4 billion gallons of renewable fuel be produced by 2006 and at least 7.5 billion gallons by 2012. The RFS also contains other production provisions for renewable fuels, such as mandating cellulosic-derived ethanol (minimum of 250 million gallons) in 2013. Cost goals submitted by the National Renewable Energy Laboratory (NREL) for ethanol derived from lignocellulosic feedstocks are to be competitive with grain-based ethanol at $1.07 per gallon by 2012 and at about 60 cents per gallon by 2020 (U.S. House of Representatives).

25 x ’25

Recently, a national focus, 25 x ’25, (http://www.25x25.org) has emerged with the goal of having U.S. agricultural lands provide 25 percent of the total energy consumed in the United States by the year 2025, while continuing to produce safe, abundant and affordable food, feed, and fiber. The main objective is to determine how large a role agriculture can play in helping the nation improve energy security with the primary goals being 1) to develop a common vision for energy production from America’s farms, ranches, forest land and horticultural industry, and 2) to develop a comprehensive strategy to make this vision a reality. While the focus of this organization/effort is on the total renewable energy picture (wind, solar, biomass, etc.), a pronounced emphasis on biomass will exist since the agricultural sector is highlighted.

Major Cellulosic Biomass Resources and Applicability to Kansas

Agricultural crop residues such as corn stover and wheat straw and herbaceous energy crops such as switchgrass and big bluestem are the main cellulosic biomass resources that have received the most attention nationally with respect to alternate energy production.

Agricultural Crop Residues

Agricultural crop residues, a subset of the biomass resource base, are lignocellulosic biomass that remains in the field after the harvest of agricultural crops. The most common residues include the stalks, ears, and/or cobs from corn (stover) and straw from wheat production. Agricultural residues play an important role in controlling erosion and maintaining soil carbon, nutrients, and soil tilth.

Removal of agricultural residues from agricultural cropland for bioenergy and bioproduct use is directly influenced by a number of factors including grain yield, crop rotation, field management practices within a rotation (e.g., tillage), climate, soil characteristics controlled for (erosion, organic matter, moisture, etc.), and soil type and topography. Therefore, removal of agricultural residues for bioenergy and bioproduct use will require consideration of the quantities that must be left to maintain various aspects of soil quality.

While agricultural crop residue quantities produced are substantial, only a percentage of them can potentially be collected for bioenergy and bioproduct use due to soil and water sustainability concerns. In addition, harvesting, transport, and processing costs are incurred with stover before it can be used as an alternative energy source which, due to the diffuse nature of the resource, could be cost-prohibitive.

Corn Stover Supply Analysis for Kansas

Table 10 contains two sets of supply estimates (dry tons) of corn stover from a continuous corn cropping scenario at edge-of-field price increments between $45.00 and $75.00 per dry ton for all 105 counties in Kansas subject to low and high diesel price ($1.00 and $2.25 per gallon) and low and high nutrient replacement value ($0.22 and $0.41 per pound of N). Supply estimates are a function of 1) amount of residue (dry tons) that can be removed on a sustainable basis with respect to soil sustainability, 2) tillage scenarios employed, 3) cost to operate harvesting equipment, which includes diesel fuel cost, and 4) value of the nutrient replacement due to stover removal. Data contained in tables 10 and 11 only represent possible quantities based on low and high diesel fuel price, low and high nutrient replacement value, and current tillage mix, which in Kansas is predominantly aligned with conventional tillage.

Table 10. Potential Corn Stover Supply for Kansas Under Various Diesel Fuel and Nutrient Replacement Value Scenarios.

	Price per dry ton						
	$45	$50	$55	$60	$65	$70	$75
	Total dry tons supplied						
Low diesel price Low nutrient replacement value	81,925	254,705	627,106	843,697	1,087,341	1,166,042	1,180,820
High diesel price High nutrient replacement value	0	0	140,736	254,705	627,106	843,697	1,087,341

Herbaceous Energy Crops (Switchgrass, Big Bluestem)

Switchgrass, a native perennial grass, has received the most attention concerning the Department of Energy's herbaceous energy crop effort as a feedstock for alternative energy production, especially bioethanol. Yields of switchgrass in the eastern United States generally surpass those of corn stover. As previously stated, switchgrass has many environmental advantages. However, while corn stover is generated as a by-product due to the production of a food-based crop, herbaceous energy crop production will have to compete against the market value of the agricultural commodity typically produced on the land base. In general, the feasibility of herbaceous energy crop production and use as an alternative energy source will be a function of a number of factors, including:

