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The
Kentucky Institute
for the
Environment
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Development

Our Energy Future

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The Kentucky Institute for the Environment and Sustainable Development (KIESD) was created in July 1992 within the Office of the Vice president for Research, University of Louisville. The Institute provides a forum to conduct interdisciplinary research, applied scholarly analysis, public service and educational outreach on environmental and sustainable development issues at the local, state, national and international levels.

KIESD is comprised of eight thematic program centers: Environmental Education, Environmental Science, Environmental Law, Sustainable Urban Neighborhoods, Pollution Prevention, Environmental and Occupational Health Sciences, Environmental Policy and Management, and Environmental Engineering.

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Cover Photo: Solar street light installation: Louisville, Kentucky

The Road to Future Fuels and Vehicles

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As we pull into our local gas stations, glancing quickly at the signs overhead, many of us might be wondering if today's price for a gallon of gasoline will be the same as the one that was on the pump yesterday—or with any luck, lower. And some of us might be thinking about how much more we pay for gasoline and diesel fuel than the price shown on the pump. For example, because we now import about 60% of our crude oil, we are vulnerable not only to price-per-barrel fluctuations but also to costly disruptions in supplies and to political instabilities that affect our entire economy.

We also pay a price in terms of our environment and health. More than 30% of the heat-trapping greenhouse gases in our air come from burning fossil fuels for transportation, according to the International Center for Technology Assessment and other sources. In addition, ground-level ozone, which forms when hydrocarbons and other transportation-related emissions react with sunlight, and the fine particulate emissions which result from burning fossil fuels are suspected to aggravate or even cause certain lung diseases in children and adults, according to the American Lung Association.

At least 240 million U.S. vehicles—one for 80% of all the men, women, and children in the country—were registered in 2004, according to U.S. Department of Transportation statistics. It takes a lot of fuel to keep all those wheels moving. The U.S. Department of Energy (DOE) reports that the average American household uses more than 1,000 gallons of gasoline each year. And gasoline makes up nearly half of the 20 million barrels of petroleum products that we consume each day to travel more than 7 billion daily miles. Clearly, the nation has been relying heavily on petroleum to meet its transportation needs.

In February 2006, President Bush addressed many of these issues when he announced the Federal government's Advanced Energy Initiative. In addition to calling for greater reliance on several different renewable energy technologies, the initiative increases funds for research and development (R&D) in advanced batteries for hybrid vehicles, electric cars, and hydrogen-powered vehicles as well as for alternative transportation fuels, particularly ethanol.

In partnership with both public and private organizations, the scientists and engineers at DOE's National Renewable Energy Laboratory (NREL) and other laboratories are assisting in this effort by conducting R&D in clean, innovative fuel and vehicle technologies. These will help to reduce our nation's dependence on imports, enhance our energy security, and improve the quality of our air.

In this article, we review where we are now in terms of government-funded R&D, government-industry partnerships, and market readiness, as well as where we plan to be in the next few decades. This R&D has been, and will continue to be, key to developing tomorrow's fuel and vehicle technologies. These environmentally friendly technologies include advanced hybrid electric vehicles, plug-in hybrids, biodiesel and other biofuels, ethanol from cellulosic biomass, advanced batteries, hydrogen fuels, fuel cells, and more.

Where We Are Now

Today, ethanol, biodiesel, flexible-fuel vehicles, and hybrid-electric vehicles are all available in some form, though in limited quantities, in the United States. The Energy Policy Act of 2005 establishes a renewable fuels standard requiring total U.S. transportation fuel sales in 2012 to include 7.5 billion gallons of renewable fuel, and current estimates from the Renewable Fuels Association indicate that we are now producing enough alternative fuel to meet that goal. So we should see steady increases in the use of biofuels and the vehicles that run on them.

Currently, more than 30% of U.S. gasoline is E10—gasoline blended with 10% ethanol. About 90% of the U.S.-produced ethanol in this blend is made from the starch and simple sugars in corn. The availability of E10 depends on local prices and air-quality regulations. In some parts of the country, particularly the Midwest, consumers can also purchase E85—an ethanol blend containing 15% gasoline. But E85 can be used only in "FFVs"—flexible-fuel vehicles that run on either gasoline or ethanol blends.

U.S. automakers have been manufacturing flexible-fuel versions of several models, such as the Chevrolet Suburban sport utility vehicle, the Dodge Ram series 1500 pickup, and the popular Ford F150 truck. In fact, about 4 million to 5 million FFVs are estimated to be on the road today. However, strange as it may seem, most FFV owners do not know that they have one. A recent survey of FFV owners by an ethanol producer found that 70% were unaware that they owned a vehicle that can run on E85. Those who do know might wonder where they can purchase this fuel; fewer than 600 service stations offered E85 in January 2006, according to DOE. A tax credit in the Energy Policy Act of 2005 provides for developing an alternative fuel infrastructure, and this could help increase the number of E85 stations. At least one U.S. automaker, GM, has stepped up public information efforts regarding FFVs and E85.

Increases in traffic and air pollution are becoming major problems in many urban areas, such as this expressway in Denver, Colorado (photo by Warren Gretz).

DOE is helping to expand the market for alternative fuels and vehicles through the Alternative Fuels Data Center (www.eere.energy.gov/afdc), a searchable electronic library of technical data, publications, and information on advanced vehicles and alternative fuels. One of its popular features is an Alternative Fuel Station Locator that provides maps of U.S. fueling stations.

Though they are still the new kids on the road, hybrid-electric vehicles—HEVs—are becoming increasingly popular; about 1.3% of light vehicle sales in 2005 were HEVs, according to DOE. To improve fuel efficiency and performance, HEVs combine a small but efficient gasoline engine with an electric motor. Estimates indicate that if everyone drove an HEV, we could reduce our petroleum consumption right now by at least 20%, and perhaps as much as 40%, though that might not happen any time soon. Researchers are continuing to investigate ways to improve the performance of HEV components and to work with industry to put improvements into practice.

One key to making HEVs more practical is to incorporate low-cost, integrated power electronics. Researchers at the DOE national laboratories and in industry are working on advanced components that condition the electrical signal between the power generation unit (a battery or fuel cell) and the electric motor to improve cost effectiveness and performance. And R&D is being conducted in advanced hybrid components and systems for heavy duty-vehicles that consume much more fuel per vehicle than passenger vehicles. The results of this work could increase the fuel efficiency of large trucks as much as 100%.

For diesel-powered vehicles, one promising renewable fuel option is B20—a blend consisting of 20% fatty acid methyl ester (biodiesel) and 80% petroleum diesel fuel. Biodiesel can be made from any animal or vegetable fat or oil and be used in just about any diesel vehicle. It can reduce environmental emissions dramatically, depending on the blend. U.S. biodiesel is produced largely from soybean oil and recycled restaurant cooking oil.

Researchers have been working to reduce the technical barriers that stand in the way of producing biodiesel on a large scale and using it widely. Their work will help to make biodiesel more cost-competitive, reliable, and plentiful.

Where We Should Be in 5 to 10 Years

Mid-term technology options like cellulose-based ethanol and "plug-in" hybrid-electric vehicles are in the latter stages of development. But in general, they are still too expensive to compete effectively in the marketplace. So, researchers and engineers are working to improve them so they can be cost-competitive and widely available.

The starchy material in corn kernels now used to produce most of our ethanol is only a small fraction of the biomass (e.g., the plant-based materials and organic waste products) that could be used. Two other components of plants, cellulose and hemicellulose, are also made of sugars, but those sugars are linked in long polymer chains that are not easy to convert to ethanol. Advanced biomass conversion technologies are needed to break down the polymer chains into their component sugars and then ferment them to alcohol to produce cellulosic ethanol.

This is a good way to turn ordinary, low-value plant materials—such as corn stalks, sawdust, wood chips, wastepaper, and fast-growing trees and grasses—into ethanol and other valuable fuels and chemicals. Cellulosic ethanol could do much to reduce our dependence on imported oil and curb U.S. greenhouse gas emissions. The technology works, but it's still too expensive. So, national laboratories and private-

This fuel dispenser at a Santa Fe, New Mexico, station offers B20 biodiesel, E85 for flexible-fuel vehicles, and E10 for any vehicle that runs on gasoline (photo courtesy of Charles Bensinger and Renewable Energy Partners of New Mexico).

sector groups alike are developing more cost-effective production methods.

For many years, researchers at NREL have been developing technologies that produce ethanol and other valuable fuels and chemicals from cellulosic biomass. They have conducted much of the basic research underpinning a process in which a dilute acid is used to break down hemicellulose. In a step known as enzymatic hydrolysis, enzymes break cellulose down into its component sugars. While NREL focused on the process, its research partners made great strides in reducing the cost of the enzymes. Four years ago, these enzymes were too expensive to be used in a cellulosic ethanol process. Today, enzymatic hydrolysis is the lowest cost option for hydrolyzing cellulose to glucose.

In NREL's alternative fuels pilot plant, researchers continue to partner with companies in the vanguard of this emerging industry to validate new biomass-to-ethanol technologies. The technologies, though promising, still need to be simpler and less expensive; for example, the capital equipment and sophisticated processing steps required are costly. But researchers hope to ultimately enable industry to produce this fuel for only about $1.00 per gallon, which will make cellulosic ethanol competitive with ethanol from starch and perhaps even with gasoline.

Fuel-efficient hybrid electric vehicles like this Toyota Prius were made part of the city's fleet in Plano, Texas (photo courtesy of the City of Plano).

Researchers and their partners are also working to help industry produce fuels, chemicals, and other products in the biorefineries of the future. These refineries would manufacture a variety of products from biomass—much as today's oil refineries and petrochemical plants do from petroleum. Some biorefineries might feature processes for gasifying or liquefying biomass and converting the resulting synthesis gas to diesel substitutes and other fuels. In fact, some biomass gasification and pyrolysis plants are already up and running. In other biorefineries, certain plant sugars and intermediates could be made into high-value products for various markets, and the remaining sugars could be fermented to ethanol fuel. Eventually, the lignin in plants might also be converted to valuable fuels and chemicals.

Another option being explored is known as "green diesel." Biodiesel contains molecules produced by trans-esterifying triglycerides with methanol. Green diesel consists of paraffin molecules produced by hydrogenating triglycerides using a conventional petroleum refining process. Green diesel has a very high cetane number, which means it ignites fairly quickly after injection, and a low pour point, the lowest temperature at which a fuel will pour. Thus, it is a high-quality diesel fuel that is totally compatible with petroleum diesel.

In addition to producing transportation fuels from biomass, we can also put electricity to work to reduce our petroleum usage. Electric vehicles are clean and quiet, and there are already some vehicle recharging stations around the country. This vehicle technology could be fully renewable if the recharging stations provided electricity generated by wind, solar, and other renewable energy technologies.

Today's HEVs do not depend on an external means of recharging their batteries. Taking HEV technology a step further, hybrids are being developed that can be plugged in to conventional outlets, thus storing electricity for later use. By adding extra batteries to an HEV and a means to plug them in, we could drive most of a typical day on domestic electricity and still have fuel in the tank for longer trips. But today's batteries are heavy and expensive. So, researchers are working on advanced batteries, drive trains, and other vehicle components that can be used cost-effectively in conventional, hybrid-electric, and plug-in hybrid vehicles. They are also exploring ways to make plug-ins reversible, so that excess power stored in the vehicle would go back into the utility grid, to the owner's credit.

Where We Need to Be in 20 Years

Taking all this another step further, it is not hard to imagine future "renewable communities" that would feature plug-in hybrids, zero-energy homes, and various renewable energy technologies. These might not be featured on a television "reality show" today, but they are certainly part of an attainable vision for tomorrow.

In terms of alternative fuels, DOE has established a "30 by 30" goal, which means that ethanol will make up at least 30% of our nation's transportation fuels by 2030. Research in other long-term technology options, such as renewable-based hydrogen fuel and fuel cells, is also important, especially in terms of the basic science underlying those technologies. Hydrogen fuel cells for transportation and hydrogen vehicles are so promising that California and some states on the Atlantic Coast are already setting up prototype hydrogen fueling stations to test new technologies as they develop.

Producing hydrogen by steam-reforming natural gas, today's most economical method, would increase our reliance

In a biofuels laboratory at NREL in Colorado, researchers use a reactor built by Metso Corp. to pretreat hemicellulose for conversion to ethanol and other valuable chemicals (photo by Warren Gretz).

on an increasingly scarce fossil fuel. So, researchers are pursuing a renewable option: gasifying biomass and reforming the resulting syngas to hydrogen through a water-gas shift reaction. They are also exploring the use of cost-effective solar, wind, and other renewable technologies to electrolyze water to produce hydrogen. And they are pursuing both photoelectrochemical and photobiological technologies that could produce hydrogen directly. In the photoelectrochemical approach, the absorption of light energy triggers the splitting of a water molecule in an electrolyte. The photobiological approach takes advantage of the fact that certain microorganisms—such as green algae—naturally split water to produce hydrogen as a way to dissipate the energy they do not need in certain circumstances.

Fuel cells are complex, but they could revolutionize the way we power our nation and provide cleaner, more efficient alternatives to the burning of fossil fuels. However, many challenges must be overcome before fuel cells will be competitive in the marketplace. Therefore, R&D is focusing on improving the performance and cost effectiveness of fuel cell systems, subsystems, and components.

A basic problem underlying our dependence on imported oil is that today's cars and trucks are not very efficient. Even a hybrid-electric vehicle uses less than one-fifth of the energy—fossil or renewable—that goes into it. Because several different configurations for hybrid-electric and fuel-cell vehicles are possible, and numerous alternative technologies could be used in key vehicle components, computer modeling is critically important.

Using models such as ADVISOR (the Advanced Vehicle Simulator), which is now commercially available, we can simulate potential vehicle technologies and combinations of technologies in days or weeks. This is in marked contrast to the months or years it takes to build and test prototypes. Computer tools can help to show automakers and equipment providers the most promising avenues to pursue to reduce the environmental impacts of vehicles and improve their efficiency and performance. NREL has also developed a unique thermal comfort manikin known as ADAM (the Advanced Automotive Manikin), which is designed to help the automotive industry design smaller, more efficient climate-control systems in vehicles.

In Conclusion

The ultimate goal of this research, development, and deployment is to enable U.S. industry to produce advanced, low-emission, economically competitive fuels and vehicles that will meet our future transportation and environmental needs. Pursuing all options, we are well on our way to greater energy independence and a healthier future.

This article was adapted with permission from portions of the cover story in the National Renewable Energy Laboratory 2005 Research Review*; please see www.nrel.gov/research.html for more information. The authors wish to thank all those at NREL and DOE who provided valuable expertise and guidance. NREL is operated for DOE by Midwest Research Institute and Battelle under contract no. DE-AC36-99-GO10337.*

Researchers like Maria Ghirardi, NREL, are working on ways to use green algae to produce hydrogen for use in clean energy technologies like fuel cells (photo by Warren Gretz).

This nonpolluting ThunderPower fuel cell bus was developed by Thor Industries and ISE Research and demonstrated recently in a transit system in southern California (photo courtesy of SunLine Transit Agency).

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Selected Programs and Policies for Biofuels in Kentucky

The Commonwealth of Kentucky is actively supporting the development and use of alternative fuels. Regulations include the Kentucky Energy Security National Leadership Act of 2006, which directs the Office of Energy Policy to develop and implement a strategy for producing transportation fuels and synthetic natural gas from biomass resources. And, according to the DOE Alternative Fuels Data Center, the Kentucky Transportation Cabinet is promoting the use of clean E85 in its fleet of flexible fuel vehicles, among other measures. The Data Center also notes that Kentucky has established an income tax credit of $1.00 per gallon for biodiesel producers and blenders, with a total annual credit cap of $1.5 million. In addition, a number of initiatives, grants, and matching-fund programs with the Federal government support the production of renewable fuels.

In 2005, the Kentucky Office of Energy Policy announced the formation of a Rural Energy Consortium. This consortium fosters private sector-national laboratory partnerships that facilitate research in efficient energy use, renewable energy production, and other activities important to Kentucky's agricultural sector, rural communities, and related industries. In 2006, Governor Fletcher's office announced funding for seven new research projects that focus on energy research and development and are being conducted at the University of Louisville and the University of Kentucky. Four projects directly relate to biofuels, and one involves developing materials to help produce hydrogen and electricity from water and sunlight. In addition, new biodiesel plants already up and running in Kentucky include the Griffin Industries Biodiesel Plant in Butler and a large plant in Owensboro. The Owensboro Grain Biodiesel plant could produce as much as 45 million gallons of biodiesel per year, according to news sources.

Kentucky's Renewable Energy and Energy Efficiency Programs

John Davies, Director
Gregory Guess, Assistanat Director
Division of Renewable Energy and Energy Efficiency
Kentucky Office of Energy Policy

Americans are once again being shocked by higher energy prices. During the summer of 2006 we flirted with $3.00-a-gallon prices for gasoline. The press reports that sales of large trucks and SUVs are down; people are shopping for hybrids and other cars that get better gas mileage. There are even reports of people torching their gas-guzzling SUVs — they can't afford the gas and they need to collect the insurance money because they are "upside down" on their payments.

Crude oil prices have been above $76/BBL (a barrel is 42 gallons) several times this year – and that's after trading in a $10 to $20 price range during most of the period from 1986 to 1999. Crude oil even dipped to almost $10 as recently as 1998!

We have seen natural gas prices perform similar gyrations in the market. After hovering around $2.00/MMBtu (million Btu) for most of the period from 1980 to 1999, wholesale prices exploded to $15/MMBtu in December of 2005. At press time, the price had dropped to the $7 range – still well above historical levels.

Electricity prices have increased also, though not quite as dramatically, that is, if you don't count the spikes in California during the summer of 2000 through the summer of 2001 that saw wholesale electricity jump from around $12/MWh to above $200/MWh, while briefly "gusting" to over $500/MWh. A similar phenomenon took place in the summer of 1998 in the upper Midwest when electricity that had been trading at $50/MWh spiked briefly to $7,500/MWh. Whether because of market manipulation, panic buying on the part of inexperienced traders, inadequate transmission systems or the confluence of events creating a "perfect storm," it is clear that electricity price increases of this magnitude threaten our economic well-being. Even without these "perfect storm" events, government and industry predict higher electricity prices due to increased demand and the infrastructure needed to support that demand, and we jeopardize the health of our economy with higher natural gas and petroleum prices.

But these price shocks alone are not the only reason to be concerned. After all, we experienced similar price shocks some 30 years ago when crude oil prices increased dramatically as a result of the Arab Oil Embargo.

Our dependence on foreign oil has other serious consequences. Our balance of payments suffers, in part, because we are exporting nearly $300 billion annually to pay for imported oil. We are preparing to import significantly more natural gas in the form of liquefied natural gas or LNG. Plans to build some 40 LNG plants have been announced (compared to only 5 in operation in the U.S. now). While not all of these will be built, it does indicate how the market perceives the magnitude of the increased demand in the coming years.

Of course, our dependency on (frequently unstable) foreign sources of supply for oil (we're importing almost twice as much crude oil as we produce domestically) leads to profound national security concerns. The U.S. Department of Energy predicts that the percent of oil we import from foreign sources will increase from 58 percent in 2004 to 68 percent in 2025. Many would say that our last decade-and-a-half of military involvement in the Middle East (Gulf War, War in Iraq) is a direct result of this dependency.

We know too that dependence on fossil fuels has significant environmental impacts, from smog in most of our large population centers to the increasing threat of global climate change.

Most would agree that our domestic reserves of petroleum are too small to offer long term independence from oil imports. And, while we have several hundred years of coal supply available right here in the United States, we still are not able to economically convert it to a clean liquid or gas that we could use conveniently in our homes and cars – although we are moving in that direction. Moreover, techniques like coal-to-liquids and coal-to-gas don't solve the "carbon problem" driving global climate change; nor do they address the environmental concerns associated with mining operations.

Increasing concerns over greenhouse gases and CO2 emissions from fossil fuels will drive new regulation and mitigation responses. These efforts will place upward pressure on electricity and fuel prices strengthening energy efficiency and renewable energy's position as the "least-cost" option.

Expanding economies, particularly in China and India, will continue to put pressure on the demand side of the energy equation. Sustained economic growth in these countries whose populations want the same lifestyle (largely supported by abundant energy consumption) that they see in the West, particularly in the U.S., will put increased pressure on prices and supplies.

Meanwhile, the U.S., with 5 percent of the word's population, consumes 25 percent of the world's energy. And that is not because we are manufacturing 25 percent of the world's goods! We use twice as much energy per person as Europeans, eight times as much energy per person as China and 15 times as much per person as India. Simply put, we are energy intensive.

Fluctuating but generally increasing energy prices, steady increases in worldwide energy demand particularly in developing economies, increased competition for finite fossil fuel resources and the continued threat of global climate change presents overall a pretty sobering picture.

But there is a promise of a better future – however it comes with a challenge. It requires that we change the way many of us have viewed the world in the past, and it requires that many of us change the actions we take as a result the way we see the world in the future. The other piece of good news is that our past inefficiencies are creating tremendous opportunities for us to be more efficient.

A sitting U.S. Vice President once said, "Conservation may be a sign of personal virtue, but it is not a sufficient basis all by itself for sound, comprehensive energy policy." He is correct; conservation (or better, energy efficiency) is not enough by itself, just as increased production is not enough by itself. However, any path to energy independence must include aggressive, cost effective and sustainable energy efficiency and renewable energy practices and technologies.

The first 12 recommendations in Kentucky's comprehensive energy strategy (see Figure 1) address the energy efficiency and renewable energy actions that state government should take. These recommendations also form the basis for program design and implementation by the Governor's Office of Energy Policy (GOEP - see Figure 2).

The strategy points out that there are significant opportunities for energy efficiency and renewable energy in Kentucky. Opportunities for energy efficiency stem from the fact that we are an energy intensive state. Our historically low electricity prices have encouraged us to use more energy. The combination of low prices and high demand results in relatively high energy bills. For example, although our electricity rates are 16 percent lower than Indiana's, Kentuckians paid only four percent less on their electric bills. Kentuckians should not only benefit from the lowest electricity prices in the nation but also the lowest electric bills.

ENERGY STRATEGY

Governor Ernie Fletcher released *Kentucky's Energy – Opportunities for Our Future: A Comprehensive Energy Strategy* in February 2005. State government energy policy is guided by the strategy which is based on three principles:

- Maintain Kentucky's low-cost energy.
- Responsibly develop Kentucky's energy resources.
- Preserve Kentucky's commitment to environmental quality.

The strategy contains 54 recommendations that address

- Energy Efficiency
- Renewable Energy
- Low Cost Electricity
- Coal
- Natural Gas
- A Perpetual Commitment.

The Governor's commitment to the development and implementation of a strong, effective and comprehensive energy policy was reflected in the make up of the Commonwealth Energy Policy Task Force. The seven-member body included five Cabinet secretaries and two legislators.

To review the strategy, go to www.energy.ky.gov.

Figure 1

Kentucky also enjoys a strong and untapped renewable energy opportunity that we have just begun to develop. This past year we've seen the groundbreaking for an additional 50 million gallons per year of biodiesel production, and our only ethanol plant (in Hopkinsville) has recently increased its production capacity from 24 to 33 million gallons per year. Additionally, efforts by our universities to find cost-effective applications for biomass and solar energy will help develop other renewable energy markets in Kentucky.

Renewable Energy and Energy Efficiency (RE3) Program Design

GOEP promotes and encourages sustainability in two ways. First, GOEP supports research and analysis of technolo-

GOVERNOR'S OFFICE OF ENERGY POLICY (GOEP)

GOEP's predecessor agency, the Kentucky Office of Energy Policy (KOEP) was established in 2005 as a result of Governor Fletcher's comprehensive energy strategy. An October 2006 Executive Order transferred the KOEP to the Governor's office and renamed the agency. GOEP has the mission to oversee the implementation of 54 recommendations outlined the energy strategy.

GOEP is a consolidation of the former Kentucky Division of Energy and the Kentucky Coal Council. The Kentucky Division of Energy is now the Kentucky Division of Renewable Energy and Energy Efficiency. The Kentucky Coal Council is now the Division of Fossil Fuels and Utility Services. The Executive Order also established the Division of Research, Development and Demonstration.

The Division of Renewable Energy and Energy Efficiency encourages energy efficiency in all sectors of Kentucky's economy and promotes the use of renewable energy where it is cost effective.

The Division of Fossil Fuels and Utility Services helps to increase the economic opportunities and benefits of fossil energy to Kentucky citizens and industry. This is done through the expansion of current markets and development of new markets for Kentucky's coal, natural gas, petroleum and oil shale.

The Division of Research, Development and Demonstration is responsible for the program developed by the Governor and the Legislature to increase energy research and development capacity at our public universities and foster an intellectual exchange between our schools, national energy laboratories and private industry.

For more information, visit our Web site at www.energy.ky.gov.

Figure 2

gies and processes that are sustainable, or that move us toward being more sustainable than current practice. For instance, while we are not yet at the stage where we can design and build a school that is truly sustainable (one that generates and supplies ALL of its energy needs cost effectively), we can certainly build schools that use significantly less energy than most of the new schools being built in Kentucky today.

Governor Fletcher recognized GE Consumer & Industrial of Louisville, Toyota Motor Manufacturing North America of Erlanger, the Governor's Office of Energy Policy (GOEP) and the McCreary County Community Housing Development Corporation for their outstanding contribution to the ENERGY STAR program.