- crop yield (removable dry tons per acre) as a function of soil type;
- competing conventional energy source the biomass will replace;
- market value of agricultural commodities produced on the competing land base over the period of potential herbaceous energy crop production;
- government payments (if applicable);
- market value of the energy source being replaced by switchgrass;
- cost of diesel fuel and nutrients relative to competing commodity crop or land use;
- environmental/carbon credits.

Development of herbaceous energy crop supply estimates within individual counties and at the soil type level were not developed in this project due to the level of detail required in obtaining accurate information for a number of factors listed above – all of which will have a pronounced affect on the economics of production and hence edge-of-field cost. Supply estimates have been developed by the Department of Energy at the agricultural statistic district (ASD) level in Kansas, but are felt to be insufficient and not representative of a totally accurate economic picture primarily due to the use of a single yield across the entire ASD as well as the methodology used to estimate switchgrass yields. Switchgrass yields are correlated with temperature and rainfall as well as a number of other agronomic factors, which in Kansas can vary appreciably within a single county and certainly across large geographic areas such as an ASD. For this reason, economics of herbaceous energy crop production should not be tied to a single, average yield.

Anaerobic Digestion of Dairy Manures

Background

Generation of livestock manures/waste from beef and dairy cattle and swine operations and their subsequent disposal problems presents a potential opportunity to utilize a negative-value by-product as an alternative energy source. Livestock manures, in particular dairy wastes, have been utilized in select geographic areas of the United States as an alternative energy resource utilized to generate on-site heat and electricity. The feasibility, both technical and economic, depends on a number of factors such as prevailing natural gas/propane and electricity costs and buy-back rates, concentrated herd size, labor and maintenance, and system size (kW) and cost.

Calculation of energy (Btu and kilowatt-hours) from dairy operations across Kansas

Table 11 presents general industry-accepted manure generation rates for dairy cattle as well as gross energy (BTU and kilowatt-hours) production data for each of the three herd sizes. Energy generation (kilowatt-hours) from dairy manure is based on an assumption of 32,175 BTU per head per day derived from manure production, a 90% manure recovery rate, a 70% annual capacity factor, and a thermal conversion rate of ~25%.

Table 11. Energy (BTU and kilowatt-hours) Generation Rates.

	# of dairy cattle		
	300	3,000	9,000
Gross MMBtu	3,523	35,232	105,695
Capacity, kW	39	390	1,170
Annual kilowatt-hours	169,089	1,690,889	5,072,668

Economic Feasibility ($/kilowatt hour) as a Function of Herd Size

A general and basic gross economic feasibility was performed on three different size dairy herds (300, 3,000, and 9,000 head) utilizing system capital cost curves generated by the Western Governors' Association Clean and Diversified Energy Advisory Committee – Biomass Task Force. The economic feasibility was concerned with determining the on-site cost of electricity production resulting from anaerobic digestion of livestock manures for each herd size. The system cost curve utilized is presented in equation 1:

$$\text{\$/kilowatt (kW) installed} = \$50,305 * (\text{herd size})^{-0.353}. \qquad (1)$$

A constant operation and maintenance (O&M) cost of $0.015 per kilowatt-hour was assigned to each system based on a lack of long-term reliable operating data for anaerobic digestion systems. Table 12 shows projected annual cost of production (cents per kilowatt-hour) for each of three sizes based on the above cost curve, a life expectancy of 10 years, no salvage value, and an annual rate of return of 15%. Electricity production costs provided do not include any local utility interconnection charges nor do they include any potential carbon emission reduction payment.

Table 12. Projected Annual Electricity Cost of Production versus Dairy Herd Size.