Second, GOEP places an emphasis on developing programs that are sustainable. This relates not so much to the message we deliver as the way we get the message delivered. The development of partnerships is the key element that enables us to more effectively leverage our influence. These partnerships not only increase our effectiveness, they offer the benefit of potential long-term involvement by our partners in delivering the same or similar message we would deliver ourselves.

Our partnerships are with federal agencies, state agencies, universities, non-profits and other organizations. Sometimes we are able to channel grant funds to our partners for the work we do together. At other times, people partner with us because we have similar goals, creating a community of interest that multiplies our capabilities and allows us to accomplish more together than each could acting on its own. Over the years, our partnerships have proven effective and we strive to work with all sectors of Kentucky's economy.

Programs, Partnerships and Activities

GOEP's programs, partnerships and activities may be broadly divided into two general categories – energy efficiency measures and renewable energy.

1. Energy Efficiency

KEEPS (Kentucky Energy Efficiency Program for Schools). GOEP has a grant with the Kentucky Pollution Prevention Center (KPPC) at the University of Louisville that pays for a program manager to work with K-12 schools and universities to improve energy efficiency and reduce costs. Last year, Kentucky's publicly supported K-12 schools spent $118 million on energy for buildings. We should ultimately be able to save 10 to 15 percent of this by implementing strong, low-cost/no-cost energy efficiency programs. Additional savings can be realized with capital investments. This is the first year for KEEPS, which is being operated on a pilot basis with three


Groundbreaking Ceremony, Owensboro Grain Biodiesel, LLC.

school systems and three universities as participants. KPPC will provide engineering and technical support to the participants and the KEEPS program manager will "coach" each school's energy team to guide them to implement the best measures for their school.

NEED (National Energy Education Development Project). GOEP has a grant with the Kentucky NEED Project to support energy education activities in Kentucky. NEED, established in 1980 and with programs in 46 states, provides non-biased, grade-appropriate, energy curriculum materials that, in Kentucky, are correlated to the Kentucky program of studies. NEED conducts workshops for students and teachers that enables them to transfer their new knowledge to others back at their school (NEED uses a "Kids Teaching Kids" philosophy). In addition, Kentucky NEED is a key partner in the planning and production of the annual High Performance Schools workshop and is the curriculum partner for elementary and secondary schools participating in the KEEPS program.

ENERGY STAR® Program. ENERGY STAR is a voluntary program backed jointly by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) designed to help Americans save money and protect the environment through superior energy efficiency. ENERGY STAR "brands" a variety of electronic appliances, computers and other equipment identifying them as being the most energy efficient of their type on the market. For businesses, ENERGY STAR partnership offers a proven energy management strategy that helps in measuring current energy performance, setting goals, tracking savings, and rewarding improvements. For many types of buildings, including new homes, ENERGY STAR offers a means of certifying that the building exceeds the energy performance of a similar building that just meets energy code requirements. ENERGY STAR provides a wealth of resources for business and individuals who need guidance on how to become more energy efficient.

GOEP has a grant with the University of Kentucky that supports a UK Cooperative Extension Agent who travels across the state promoting ENERGY STAR at more than 50 events including home and garden shows and electric cooperative annual meetings, as well as a large exhibit at the Kentucky State Fair. This grant also helps to educate other UK Cooperative Extension Agents about ENERGY STAR and energy efficient practices. These agents, in turn, will take the energy efficiency message to Kentuckians in every county.


Governor Ernie Fletcher proclaimed October 4, 2006, as ENERGY STAR Change a Light, Change the World Day in Kentucky.

So far Kentucky has four ENERGY STAR certified schools. Third party verification shows that these schools use at least 30 percent less energy than conventionally built schools.

Kentucky became only the fourth state in the nation to be declared an ENERGY STAR partner by the U.S. DOE and the U.S. EPA. GOEP was recently honored with a 2006 Excellence in ENERGY STAR Outreach award by the U.S. DOE and U.S. EPA.

2. Renewable Energy

Kentucky Rural Energy Consortium (KREC). GOEP is a founding member of the Kentucky Rural Energy Consortium. GOEP, the University of Louisville, the University of Kentucky and 16 other partners joined in 2004 to establish KREC with the mission to sponsor research and development of renewable energy resources, bio-based products and energy efficient technologies across the Commonwealth. To date KREC has awarded over $1.3 million dollars to our public universities for the purposes of conducting research and building intellectual capacity in the fields of renewable energy and energy efficiency. Projects funded include research in solar energy, biomass, hydrogen and energy efficient buildings. KREC is supported with federal funds through the assistance of Kentucky's Congressional delegation in Washington D.C.


High Performance School in Kenton county.

KCFC (Kentucky Clean Fuels Coalition). GOEP supports KCFC through grants designed to promote the adoption and use of clean fuels throughout the Commonwealth. These grants have supported biofuels infrastructure, biodiesel buy-down for public schools, clean fuels infrastructure, student education and public outreach. KCFC is a non-profit organization whose goal is to improve air quality and support economic development across Kentucky by promoting the use of clean fuels. It is affiliated with the U.S. Department of Energy Clean Cities program. KCFC has received numerous national awards and is recognized as one of the nation's most successful Clean Cities programs.

Research Grants. In 2005, the Governor and the Kentucky General Assembly established the Energy Research, Development & Demonstration Program to benefit the citizens of the Commonwealth by encouraging our public universities to conduct energy research, development and demonstration projects. GOEP was given the responsibility to manage this program. As part of this initiative, GOEP awarded nearly

OTHER PARTNERSHIPS AND PROGRAMS

GOEP is involved with other partnerships and programs that play an important role in promoting a more sustainable energy future for Kentucky.

- GOEP promotes the use of Energy Savings Performance Contracts (ESPCs) for state government buildings and has worked with the Finance Cabinet to support cumulative awards of some $45 million, which are estimated to result in savings of $4.1 million annually. GOEP helped establish the Kentucky Energy Services Coalition (KESC) to promote the adoption of ESPC. Nationally, the Energy Services Coalition (ESC) is a nonprofit organization composed of a network of experts from a wide range of organizations working together at the state and local level to increase energy efficiency and building upgrades through energy savings performance contracting. Energy savings performance contracting enables building owners to use future energy savings to pay for up-front costs of energy-saving projects, eliminating the need to dip into capital budgets.
- GOEP is a founding member of the Kentucky Chapter of the U.S. Green Buildings Council – a national non-profit group that promotes the design, construction and renovation of sustainable buildings. USGBC developed the LEED® (Leadership in Energy and Environmental Design) certification process for buildings.
- GOEP is working with the Kentucky Environmental Education Council, the Kentucky Department of Education and other agencies and private organizations to develop a "Green and Healthy Schools" program designed to recognize K-12 schools for their efforts to move toward greater sustainability.
- GOEP produces an annual two-day workshop addressing high performance schools. The workshop typically draws from 140 to 170 school officials, architects and engineers and features nationally recognized speakers addressing topics that move us toward better buildings and better learning environments.
- During the last several years, GOEP has funded the production of at least five workshops each year for the building industry that focus on high performance homes (1-day sessions) or commercial buildings (2-day workshops).
- GOEP just received a two-year grant from the U.S. Department of Energy (DOE) to help teach builders and the public about the benefits of energy efficient buildings. The $485,000 award will fund a partnership with the University of Kentucky's College of Agriculture (which is providing a $140,000 match) to develop a program curriculum focused on design and construction of energy efficient homes. UK's Cooperative Extension Service will help spread awareness of energy efficient building practices to the public, specifically homeowners. The Kentucky Community and Technical College System (KCTCS) will also help develop curriculum and training for their classes as well as community outreach programs.
- GOEP actively supports ENERGY STAR campaigns to increase consumer awareness and understanding about energy efficiency and its impact on the environment. In 2005, GOEP worked with Kentucky's First Lady Glenna Fletcher to encourage all Kentuckians to take the "ENERGY STAR Change a Light, Change the World" pledge. This year, Governor Fletcher proclaimed Oct 4th as "ENERGY STAR Change a Light, Change the World Day" in Kentucky.

Figure 3

$513,000 in renewable energy grants for improving the processes for biodiesel, investigating new enzymes for the production of ethanol, resolving technical obstacles in the commercialization of briquetted fuels from coal and biomass, and increasing the production of enzymes for biomass conversion to energy feedstocks. This research is expected to result in processes that enhance the productivity and profitability of Kentucky's biofuels industries including on-farm production of biomass materials.

Our energy future will be what we decide to make it. As this article and the others in this issue of Sustain clearly demonstrate, we are moving in the right direction to a brighter energy future.

John Davies serves as the Director for the Division of Renewable Energy and Energy Efficiency, Governor's Office of Energy Policy. In this capacity, he manages energy efficiency and renewable energy programs for the Commonwealth and works to develop public-private partnerships throughout Kentucky that support the adoption of energy efficiency and renewable energy technologies and practices.

Greg Guess, Assistant Director for the Division of Renewable Energy and Energy Efficiency, has been involved with energy policy and programs since the Arab Oil Embargo of the mid-1970s, both in state government and in the private sector where he was associate director of the Kentucky office for a major oil industry trade association. His current focus is on energy efficiency, particularly energy efficient and sustainable building design, construction and operation.

The Ethanol Buzz

Rajesh K. Dasari, Research Assistant and
R. Eric Berson, Assistant Professor
Department of Chemical Engineering, University of Louisville

A Brief History of Ethanol

Henry Ford's original 1908 Model T was powered by a four-cylinder, two-speed, 20 horsepower motor, had wheels made of wood, came standard equipped with oil lamps and a tube horn, sat three comfortably, and was originally intended to use ethanol as its primary fuel source. But even at a time when the entire automobile listed for $850 and achieved sound fuel economy at 25-30 MPG, economics dictated a switch to a gasoline powered engine.

Now, nearly 100 years later, ethanol as a transportation fuel is poised for a comeback, and the recent $70 per barrel oil price is not the only driving factor. The United States will benefit significantly from a diversified fuel energy supply for a variety of reasons that appeal to a variety of interests. Incorporating alternative energy fuel sources into the marketplace will reduce dependence on foreign oil, reduce the risk of price increases from the whims of OPEC quotas and progressively stringent domestic environmental regulations, improve environmental quality, and increase overall energy efficiency as technologies advance. And while there is uncertainty as to the amount of crude oil reserves remaining, one certainty is that there is not an indefinite supply. Most scenarios estimate about a 50-70 year supply depending on worldwide consumption rates.

So what are the viable alternatives to gasoline that can sustain our automobile culture? Most of the recent buzz centers on ethanol and hydrogen. Hydrogen, technically, is not a fuel in the same sense as gasoline or ethanol that undergoes a combustion process to generate power, but rather is a reactant in a fuel cell that generates electricity in an electrochemical conversion process. As such, efficiency is not limited by the constraints of the Carnot cycle which governs the efficiency of a combustion engine. The process is also very clean. The only products are heat and water, making it a very environmentally friendly option.

Then, why has hydrogen not yet caught on? The answer is mainly due to infrastructure and logistics of the reformation process. A reformer converts the hydrocarbons in a source such as methanol or natural gas into hydrogen which is then fed to the fuel cell. If reformation is to occur at a central location similar to an oil refinery, a network of pipelines crisscrossing the country will be needed to transport the hydrogen. The other option is to integrate the reformer into the fuel cell and automobile. The problem with this is the reformation process also produces gases other than hydrogen, leading to the need for a purification process which kills the efficiency of the fuel cell.

Ethanol, on the other hand, integrates nicely with the current infrastructure and automobile engine design. Blends such as a 90/10 gasoline-to-ethanol ratio (referred to as E10), where the ethanol is added as an oxygenator for the combustion process, are already widely available at the pump for use in all existing engines. Flexible fuel vehicles have now entered the marketplace, and with a roughly $200 modification to the engine, are designed to run on up to an 85 percent ethanol blend (E85).

Where does ethanol come from? A small percentage is synthesized from ethylene and used as a solvent in industrial applications such as pharmaceuticals, cosmetics, detergents, household cleaners, coatings, and inks. The vast majority, however, is produced by a fermentation process where yeast or bacteria metabolizes simple sugars into what can be used as fuel ethanol. The mature technologies in the United States use corn as the feedstock from which the sugars are obtained since the high starch content is easily degraded into simple sugars ready for fermentation. If the demand for ethanol grows enough, corn as a feedstock may not remain economical, either as a fuel source or a food source. This leads to the interest in producing ethanol from far cheaper cellulosic biomass sources, which happen to be the most plentiful form of biological material on earth, such as corn stover (the parts of the corn plant you don't eat: stalks, leaves, husks), wood chips, bagasse, switchgrass, and fast growing hybrid trees.

How do these crops become fuel?

Cellulose and hemicellulose, the primary components of biomass, are polysaccharides that can be converted to ethanol once their energy-rich sugars are released. Cellulose is a six-carbon polymer made up of repeating glucose units tied together by ß-glycosidic linkages (Figure 1). The high degree of

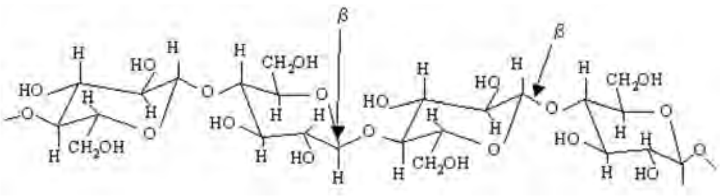

Figure 1. Linear chains of glucose linked in a crystalline structure to form cellulose.

hydrogen bonding between linear chains of cellulose is highly stable and resistant to chemical attack. In a hydrolysis reaction, which breaks the glycosidic bonds in the presence of water, cellulose is reduced to a cellobiose repeating unit, $C_{12}H_{22}O_{11}$, and ultimately to glucose, $C_6H_{12}O_6$, by enzymes as shown in the following reaction.

Cellulose → b-1, 4glucanase → Cellobiose → b-glucosidase → Glucose

Hemicellulose contains mostly five-carbon sugars (primarily xylose and some arabinose) and a few six-carbon sugars (galactose, glucose, and mannose). Hemicellulose is relatively easy to hydrolyze to its constituent sugars compared to cellulose because it is amorphous in nature due to its branched structure.

Lignin is the major noncarbohydrate present in biomass and is a highly polymeric substance with a complex, cross-linked, highly polypenolic structure. It encrusts the cell walls and cements the cells together. Lignin can be thought of as nature's way of protecting the valuable cellulosic material. Lignin is rich in energy, and when separated, can be burned for heat, converted to electricity, or gasified and converted to synthetic fuels by a Fischer-Tropsch (FT) process.

The three polymers, cellulose, hemicellulose and lignin, are assembled into a complex composite with the capability to morph and grow much like a liquid crystal. This composite provides plant cell walls with strength and resistance to degradation which makes the biomass a challenge to use as substrates for biofuel production. The conversion of corn to ethanol is a much easier process since the starch is a polysaccharide (repeating units of $C_{12}H_{16}O_5$) composed of long chains of linked α-glucose molecules (Figure 2). The α-1,6 linkages between the chains result in a branched highly amorphous structure, making it more readily attacked by enzyme systems and broken down into glucose.

The biomass to ethanol process requires several steps which will eventually occur in bio-refineries once the technologies advance to the point where the process becomes economical (Figure 3). The process begins with either a wet or dry milled grinding step for mechanical size reduction. The material is then pretreated, typically with dilute sulfuric acid at temperatures in the 160-200 °C range. The pretreatment is designed to release the cellulose from the protective lignin while maximizing the surface area on the cellulose that is available for attack by enzymes which breakdown the cellulose into simple monomeric sugars (Figure 4). The hemicellulose is amorphous in nature, so most of it breaks down to its simple sugars leaving the rigid cellulose behind for the enzyme action. The sugars are then fermented by yeast or bacteria into ethanol. Yeast has been the predominant microorganism for fermentation in the beverage industry, but recombinant type bacteria have recently been engineered that, unlike yeast, are capable of metabolizing both the five-carbon and six-carbon sugars and withstanding harmful byproducts of the pretreatment process. Purification to separate ethanol from the slurry is the final step.

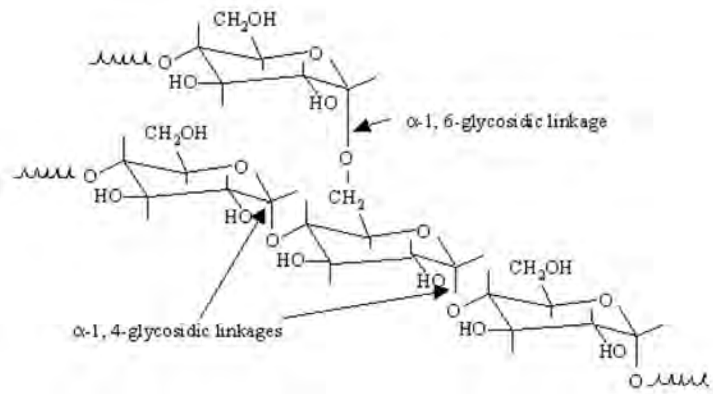

Figure 2. Linear chains of glucose linked in an amorphous structure to form starch.

The technology exists to make ethanol from biomass. The barrier, by and large, is economics. While the feedstock is cheap compared to the cost of corn, the process is more difficult and expensive as compared to ethanol production from corn. The costs for pretreatment and enzymes for cellulose hydrolysis remain prohibitive for the commercialization of biomass on a large-scale. While there has been significant progress, such as the development of lower cost enzymes and thermal and chemical resistant bacteria strains, considerable research and development is still needed to make the cellulose-to-ethanol bio-refinery a reality.

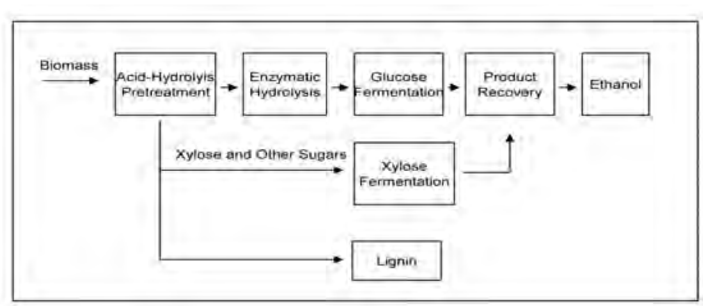

Figure 3. Biomass to ethanol process.

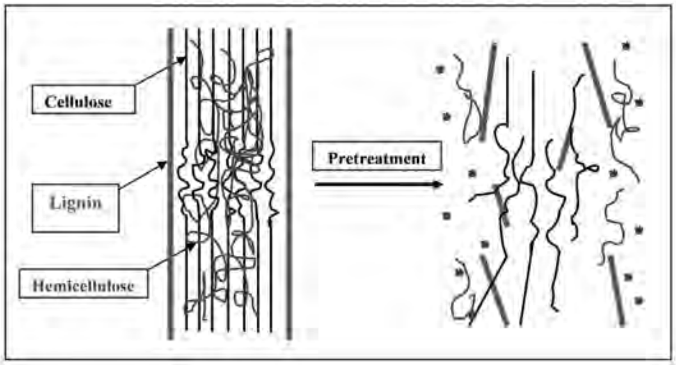

Figure 4. The result of pre-treating biomass. The hemicellulose, lignin, and cellulose are separated, making the cellulose fibers more accessible for attack by enzymes.

The net energy debate and the environment

While hard to measure, the cumulative sum of farming, collection, storage, and production of ethanol from biomass may actually result in a net energy loss. A Cornell study estimates between 29% and 57% more fossil energy is required for ethanol production than the ethanol fuel produced. The Department of Energy refutes this by a large margin, claiming that biomass produces 6.8 BTU's of energy for every BTU of fossil energy consumed. One irrefutable fact is that the energy content (BTU's per gallon) of ethanol is 30% less than that of gasoline, meaning if one gallon of gasoline moves a car 20 miles, one gallon of ethanol moves that same car just 14 miles.

Nevertheless, ethanol has its advantages or the industry would not have made it this far. The octane rating, a measure of a fuel's ability to resist knocks and pings, in an E10 blend is two to three points higher than in ordinary gasoline. And, of course, there are the environmental benefits associated with reduced toxic emissions.

Why exactly does ethanol burn cleaner? It is revealed in a life-cycle analysis that most CO_2 emissions from a tailpipe can be reduced by burning ethanol. This is because ethanol contains 35% oxygen by weight, and more oxygen results in more complete combustion and, hence, reduced harmful tailpipe emissions. An E10 blend reduces smog generating emissions like carbon monoxide by 25-30%, particulate matter by 50%, and volatile organic compounds by 7% as compared to gasoline. Ethanol is also free from toxic compounds such as benzene and sulfur that are present in gasoline. The CO_2 released by both the automobiles fueled by cellulosic ethanol and the bio-refineries where the ethanol is produced becomes part of a closed cycle since CO_2 is absorbed back by living plant material (Figure 5). In fact, growing biomass takes in more CO_2 for photosynthesis than is released into the atmosphere as opposed to the use of gasoline which leads to a net accumulation of CO_2 in the atmosphere.

How much ethanol is currently produced in the U.S.?

Gasoline consumption over the past 36 years in this country has increased from 12 billion gallons per year to more than 160 billion gallons per year. Currently, the U.S. imports about 60% of the oil we consume. The U.S. has only 3% of the world's known remaining oil reserves but accounts for 25% of global oil consumption. On the other hand, the U.S. is the second largest ethanol fuel producing country after Brazil. About four billion gallons of ethanol was produced in 2005 in this country from 101 corn ethanol facilities. As of September 2006, 42 more facilities were under construction and seven expansions underway. This will add 2.8 billion gallons of capacity to the current 4.8 billion capacity which will exceed the goal of the Energy Policy Act of 2005 for 7.5 billion gallons of ethanol produced per year by 2012. The four billion gallons of ethanol replaces just 2.5 % of the 160 billion gallons of gasoline the U.S. burns per year, and there is simply not near enough capacity or infrastructure for an immediate massive switch to E85.

Since biomass is a renewable source of energy, supply limitations depend on the amount of land available for harvest rather than the amount of underground reserves. Despite producing about 41% of the world's total corn supply, a multiple feedstock approach using biomass will likely be necessary. Different regions of the country could potentially support different feedstock. Most of the existing ethanol plants in this country are situated in the Midwest, close to the corn. Because shipping costs lead to higher prices for the end user, and the gas consuming population is denser towards the coasts, this is further motivation to develop cellulosic biomass-to-ethanol technologies.

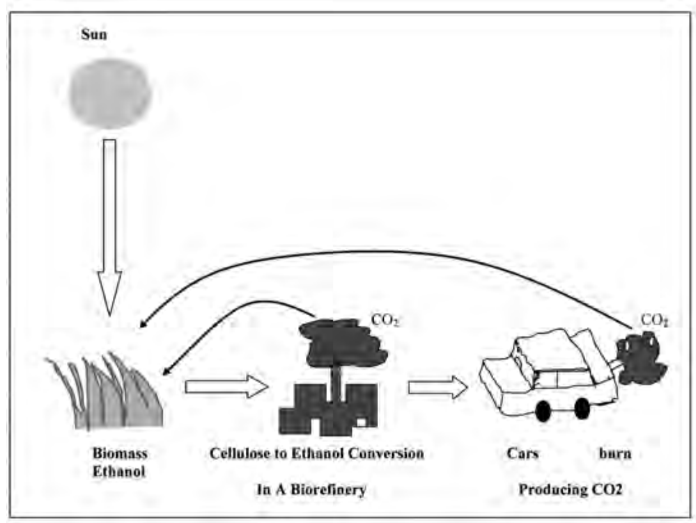

Figure 5. The closed carbon cycle when fuel is produced from biomass. CO_2 emitted from cars and biorefineries is absorbed back into plant material resulting in a zero net CO_2 contribution to the atmosphere.

Quoting Alexander Graham Bell from a 1917 issue of National Geographic, “We need never fear the exhaustion of our present fuel supplies so long as we can produce an annual crop of alcohol to any extent desired.” For a bio-refinery to be viable it is necessary to have a cost effective and sustainable supply of feedstock. The U.S. has about two billion acres of land of which 33% is forests and 46% is agricultural land from which to harvest potential supplies. Annually more than 512 million dry tons of biomass, which would produce 52.1 billion gallons of ethanol, are available in the U. S. at a cost of up to less than $50/dry ton, and by 2030 there is expected to be 1 billion dry tons of sustainable lignocellulosic feedstock available per year. The cost of feedstock is the combination of collection, storage and transportation, of which transportation will have the biggest impact on the final cost. One possible economic model consists of several small fermentation plants distributed near available supplies.

Can our cars handle ethanol?

All cars built after 1979 are compatible with E10 blends. Flexible fuel vehicles, FFV’s, have been manufactured since 1998 and are designed to burn straight gasoline, E85 or any gas/ethanol blend in between. In addition to conventional gasoline models, several manufacturers are providing alternative FFV models. The list of available models is already quite extensive: Ford Taurus, Ranger & Explorer; Dodge, Chrysler and Plymouth minivans; Dodge Stratus and Chrysler Sebring; Chevy Avalanche, S-10, Silverado, Tahoe and Suburban; GMC Sonoma, Sierra, Yukon and Yukon XL; Mercedes Benz C320 and C240; Mazda B3000 pickup; Mercury Sable and Mountaineer; Nissan Titan; Isuzu Hombre pickup.

However, logistics still remains an obstacle to the advancement of FFV’s in this country. Among the roughly 170,000 gas stations in the U.S., fewer than 800 sell E85. Even with more FFV’s finding their way onto the road, most owners still have to fill up the tank with gasoline, or at best an E10 blend.

Who supports ethanol?