	# of dairy head 300	3,000	9,000
Capacity, kW	39	390	1,170
Cost per kW installed	$6,717	$2,980	$2,022
Annual kilowatt-hours	169,089	1,690,889	5,072,668
Cost per kilowatt-hour ($ per kW-h)	$0.2834	$0.1341	$0.0958

Grain-based Ethanol

The most prevalent renewable fuel in the U.S. today is ethanol produced from grain and U.S. ethanol production is growing by leaps and bounds. The annual increase in U.S. ethanol production from 1980 to 2004 (25 years) averaged 13.2% (average increase of 134.8 million gallons per year). But the growth rate increased sharply in recent years. For example, the annual growth rate over the last five years (2000-2004) averaged 20.3% (average of 445.0 million gallon increase per year according to the Renewable Fuels Association. As of January 2006, U.S. ethanol production capacity was estimated to be 4.6 billion gallons, an increase of over 20 percent compared to 2005. By mid-2006, there were 34 ethanol plants under construction in the U.S., which could boost U.S. production capacity to 6.7 billion gallons (Roe et al). Moreover, ethanol production is expected to grow even more rapidly in the foreseeable future. For example, the Renewable Fuel Standards (RFS) mandates annual U.S. ethanol usage totaling 7.5 billion gallons by 2012, and it is likely that most, if not all, of the ethanol used to meet the standard will be produced domestically. Based on new plant construction and expectations for even more industry expansion the next few years, some industry forecasts suggest U.S. ethanol production easily will exceed the minimum requirements established in the RFS (Roe et al.). Still, despite the rapid growth in the industry's size, total ethanol production is very small compared to U.S. fuel usage. For example, during 2005 ethanol production totaled 4 billion gallons, equivalent to about 2.9 percent of U.S. gasoline consumption (Eidman).

Ethanol industry expansion has been motivated by high profit margins. Industry profitability is primarily dependent on prices of the feedstock (principally corn), ethanol, and natural gas. Although natural gas prices have been higher than normal, recent industry margins still have been very strong due to the combination of high ethanol prices and relatively low corn prices (Eidman).

Ethanol can be produced from a number of different commodities such as barley, wheat, switchgrass, brewery by-products, and even urban waste, but corn and grain sorghum have been the dominant inputs used, primarily because they have been relatively inexpensive and readily available. Since corn has been the primary feedstock used to make ethanol, it is not surprising that most existing U.S. ethanol production facilities are located in the Upper Midwest-primarily Illinois, Iowa, Minnesota, Nebraska, and South Dakota. Key factors encouraging plant construction in the Upper Midwest were large available corn supply, relatively low corn prices (compared to other regions of the U.S.), and sufficient livestock inventories to provide a reliable market for distillers grains, an ethanol by-product (Dhuyvetter et al). Over the last decade most of the industry's growth was comprised of new dry-mill plant construction. During 2005 approximately 25 percent of the industry's production was from wet mills while 75 percent of construction came from dry mills. One of the primary incentives to build dry mills was the fact that initial construction costs for dry mills were lower than for dry mills (Eidman). Dry mills market their by-products as dried distillers grains and solubles (DDGS) or as their wet counterpart (WDGS), whereas wet mills tend to have corn gluten meal, corn gluten feed, and corn oil as their byproducts.

As the ethanol industry matures, it will be important to remember that it is a commodity industry. Firms in commodity industries have little control over the price at which they sell their outputs since one firm's production is undifferentiated from other firms' output. As a result, firm-to-firm profit variability is largely explained by differences in production costs. Stated another way, being a low cost producer will be critical for long-term survival in tomorrow's ethanol industry. This is important because it could lead to some changes regarding where new ethanol plants are built in the future.

Currently, there are seven ethanol plants in operation in Kansas, all of which are dry mill plants. Total ethanol production capacity of these seven plants is about 170 million gallons per year, according to the Kansas Ethanol coalition (www.ksgrains.com/ethanol). Estimated plant capacity ranges from just 1.5 million gallons per year to 46 million gallons per year for plants that are scattered across the state. Construction of an eighth ethanol plant near Phillipsburg, Kansas got underway in fall 2005 with a projected capacity of approximately 40 million gallons. Based on estimated U.S. production totals for 2005, Kansas ethanol plants were responsible for about 4.3 percent of U.S. ethanol production.