Cleaner air is a nice outcome, but ultimately the environment is not what motivates investment. With a little help from gravity, money is still what makes the world go round. The ethanol industry in the U.S. and its 150,000+ jobs boosted household income by $5.7 billion in 2005. Further growth of the industry will create new jobs, boost local economies, and expand the government’s tax base. Projections of future growth estimate the addition of 10,000 to 20,000 jobs for every billion gallons of ethanol produced.

Support may best be measured by the amount of investment dollars. In 2005, $17 billion was invested in clean-energy projects in the U.S. Much of it has come from multibillion-dollar hedge fund groups such as S.A.C Capital Advisors and D.E. Shaw & Co., but individuals from other industries, like Virgin Group CEO Richard Branson and General Electric CEO Jeffrey Immelt are investing heavily in green ventures. Berkshire Hathaway’s Warren Buffett, Microsoft’s Bill Gates, Google’s Larry Page and Sergey Brin, and Sun Microsystems co-founder Vinod Khosla are also attracted to the potential of the ethanol industry. The most significant boost may come at the retail end. Wal-Mart announced in June 2006 that it was considering selling E85 at its 380 gas stations. The impact, if such a move were to occur, could make E85 a mainstream word.

What about the rest of the world?

Brazil is the world’s largest producer of ethanol from biomass, providing more than a million jobs in the industry. Brazil has the advantage of an extensive sugarcane crop, which makes for an efficient feedstock because of its high sugar content. Nearly half of sugarcane dry matter consists of sucrose which means time and costs associated with the preliminary pretreatment steps required for converting cellulosic materials can be bypassed. The process only requires extracting molasses from the sugar cane, which is then fermented using a yeast strain that can grow on sucrose, and then a simple separation step extracts the ethanol from the fermentation tank. Additionally, the Brazillian industry is profitable because it requires less work and fertilizer to grow sugarcane than corn, has cheaper labor costs, and has fewer environmental regulations.

Approximately 75% of the cars sold in Brazil are FFV’s. Both E100 (100% ethanol) and an E25 blend are available throughout the country. Consumers buy whichever happens to be cheapest at the pump. In 2003 and 2004, ethanol sold for 45% less per liter than gasoline. In addition to the four billion gallons of ethanol consumed in 2004, Brazil exported around 202 million gallons of ethanol to other countries.

India is the second largest producer of sugarcane in the world and is at the initial stages of using ethanol as an automotive fuel. In India, ethanol is being produced from bagasse, which is the biomass left over after the sugar is extracted from sugarcane. Since the primary feedstock is a byproduct, India may have a better future in ethanol than Brazil since Brazil’s main feedstock is also a valuable food source. So far, ethanol produced in India has been primarily used as an oxygenator in gasoline and exists as a 5% blend in gasoline.

China is home to the world’s largest ethanol distillery (the Jilin Tianhe Ethanol Distillery) and is now the world’s third largest ethanol producer with an annual production of about one billion gallons being produced from corn, rice, and the starch-rich cassava root. China, with its dependence on gas and oil to fuel its rapidly growing economy, initiated an ambitious push towards ethanol in 2001. At the time, producing ethanol was seen as a means for using up its grain surpluses and adding value to its agricultural commodities. Five years later the ethanol push is endangering the food security of its 1.3 billion people. The surpluses are gone and China is increasingly importing more grain. For example, The Tianguan Distillery in Henan has contracted with the government of Laos to lease 15 square kilometers of land for the production of cassava-based ethanol. In order to meet its goal of doubling ethanol production capacity by 2010, China will need to figure out a way to become self-sufficient and make the best use of its massive land area, which likely means developing cellulosic ethanol technologies.

What is the future of ethanol in the U.S.?

Until now, ethanol has advanced in the marketplace as an oxygenator used in low percentage blends and would not have made it this far without the help of federal subsidies in place since 1978. The current subsidy is $0.51 for every gallon of ethanol blended into gasoline, which is roughly one third of what it costs to make. Future political support for subsidies is not a given, so ethanol will have to compete one day with crude oil on its own merits.

All ethanol currently produced in this country is made from corn by a mature process without much room for significant reduction in production costs. Cellulosic biomass sources are inexpensive, and an opportunity exists to dramatically reduce the cost of making ethanol if ongoing efforts in biomass conversion are successful. A joint USDA/DOE study found that there are potentially enough agricultural resources to sustainably produce 60 billion gallons of ethanol per year if agricultural residues and dedicated energy crops were well managed and properly harvested. While this would maintain or add to the crop value for farmers, the question remains as to the effects of long-term removal of crop residues from the ground.

Before the ethanol industry can ride the back of agricultural residues and other cellulosic sources, advancements must still be made in engineering and fundamental biological research. Improvements need to be made in collecting, storing, and transporting feedstock. Innovation is needed to improve the output from biochemical and thermochemical conversion processes to provide higher quality fermentable sugar streams. Eventually all the new technology and processes need to be integrated into a large-scale bio-refinery.

Essentially, the usefulness of biomass comes down to how much it costs to make a gallon of ethanol. The President's Advanced Energy Initiative calls for accelerated research and development in order to make cellulosic ethanol competitive by 2012. The Department of Energy's Office of Energy Efficiency and Renewable Energy has set a cost goal of $1.07/gallon by then. For this to become feasible, cohesive concentrated efforts are required from government, industry, and the financial sector.

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Passive Solar Heating Strategies for Kentucky's Moderately Cold and Moderately Sunny Climate

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Abstract

Computer simulations were performed to compare the thermal performance of several conventional passive solar heating systems, including direct gain, concrete wall indirect gain and water wall indirect gain, with a novel heat pipe augmented passive solar system. Heat pipes provide one-way heat transfer into the building during sunny days, with little heat loss out of the building during nighttime and cloudy days. Simulations were performed for Louisville, KY, Albuquerque, NM, Rock Springs, WY, and Madison, WI. Results showed that the direct gain system performed well in cool and sunny Albuquerque, but produced a net loss in cold and cloudy Madison. The indirect gain systems performed better than direct gain in all locations but Albuquerque. The water wall system provided greater gains than the concrete wall in all climates. The heat pipe system performed significantly better than all other systems in all climates. The heat pipe system was especially advantageous in cold and cloudy Madison. In Louisville, the solar fractions were 22.4%, 30.8%, 38.8% and 50.7% for direct gain, concrete wall indirect gain, water wall indirect gain and heat pipe systems, respectively. These performance values were better than those in Rock Springs, which is sunnier but colder, and considerably better than Madison, which is colder but only slightly cloudier. Though Louisville receives relatively low solar radiation during the winter, it remains a favorable climate for solar heating because of its mild winter temperatures.

Introduction

Future energy supply and demand – Per capita energy demand in the United States is rising slowly, however, in developing countries such as China and India, demand is escalating rapidly. Combined with growing population, the increasing per capita appetite for energy is expected to result in a tripling of total world energy needs over the next thirty years [Dahl & McDonald 1998]. Over the same period, world oil and gas production are expected to peak and gradually decline, creating a widening gap between demand and supply from conventional sources. In fact, many scientists expect declining production within the next decade [Campbell 2006], as most major resources, including those in the Middle East and Russia have reached or are nearing their peaks. The United States, which currently imports over 60% of its oil [Energy Information Administration 2006], reached its peak of oil and gas production in 1970 and 1973 [Tester, *et al*. 2005], respectively, and already faces declining production of these fossil fuels in the future. Therefore, the US will become more dependent on foreign sources of energy in an increasingly stressed world energy market, resulting in higher consumer costs, unless technologies for conservation, efficiency and alternative energy are actively pursued.

Environmental impacts - Perhaps more important than rising energy prices or potential energy shortages is the growing evidence that combustion of fossil fuels is largely responsible for nearly doubling atmospheric carbon dioxide concentration since the mid-1800's [Tester, *et al*. 2005], which is affecting global climate. Though the world has over 200 years worth of coal reserves available with current recovery technology [Tester, *et al*. 2005], coal has the highest concentration of carbon of all fossil fuels and is, unfortunately, the worst polluter in this regard. Computer simulations predict a global average temperature increase of 2^{o}-6^{o}C over this century [Tester, *et al*. 2005], depending on population, energy use and atmospheric assumptions. Also predicted are localized areas of severe weather and drought, and an estimated increase in sea level of 10–25 cm based on thermal expansion of sea water alone, which could have serious cultural, logistic and economic impacts on coastal areas.

To limit environmental impacts to current levels, approximately two thirds of total energy consumption must be converted to non-carbon emitting by 2036. Technologies including conservation, increased efficiency, alternative energy, scrubbing of carbon emissions, geoengineering to increase earth reflectance, biological carbon sequestration and ocean fertilization have been proposed. The enormity of the task suggests that all these approaches may need to be aggressively pursued. Non-carbon emitting alternative energy sources are technically feasible, including solar, wind, geothermal, tidal and alternative hydropower. Of these, solar energy is perhaps the most plentiful. In fact, the amount of solar power striking Kentucky exceeds the world's power usage (year 2000 estimates) by about 25%.

Passive solar space conditioning - A particularly attractive avenue for saving energy and preserving the environment is to use solar energy for space conditioning, i.e., heating, ventilating, air conditioning and lighting (HVACL) of our homes, offices and commercial and industrial buildings. HVACL comprises a large portion of US energy use, an estimated 17% of total and 60% of electrical energy (National Renewable Energy Laboratory website). Experience has shown that if energy-conscious passive solar design is followed for new buildings, savings of around 25% can be expected with no increase in building cost by orienting the building, configuring the interior spaces and distributing windows to provide solar gains. Greater savings can be obtained with small investments (typically 10% greater building cost can provide up to 50% energy savings in favorable climates).

While passive solar design principles can also be used to reduce cooling loads and provide ventilation and daylighting, this paper will focus on an obvious and important application – passive solar heating. In climates with cool sunny winters, such as the southwest US, there are a wide variety of passive solar systems that can produce net heat gains. These systems offset heating loads that must otherwise be supplied by conventional sources, such as oil, gas and electricity. As the climate becomes colder, net heat gains decrease due to losses that occur when the sun is not shining, i.e., during nighttime and cloudy days. An increasingly cloudy climate similarly increases nighttime and cloudy day losses, reduces net heat gains and limits options for passive solar design. This paper will highlight strategies, including a new system design involving heat pipes, to enhance performance of passive solar systems in cold and cloudy climates such as Kentucky.

Types of passive solar heating systems - Passive heating systems can be classified as direct gain, indirect gain, sunspace and isolated gain systems. Each type of system has characteristics that tend to produce good thermal performance in different applications. In direct gain systems (Fig. 1), the living space, such as a bedroom, living room or kitchen, is directly heated by solar radiation through a south-facing window. This type of system provides quick response for heating the living space early in the morning. For systems with a relatively large window area compared with the floor area of the living space, thermal mass should be incorporated, for instance, by using a concrete slab floor, to moderate temperature swings and prevent overheating in the living space. The disadvantage of direct gain systems is that windows have much lower resistance to heat loss (about R-2 for a typical double-pane window) than an insulated wall (about R-11 for a 4 inch wall or R-19 for a 6 inch wall). Thus, the south wall loses more heat during nighttime and cloudy days than a non-solar wall, and the system performance depends on solar gains exceeding these incremental losses. For climates with many cloudy days and/or cold temperatures, the solar gains on infrequent sunny days may not offset the added losses. For Kentucky's moderately cold and moderately sunny climate, properly designed direct gain systems work well.

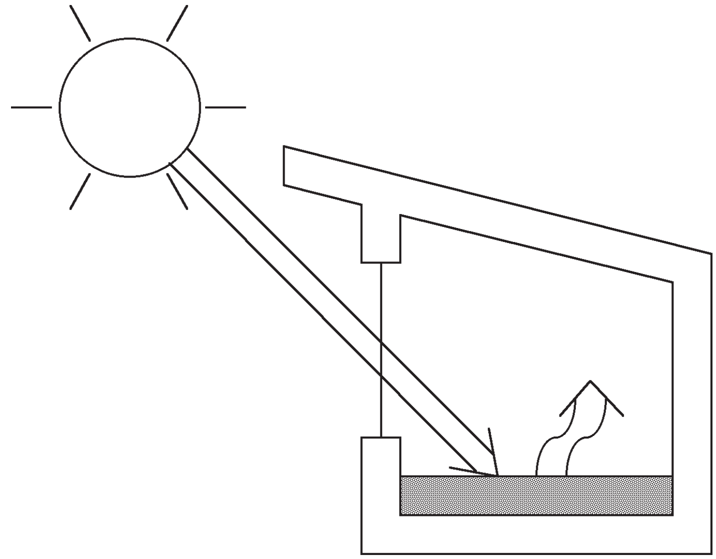

Figure 1. Direct gain system schematic. Solar energy passing through glazing is absorbed by a storage material in the living space.

In indirect gain systems (Fig. 2), an intermediate storage element between the south-facing glazing and the living space is heated by the sun. This storage element is typically a concrete wall (called a Trombe wall for its inventor) or a water wall (water in a number of different types of containers), but could be any thermal storage material. The storage element absorbs heat and then passes the heat to the building interior. For concrete walls, the peak temperature on the inside of the

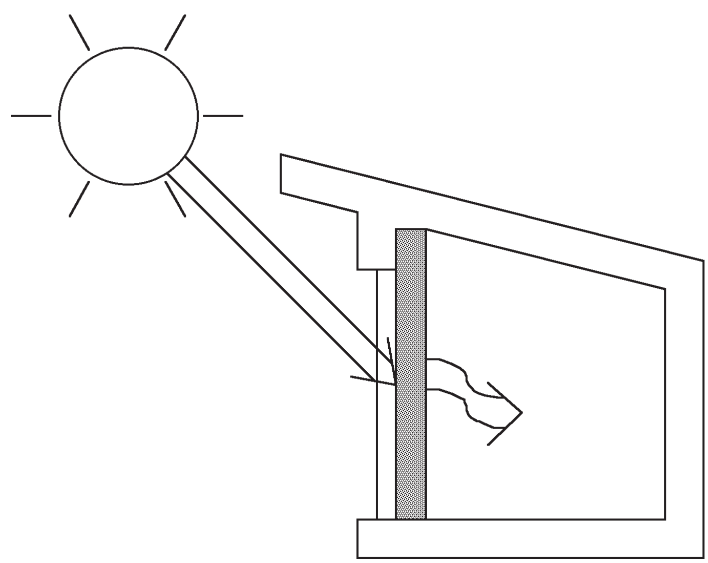

Figure 2. Indirect gain system schematic. Solar energy passing through glazing is absorbed by a storage material located between the south wall and the living space.

wall (toward the living space) lags behind the peak temperature on the outside of the wall (the absorber side) by several hours. This lag can provide a better match between the heat delivery and the heating load, which is usually highest at night. The temperature difference across a water wall is minimal due to thermal convection, but the mass of the water still provides a moderated delivery of heat to the living space. The thermal resistance of an indirect gain system is greater than a direct gain system, but is still much lower than an insulated wall. Therefore, the indirect gain system suffers from nearly the same limitations as the direct gain system in cold and cloudy climates.

Sunspace, or greenhouse, systems (Fig. 3) feature a secondary space – the greenhouse – between the glazing and the thermal storage wall. The sunspace system provides the same temperature moderating advantages for the primary living space as the indirect gain system, as well as adding the benefits of an indoor garden. If the sunspace temperature is allowed to swing and no auxiliary heating is used to heat the sunspace, then the performance of the sunspace system can be similar to that of indirect gain. If sloped glazing is used that is more perpendicular to the wintertime rays from the sun, then the sunspace can have greater performance. If, on the other hand, the sunspace is heated at night, then daytime gains can be negated and sunspace system performance can be less than for an indirect gain system.

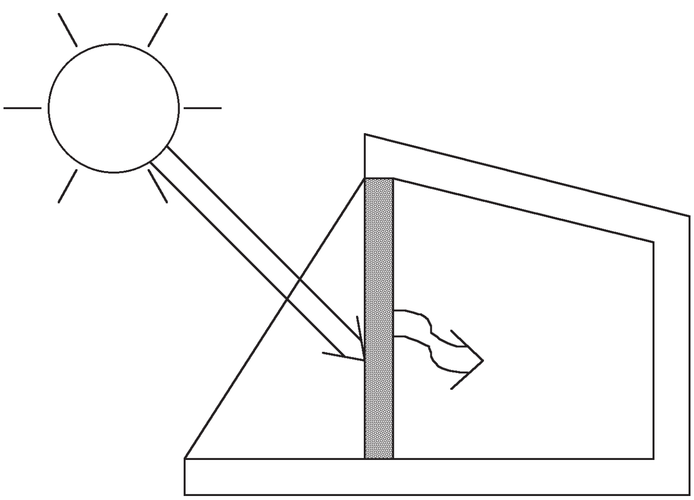

Figure 3. Sunspace (greenhouse) system schematic. Solar energy passing through glazing is absorbed by a storage material located between the sunspace and the living space.

Isolated gain systems (Fig. 4) incorporate solar collectors that are separated from the living space. A circulating fluid transfers heat from the collector to the living space or to the thermal storage element and then to the living space. Isolated gain systems are similar to active solar heating systems except that circulation is accomplished without added power, for instance, by thermosyphon. Because the collectors must be located below the living space for the heated circulating fluid (normally air) to rise to the living space, opportunities for installing these systems are limited. Homes built on south-facing slopes, for instance, can have collectors located below the house.

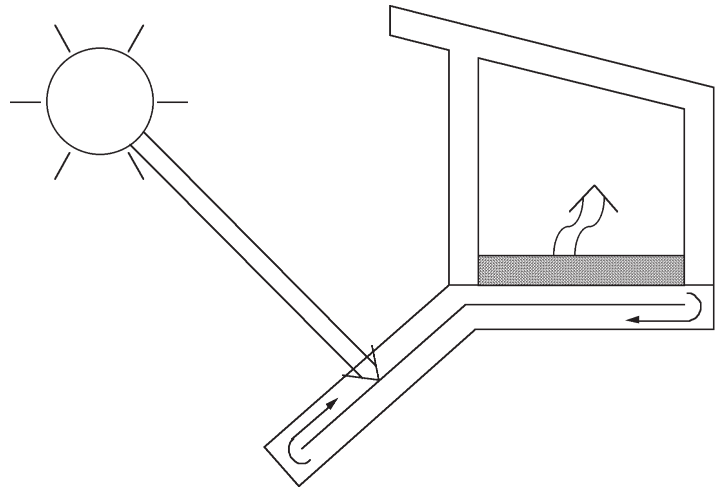

Figure 4. Isolated gain system utilizing thermosyphon. Solar energy passing through glazing is absorbed by a remote collector unit. Heat is circulated to a storage material.

The main disadvantage of passive solar systems, with the exception of the thermosyphon isolated gain system, is that the solar aperture has thermal losses that are greater than a typical non-solar insulated wall. Net heat gains are produced only when daytime solar gains exceed nighttime and cloudy day losses. Thermosyphon systems avoid the problem of nighttime and cloudy day losses, because circulation only occurs when the collector is hotter than the living space. Note that direct gain and indirect gain system performance could be significantly improved by adding insulation during nighttime and cloudy days. However, to achieve performance similar to isolated gain systems, the moveable insulation would need to have thermal resistance comparable to an insulated wall, i.e., R-11 to R-19. Such insulation units would necessarily be thick and large, and would, therefore, present aesthetic challenges for storing the insulation during the day. Additional complications arise for manual or automatic installation and removal of the insulation each day.

Heat pipes (Fig. 5) are essentially thermosyphoning devices, but with some important differences. In a heat pipe, energy is absorbed in the lower (evaporator) end of the pipe by boiling a liquid. The resulting vapor rises to the upper (condenser) end and transfers the energy there by condensing back to the liquid phase. The liquid then falls back to the evaporator end to complete the circuit. Note that, just like single-phase thermosyphon systems, heat pipes have virtually no heat loss in the reverse direction. This feature has prompted heat pipes to be called "thermal diodes." Important distinctions relative to single-phase thermosyphon systems include the following.

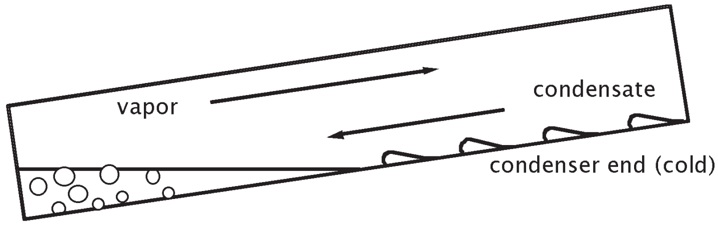

Figure 5. Heat pipe schematic. Heat is transferred one direction only – by boiling in the evaporator end and condensing in the condenser end.

First, phase change greatly increases the rates of heat transfer at both ends. Second, fluid flow, which is driven in thermosyphon systems by the density difference between the light rising fluid and the heavy falling fluid, is larger because vapor is much lighter than liquid. This greater driving force allows heat pipes to operate effectively with only a small difference in elevation between the evaporator and condenser ends, which allows close integration of collector, storage and living space heating functions in a passive solar system (Fig. 6). As shown in Fig. 6, the absorber and storage can be located at the same level, with heat pipes passing through the insulated wall to connect the two.

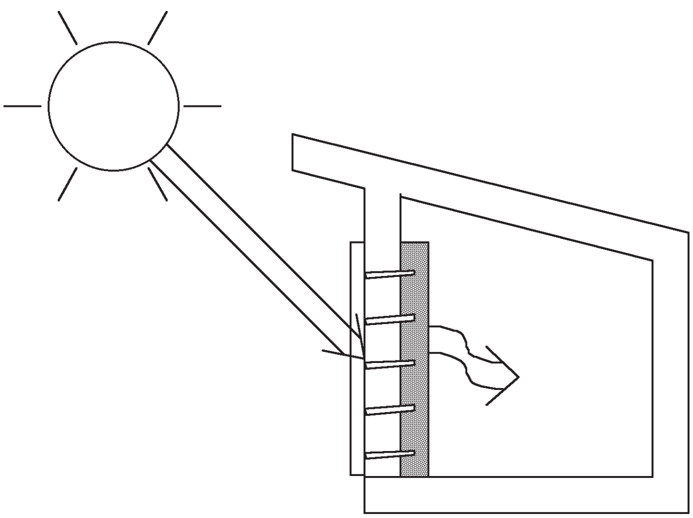

Figure 6. Isolated gain system utilizing heat pipes. Solar energy passing through glazing heats an absorber plate. Heat pipes transfer energy from the absorber through an insulated wall to a storage material.

Several types of thermal diode devices were reviewed by Susheela & Sharp [2001]. Trefethen [1970] studied heat transfer in slightly inclined horizontal tubes filled with liquid. Trefethen & Chung [1978] studied single-phase heat transfer in inclined parallelogramic cavities between two walls at different temperatures. Jones [1986] studied a convective diode consisting of a water-filled rectangular reservoir with a vertical slot (referred to as a tongue) connected by an offset channel.

Phase change materials and fluids have also been used in passive solar heating applications not involving heat pipes. For instance, Faunce, *et al*. [1978] used Glaubers salt as the storage medium with thermosyphoning vertical collectors. Askew [1978] simulated a passive solar system with rotating storage panels containing n-Octadecane backed by insulation and placed behind double glazing on a south-facing wall.

Bairamov & Toiliev [1981] used heat pipes to connect solar collectors to a water-filled storage tank and found storage tank temperatures 10^{o}-11^{o} C greater than in a similar system without heat pipes. Evacuated tube heat pipe solar collectors for active systems are commercially available [Walker 2006] and a novel thin membrane heat pipe collector has been evaluated [Riffat, *et al*. 2005]. Muramoto, *et al*. [1985] conducted experiments applying heat pipes in several configurations, including panel heating and Trombe wall systems, and concluded that heat pipes were well-suited to these applications.

Corliss, *et al*. [1979] conducted a detailed study of a heat pipe augmented passive heating system with different heat pipe materials, working fluids and collector configurations. Simulations of heat pipe and conventional passive solar systems performed for Madison, WI, Phoenix, AZ, Albuquerque, NM, and Columbus, OH, demonstrated higher efficiency for the heat pipe system in all locations. The collector configuration chosen for experiments incorporated six individual black coated absorber plates with grooves into which the evaporator end of the heat pipes were epoxied. The condenser end of the heat pipe extended into an individual water-filled tank on the opposite side of an insulated wall. The absorber and water tank assembly was mounted in a frame adequate for supporting roof loads, so that the system would serve as a structural element in the wall of the house. The heat pipes were inclined 5_{o} from horizontal for gravity driven return of the Freon-21 working fluid to the evaporator section. Van Dijik, *et al*. [1983] performed a detailed analysis similar to that of Corliss, *et al*. [1979] in analyzing the thermal, economic and manufacturing aspects of a heat pipe system. Their system was similar to that of Corliss, *et al*., except that an additional insulating panel was used between the room and the storage to regulate thermal conductance between these two elements. Saman, *et al*., [1989] also studied heat pipes for reducing the heat load of walls.

Susheela & Sharp [2001] performed computer simulations comparing a heat pipe system to water wall and Trombe wall systems in Madison, WI, Albuquerque, NM, and Salt Lake City, UT. Thermal performance advantages for the heat pipe system were found in all locations. They also tested a prototype heat pipe system that achieved 60 – 80% heat pipe efficiency during sunny days. In contrast to earlier configurations, the Susheela & Sharp system was designed to be installed in two parts, a collector unit on the outside of the existing south wall and a storage unit inside the south wall. Flexible hoses passed through the wall to connect the evaporator and condenser sections of the heat pipe. This arrangement allows more convenient installation on existing homes. By comparing experimental results to computer simulations and to empirical heat transfer analysis, they concluded that improvements in heat pipe efficiency might be gained by adding fins to the inside of the condenser section, by optimizing the fluid fill fraction and by insulating the heat pipe between the evaporator and condenser sections.