Future ethanol plant locations will be determined not only by the factors already mentioned, but also by several other key variables. The feedstock in ethanol production, typically corn, represents the single largest cost and thus is the input that receives the most attention. However, with high energy prices, such as those faced in 2005 and 2006, it is important to account for all inputs and credit all co-products when determining the net cost to produce ethanol. This is especially true given that there is very little relationship between ethanol and corn prices. That is, high corn (input) prices do not imply high ethanol (output) prices. Both natural gas and diesel fuel prices are significantly higher today than just five years ago. The shift in energy prices, if it is long-lived, will provide an economic incentive to market distillers grains wet (WDGS), rather than as dry distillers grain, and at locations as close to plants as possible to reduce transportation costs. Furthermore, the market for WDGS is almost exclusively driven by ruminants (i.e., cattle). Looking ahead, if the net benefits associated with marketing WDGS in close proximity to ethanol plants exceed the cost of shipping in dry corn from major corn producing regions, it will encourage construction of ethanol plants in the High Plains regions of southwest Kansas and the Texas Panhandle, where large numbers of cattle are concentrated (Dhuyvetter et al.). Determining the impact shifts in energy price relationships will have on future plant location decisions is beyond the scope of this report, but it is a topic that merits further research and consideration.

Review on Transportation and Energy

The United States has the most efficient freight transportation system in the world. At present, the U.S. freight transportation system is characterized by a high level of dependence on highway-based carriage. However, if we continue to rely inordinately on trucks and highways, the demand for freight transportation over the next two decades will far exceed infrastructure capacity (Brown and Hatch).

Railroad fuel efficiency has increased by 72 percent since 1980. In 1980 a gallon of diesel fuel moved one ton of freight an average of 235 miles. In 2001, the same amount of fuel moved one ton of freight an average of 406 miles. According to the Union Pacific, trains are 2-4 times more fuel efficient than trucks on a ton-mile basis. If just 10 percent of the freight moved by highway were diverted to rail, the nation could save as much as 200 million gallons of fuel each year.

Kansas is situated in the middle of the contiguous United States and consequently in the middle of most market transportation routes. Therefore, it comes as no surprise that Kansas ranks in the top ten states for miles of highway and miles of rail. Much of the railroad track that was lost in the past was due to the growth of the highway system and increased competition from truck traffic. Since 1982, Kansas has lost approximately 40% of its rail through abandonment and during the same period of time, the ton-miles of freight moved by rail increased three-fold. Even with the increased freight movement, over 200 miles of track are slated to be abandoned within the next few years. Of the 207 miles of rail line on the chopping block, 48% of this track is owned by short-line railroads (Bittel).

Increasing railroad abandonment and other changes in the Kansas grain transportation system have encouraged increased trucking of grain. A study conducted by Babcock et al. found that further losses of short-line railroads would have negative effects on rural Kansas communities, including increased road damage costs and reduction in farm income. If the four short-lines serving the study area (the western 2/3 of Kansas) are abandoned, there will be a large diversion of wheat shipments from railroads to trucks and traffic will increase beyond the counties' capacity. Increases in transportation and handling costs of grain would increase by $0.056 per bushel, for a total income loss to Kansas farmers of $20.5 million. Furthermore, the short-line railroad system in the study area annually saves the state of Kansas $57.8 million in road damage costs.

Policy Considerations

Up to now we have given several examples about how policy makers would be wise to consider underlying economic forces in their decisions. That is, they should seek out and work with underlying economic trends that are consistent with their social objectives, rather than use government policies to reverse economic trends. Second, it is likely that carrots (e.g., subsidies) are politically preferred to sticks (e.g., more restrictive laws and regulations) because decision makers generally find the choice between status quo and engaging in an activity to collect a financial reward more palatable than the choice between adopting a new practice and the status quo, where the status quo would require breaking a new regulation or law.

As already noted, subsidies generally are most effective (i.e., acquire the most change in business or consumer behavior for the least taxpayer dollar or political capital expenditure) when they reinforce or catalyze existing economic trends. Economic trends often develop because all decision makers do not adopt a new technology or practice simultaneously. Rather, some managers immediately recognize an opportunity to increase profit while others, partly because of fear of risk and partly because of simple unawareness, wait for years before adoption. Such managers may need only a slight nudge via a subsidy or perhaps via an educational program to make the society-desired change – because they expect such change to result in increased profits over time; they merely are unsure of the magnitude and timing of such increased profits and so delay adoption.