A new study is being undertaken at the University of Louisville to compare the thermal performance and economic viability of a passive solar heat pipe system to that of other types. The study will include computer simulations of heat pipe systems with a range of performance enhancing features. Of particular interest are improvements in heat transfer between the absorber and the heat pipe and between the heat pipe and storage. Preliminary comparisons of a baseline solar heat pipe system with direct gain and indirect gain systems are shown in this paper.

Methods

Thermal network model

Performance of the passive solar systems was simulated with thermal network algorithms adapted from Susheela & Sharp [2001]. The systems were divided into a number of interconnected isothermal nodes (Fig. 7). The concrete storage elements of the direct gain and indirect gain systems incorporate surface nodes and four internal nodes to account for transient temperature gradients within the material. The water storage elements of the heat pipe and indirect gain systems use a single node, because natural convection keeps temperature differences small within the fluid. The conductance values were chosen to produce the same rate of heat loss through the nonsolar parts of the building for each system. Losses to ambient through the south glazing were deducted from the solar gains to determine the net contribution of the solar heating system to the heat load of the building. For the heat pipe system, two parallel conductances modeled the one-way transfer of heat by the heat pipe and the losses through the insulation between the absorber and the water wall.

The energy flow between two typical nodes i and j was assumed to be linearly related to the temperature difference between the nodes

Equation 1 $$Q_{ij} = K_{ij}(T_j - T_i)$$

where the heat transfer coefficient K_{ij} may depend on the nodal temperatures. The energy balance for the i^{th} node is given by

Equation 2 $$M_i \frac{dT_i}{dt} = \sum_j K_{ij}(T_j - T_i) + E_i$$

where M_i is the product of specific heat and mass of the i^{th} node and E_i is the direct energy gain of the i^{th} node. Equation 2 written for all nodes yielded a set of equations that were solved simultaneously to determine the temperatures of these nodes as a function of time, beginning with a set of initial node temperatures at time t. The temperatures of the nodes at the next time step $t + \triangle t$ was computed by integrating equation 2 from t to $\triangle t$. A backward-difference scheme was used to discretize the derivative in equation 2 for small time step $\triangle t$

Equation 3 $$\{\frac{M_i}{\Delta t} + \sum_j K_{ij}\}T_i - \sum_j K_{ij}T_j = \frac{M_i}{\Delta t}T_{io} + E_i$$

where the subscript zero refers to conditions at the previous time step t. The set of equations for all nodes was solved by matrix algebra. If any values of K_{ij} depended on node temperatures, iterations were used to converge to a matched solution. When the room temperature exceeded preset comfort limits, the room temperature was reset to the limit, and the vented or auxiliary heat necessary to maintain room temperature was calculated.

Comparison of systems in four climates

Simulations were performed for the four different climates of Louisville, KY (a cool and cloudy climate), Albuquerque, NM (cool and sunny), Madison, WI (cold and cloudy), and Rock Springs, WY (cold and sunny). As shown in Fig. 8, Louisville and Albuquerque have similar mean January temperatures, but Albuquerque experiences greater solar radiation in January. Similarly, Madison and Rock Springs are both cold, but Rock Springs is sunnier. Parameters were fixed at values suggested by Corliss, *et al*. [1979] (Table 1). Conductance and thermal mass values are given in Table 2. TMY2 weather data was used in these simulations.

Results

Simulation results comparing the relative performance of direct gain, concrete wall, water wall and heat pipe systems in Louisville, Albuquerque, Rock Springs and Madison are shown in Fig. 9. All the systems had impressive performance in Albuquerque. Here, the direct gain system provided a greater solar fraction than the concrete wall and nearly as great as the water wall. The heat pipe wall in Louisville provided solar fractions similar to Rock Springs, but the other systems had significantly lower performance in Rock Springs, with the direct gain system exhibiting about half the solar fraction of Louisville. In Madison, the solar fraction for direct gain was negative. The heat pipe wall provided 15.3%, 30.5%, 38.1% and 53.6% higher relative solar fraction than the water wall in Albuquerque, Louisville, Rock Springs and Madison, respectively. The heat pipe wall exhibited 42.8%, 64.7%, 82.4% and 99.0% greater solar fraction than the concrete wall and 16.7%,

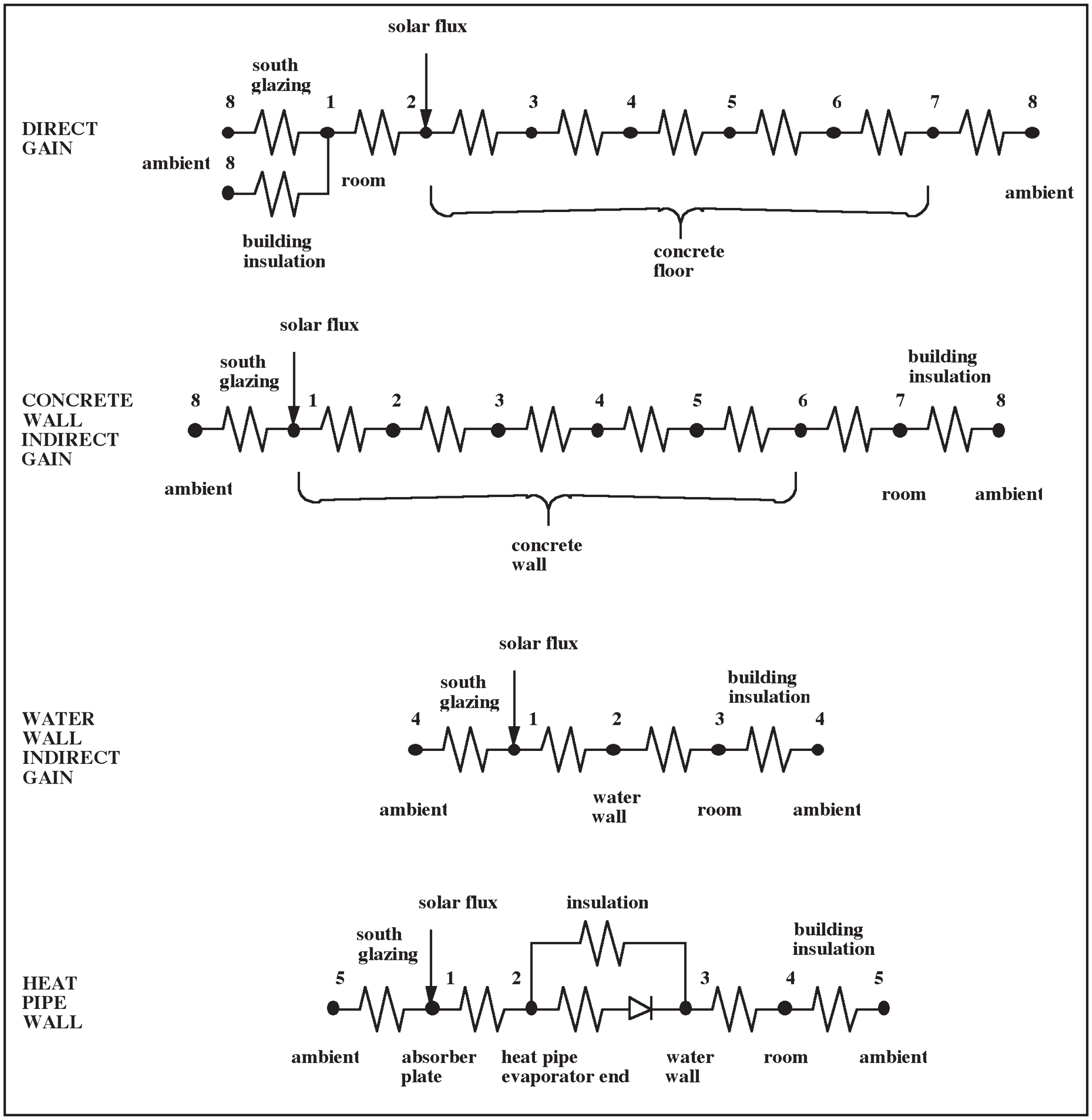

Figure 7. Thermal networks for the passive solar systems.

126%, 278% and an undefined percentage (because the Madison solar fraction is negative) greater than direct gain in the same locations.

Discussion

A significant advantage of direct gain is that solar gains heat the room more directly and, thus, reduce the need for auxiliary heating sooner than is possible with an unvented indirect gain system. A disadvantage is that this more direct heating promotes overheating later in the day in systems with high solar fraction. It appears that in the sunny climate of Albuquerque, the quicker morning gains offset losses associated with venting of excess heat in the afternoon. The high nighttime and cloudy day losses through the solar glazing in the cold climate of Madison overpower the low solar gains and prevent the direct gain system from contributing positively to the heating load of the building. Thermal mass placed between room and ambient helps considerably in this challenging climate, allowing the concrete and water walls to produce respectable solar fractions. The water wall system provides better performance than the concrete wall in all climates, since the natural convection reduces temperatures on the absorber side of the wall and increases solar collection efficiency.

In Louisville, the relative mildness of the winter heating season allows all passive solar heating systems to achieve higher solar fractions than their counterparts in Rock Springs, in spite of the considerably higher solar radiation available there. Nonetheless, significant differences in solar fractions among

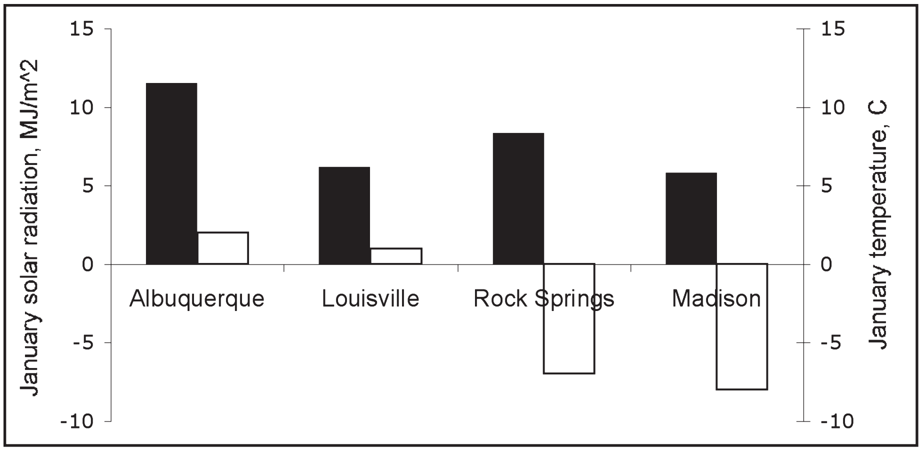

Figure 8. Comparison of climates. Black columns - radiation, white columns - temperature.

the systems are evident in Louisville. The concrete wall performs 37.4% better than direct gain, water wall does 26.2% better than concrete wall, and the heat pipe system is 30.5% better than water wall.

The heat pipe system provides the highest solar fraction in all locations. The heat pipe keeps absorber temperature low, and maintains low nighttime and cloudy day losses due to the one-way heat transfer feature. These losses can be reduced in direct gain and indirect gain systems by adding moveable insulation, however, such insulation systems require automatic or manual control and can present architectural challenges for storage of the insulation material during the day. One convenient moveable insulation product comprises a thick fabric (Window Quilt tm) that is rolled up like a window blind above the solar glazing, but its insulation value is only R-3.8. This added insulation would significantly improve system performance, however, to reach solar fractions similar to the heat pipe system, a moveable insulation value similar to that of the fixed insulation in the heat pipe wall would be required, which is more difficult to achieve in an aesthically pleasing way.

Conclusions

Computer simulations performed for Louisville, Albuquerque, Rock Springs and Madison demonstrated the differences in thermal performance among several passive solar heating system types. For the values of parameters simulated, the direct gain system provided positive gains for all but the cold and cloudy climate of Madison, and performed better than indirect gain in the cool and sunny climate of Albuquerque. The concrete and water wall indirect gain systems exhibited performance significantly better than direct gain for all locations except Albuquerque. The water wall system produced higher solar fractions than concrete wall in all climates. The simulations showed that the heat pipe system performed better than all other systems, and was especially advantageous in cold and/or cloudy climates.