In regards to technology adoption, subsidies that affect capital investment decisions typically have a longer impact than current expenditure- or receipt-related subsidies. For example, subsidizing the installation of insulation in a farm building to reduce energy-related heating and cooling costs will result in energy savings that go on long after the subsidy goes away – because removing such insulation generally is costly and without offsetting financial benefits. On the other hand, the energy savings wrought by subsidizing the transportation of manure from a commercial feedlot to a farm so that it can substitute for commercial N fertilizer likely will end when the subsidy ends. This is not to say that such capital-investment subsidies automatically are the most efficient use of taxpayer funds, but rather that the long-run economic impacts of policies should be considered in policy decisions.

Finally, despite agriculture being a small part of the overall energy picture in the U.S., and to some extent even in Kansas, policy makers should not underestimate the political importance of that sector. That is, perhaps because of its past importance, or perhaps because of its current political unity, agriculture regularly appears to dominate a disproportionate (in terms of economic size and population) share of political activity at the national and the state level. So, policy makers would be wise to consider the impact of any proposed policy change on agriculture.

Based on the work reported here we would suggest the following. First, the temptation to "use money to do something" is always great among policy makers. In that vein, we urge caution. That is, it is our experience that, in a competitive and free-market economy, market forces generally are more efficient at inducing change than are government-sponsored policies. By efficient we mean achieving the desired social goals at the lowest cost to taxpayers. That said, we recognize that there may be some opportunities to use public funds to accomplish worthwhile goals associated with energy policy. We believe that such opportunities best arise from first identifying economic trends that are consistent with desired social goals. Then, consideration should be given to whether such trends should be enhanced with a gentle economic nudge, such as a subsidy.

A few specific opportunities for worthwhile public expenditures are as follows. The first opportunity may be with no-till. No-till is a technology that reduces direct energy usage at the farm level, especially of the type that is used in motor vehicles and which appears to be most in demand currently, namely diesel fuel. Assuming there are 30 million acres of crop land (harvested acres and fallow) in Kansas, with only around 7 million acres under no-till, there is a potential to convert around 23 million crop acres to no-till. Assuming that no-till would result in about 2 gallons or $4.50 less fuel usage per acre than competing tillage systems, no-till offers the potential to reduce diesel usage for Kansas agriculture by around 46 million gallons annually, which is valued at about $103.5 million. It is possible the pace of no-till adoption could be accelerated somewhat if provided a few well-positioned incentives.

The second opportunity to make a difference to energy consumption in Kansas agriculture via public expenditures may surround the area of soil testing. Soil testing is a well-established technique that results in improved fertilizer use efficiency and likely would result in reduced fertilizer usage at the same time. We believe that subsidizing a portion of farmers' costs associated with soil sampling will substantially increase use of this technique, especially if it is coupled with a strong educational effort to aid interpretation of soil tests and to guide fertilizer rate decision making.

Third, it is possible that electricity, as an energy source for pumping irrigation water, will offer an economic advantage to diesel and natural gas for a number of years to come, and perhaps for decades if the price difference widens between stationary energy sources (e.g., coal, methane, wind) and energy sources that are more suitable for motorized vehicles (e.g., diesel and gasoline). But, conversion of irrigation pumping plants from one fuel source to another requires an investment. So, there may be policies that can encourage, or at least not hinder, such conversions.

Fourth, regardless of what energy-related policies might be forthcoming in agriculture, it is most clear that they should be heavily coupled to increased educational effort. In fact, it is possible that using taxpayer funds to increase education regarding existing agriculture-related energy decisions might be an efficient approach to the energy problem.

Finally, we especially urge caution in the area of promoting cellulosic ethanol production based on crop residues. First, the technology to be used has yet to be perfected. Second, since markets for such residues are immature at this time, and since such residues routinely are considered waste products, it is tempting to believe that they can be acquired inexpensively, say for only the cost of harvesting and transportation. But, with increasing adoption of no-till farming practices it is increasingly becoming clear that crop producers might value crop residues quite highly, especially in the western part of the state. For example, we perceive increasing reluctance on the part of no-till crop producers to allow livestock grazing of crop residues, indicating such residues may be more expensive to acquire than previously believed. A significant rise in residue values could render some residue-dependent cellulosic ethanol plants infeasible, even with substantial subsidies. So, substantial investment in cellulosic ethanol production by taxpayers in the form of subsidies should not be undertaken without much more detailed analysis.

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