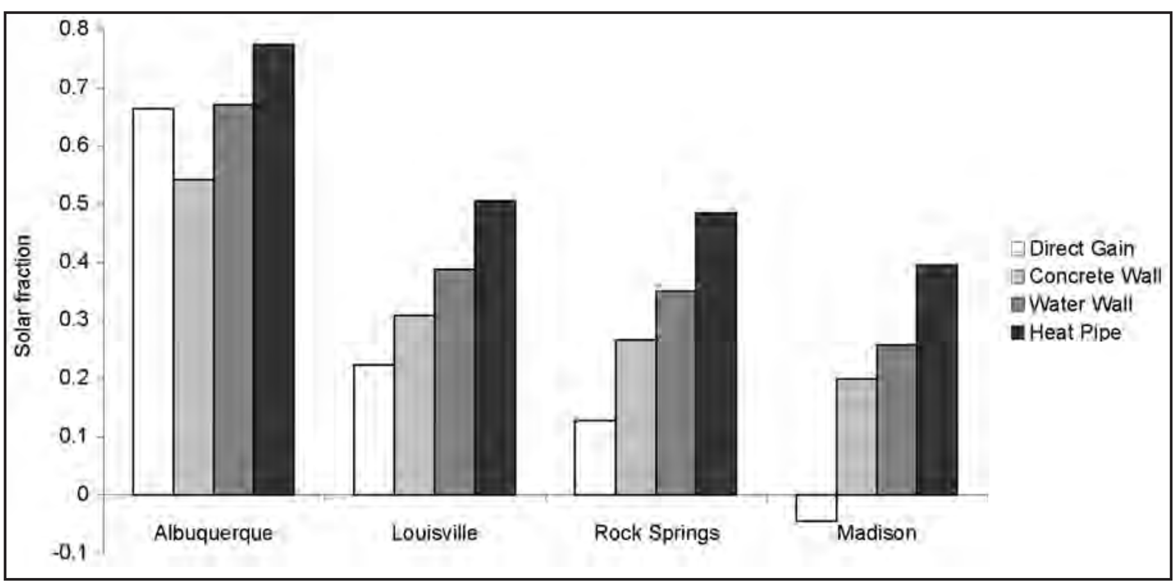

Figure 9. Performance of passive solar heating systems.

Only Albuquerque produced higher solar fractions for the same system than Louisville. In cool and cloudy Louisville, all systems performed better than in cold and sunny Rock Springs, with direct gain in Louisville providing nearly twice the solar fraction of Rock Springs. All systems in Louisville performed much better than in colder, but similarly cloudy, Madison. Though Louisville receives less solar radiation in the winter than other locales, it is nonetheless a favorable environment for solar heating, because of its relatively mild winter temperatures.

Acknowledgement

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Table 1. Parameter values used in this study.

Parameter	Value used in the simulation
Heat transfer coefficient between the room air and the mass storage wall	5.67 $W/m^2\ ^oC$
Allowable room temperature	19-24 ^oC
Glass extinction coefficient	0.05
Collector plate absorptivity	0.95
Building insulation conductance	5.67 $W/m^2\ ^oC$

Table 2. Conductance and thermal mass values.

Direct Gain			
Variable	Value	Variable	Value
K_{12}, $W/m^2\ ^oC$	5.67	$K_{18,glazing}$, $W/m^2\ ^oC$	2.83
K_{23} and K_{67}, $W/m^2\ ^oC$	26.7	$K_{18,building}$, $W/m^2\ ^oC$	4.88
K_{34} thru K_{56}, $W/m^2\ ^oC$	13.1	M_3 thru M_6, $MJ/m^2\ ^oC$	163.5
K_{78}, $W/m^2\ ^oC$	0.79	-----	---
Concrete Wall – Indirect Gain			
K_{12} and K_{56}, $W/m^2\ ^oC$	26.7	K_{78}, $W/m^2\ ^oC$	5.67
K_{23} thru K_{45}, $W/m^2\ ^oC$	13.1	K_{18}, $W/m^2\ ^oC$	2.83
K_{67}, $W/m^2\ ^oC$	5.67	M_2 thru M_5, $MJ/m^2\ ^oC$	163.5
Water Wall – Indirect Gain			
K_{12}, $W/m^2\ ^oC$	56.7	K_{14}, $W/m^2\ ^oC$	2.83
K_{23}, $W/m^2\ ^oC$	5.67	M_2, $MJ/m^2\ ^oC$	715.0
K_{34}, $W/m^2\ ^oC$	5.67	-----	---
Heat Pipe Wall			
K_{12}, $W/m^2\ ^oC$	56.7	K_{45}, $W/m^2\ ^oC$	5.67
$K_{23,day}$, $W/m^2\ ^oC$	56.7	K_{15}, $W/m^2\ ^oC$	5.67
$K_{23,night}$, $W/m^2\ ^oC$	0.283	M_3, $MJ/m^2\ ^oC$	404.0
K_{34}, $W/m^2\ ^oC$	5.67	-----	---

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American Energy Independence: The Kentucky Strategy

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Kentucky Energy Summit

On October 20, the Kentucky Energy Summit, "Unbridled Energy: The Industrialization of Kentucky's Energy Resources – Leading the Way to Energy Independence," was held in Louisville. At the summit, Governor Ernie Fletcher, Senator Jim Bunning, national energy industry leaders, and state energy officials discussed what Kentucky is doing to ensure reliable energy for national security and economic growth in a politically unstable, carbon-constrained, world. The following describes Kentucky's policies, programs, and activities in this regard. In this article, emphasis will be on policies, programs, and activities for the production of transportation fuels and synthetic natural gas from coal or agricultural materials. Kentucky, through the Governor's Office of Energy Policy and other agencies, has numerous other policies, programs, and activities relating to coal, agricultural materials, and the Commonwealth's other important energy resources, including renewables and energy conservation. These may be mentioned as part of Kentucky's comprehensive energy strategy; however, elaboration of the policies, programs, and accomplishments relating to these will not be provided in this article.

In his keynote address to the summit, Governor Fletcher stated that Kentucky must again become a leader in new energy technology relating to clean-coal, biofuels, and other cutting-edge applications. He explained that technology for producing transportation fuels from coal and biomass and for producing synthetic natural gas from coal, in combination with energy conservation and development of renewable energy resources such as solar, wind, and hydropower, is key to reducing America's growing dependence on imported oil, ensuring national security, and creating jobs and economic growth for the nation. The Governor pointed out that modern technology enables energy production to be increasingly environmentally sound. Referring to public concern over the potential effects of energy production upon the global climate, Governor Fletcher stated that, whether global climate change is a threat or not, "the fact is that we do have an important responsibility to be good environmental stewards." Governor Fletcher also announced that he had promulgated an executive order moving the Kentucky Office of Energy Policy from the Commerce Cabinet and placing it in the Office of the Governor.

Kentucky's Comprehensive Energy Strategy

The energy goals enunciated by Governor Fletcher at the Kentucky Energy Summit are an extension of Kentucky's current comprehensive energy strategy (www.energy.ky.gov/). In 2004, the Governor created the Commonwealth Energy Policy Task Force and charged it with developing Kentucky's first comprehensive energy strategy. In his charge to the Task Force, he outlined three principles to guide policy development:

1. Maintain Kentucky's low-cost energy;
2. Responsibly develop Kentucky's energy resources; and
3. Preserve Kentucky's commitment to environmental quality.

The Commonwealth Energy Policy Task Force traveled throughout Kentucky, holding public meetings with private citizens, representatives of environmental organizations, industry leaders, officials of state and local government, educators, civic leaders, and others. Over 60 organizations and numerous individuals provided statements or comments. The comprehensive energy strategy that resulted from the work of the task force contains 54 recommendations. Six of the recommendations relate to assessing the Common-wealth's future electricity generation needs, ensuring that these will be met in a timely and economical manner, and encouraging the use of renewable resources in electricity generation. Nineteen of the recommendations relate to increasing the Commonwealth's production and use of coal with attention to for the environment and safety; these recommendations include development of clean coal technologies and of new and innovative markets for Kentucky coal. Other recommendations relate to other areas of energy resource development including oil and gas resources, energy conservation and efficiency, and renewable resources.

The comprehensive Kentucky energy strategy creates a partnership of state government, industry, and the Commonwealth's universities to ensure the wise development and use of Kentucky's energy resources. The comprehensive Kentucky energy strategy is multi-faceted, calling for development of all of the Commonwealth's energy resources. It is technology-centered, recognizing that technologies currently exist and are being perfected for producing clean energy from the Commonwealth's vast coal and agricultural resources and from other energy resources. The strategy insists on the protection of Kentucky's environment recognizing that Kentucky is one of the nation's leading states in energy-production and consumption. Finally, the strategy recognizes the contributions that Kentucky's energy resources, especially coal, make to the growth of the Kentucky economy and to the well-being of its citizens

Kentucky Energy Policy in the 1970's and 1980's

Kentucky's comprehensive energy strategy, titled "Kentucky's Energy – Opportunities for Our Future," establishes the vision central to Kentucky's reasserting the leadership it attained among the states during the 1970's and 1980's in the development of technologies for production of liquid and gaseous fuels from coal, agricultural materials, and oil shale. In response to recurring shortages of oil and petroleum products in those years and the threats that these posed to America's economic growth and national security, the Commonwealth built, equipped, and staffed an energy laboratory valued at over $13 million in 1977 dollars, created the Energy Cabinet, and established by legislation a $55 million trust fund (in 1974 dollars)to be used to attract research and production facilities to the Commonwealth. With these resources, Kentucky by the early 1980's initiated 13 major projects for producing transportation fuels, synthetic natural gas, and chemicals from coal. Four of these projects, in Western Kentucky, would have used over 28 million tons of coal, would have employed thousands of construction workers and miners, and would have produced in total the equivalent of 170,000 barrels per day of transportation fuel. The plants were the vanguard of development of a national industry, technologically and environmentally advanced, that would have greatly reduced the nation's dependence on imported energy. However, as the projects neared the bricks and mortar stage, a steep decline in world oil prices, engineered in large part by OPEC, pushed the price of oil below the level at which the plants could produce cost-competitive fuels from coal. The U.S. Synfuels Corporation, the federal entity formed to provide financial and other support for synfuels projects, was terminated in 1986, and the plants were not built.

While asserting national leadership in development of fossil fuels, Kentucky also developed leading programs for developing other energy resources. Kentucky was one of only a few states that had a comprehensive energy program comparable to the United States Department of Energy. Alongside extensive RD&D programs relating to converting coal to liquid and gaseous fuels in the 1970's and 1980's, Kentucky assessed the potential for development of alternative energy resources in the Commonwealth, including oil shale, tar sands, and renewables, and supported the development of these through tax and financial incentives and research and demonstration. Kentucky also conducted numerous programs designed to expand market opportunities for its coal.

Although, by the mid-1980's, the world energy situation was no longer conducive to the development of transportation fuels and synthetic natural gas from coal or the development of oil shale and other unconventional petroleum resources, the federal government and the states have continued active and comprehensive energy programs designed to ensure adequate, reliable, and economical energy with care for the environment. Research and development has continued with the goal of reducing the costs of producing liquid and gaseous fuels and chemicals from coal. The Clean Coal Technology Program was begun in the 1980's to develop and prove at commercial scale advanced technologies for reducing emissions from coal-fueled facilities; the program invested over $5 billion which led to the development and demonstration of 20 advanced technologies for cleaning coal and reducing emissions of criteria pollutants. Research continues on enhanced oil and natural gas recovery. Energy conservation programs have been expanded and have achieved significant savings for consumers. Production of ethanol and biodiesel has increased substantially. The environment became increasingly a major factor in energy policy, becoming as it were part of the "Three E's" equation – energy, economy, and environment – and great progress has been made in protecting and improving the environment. Perhaps the greatest environmental success has been in cleaner generation of electricity. Since the mid 1970's the use of coal in electricity generation has increased by 120 percent while emissions of sulfur dioxide have decreased by more than half.

Current Kentucky Energy Strategy

A. <u>The Background: Increasing Reliance on Foreign Energy Sources</u>

One of the speakers at the Kentucky Energy Summit stated with some irritation that the United States still does not have an energy policy. The next speaker stated that there is an energy policy and that it has accomplished a good deal; however he agreed that current energy policy is not capable of ending America's growing reliance on imported petroleum and petroleum products. The United States now imports almost 60 percent of the oil it consumes. In an increasingly unstable world, this growing reliance on foreign energy sources has serious implications for the nation's security and economic well-being. America's growing dependence on external sources of oil can be explained by, first, a continual decline in oil production, which peaked in the U.S. in 1971, and growth in population and economic activity that is creating an increasing demand for more oil. Along with oil, America is increasing its dependence on imports of natural gas due to declining production and increasing demand.

A senior official of Peabody Energy, the largest coal producer in the United States, presented at the Kentucky Energy Summit some statistics that illustrate how America's energy demand will grow in coming years. In 2005, the United States added 3 million people to its population, which now exceeds 300 million. In that year, Americans built over one million new homes, started over 3 million new businesses, and flew over 800 trillion passenger miles. The U.S. Energy Information Administration predicts that by 2030, the U.S. will require an additional 33 quadrillion Btu of energy – equivalent to the combined energy consumption of Germany, Italy, and the United Kingdom. By 2030, the U.S. will require an additional 7 million barrels per day of oil over today's 20 million barrels per day – equivalent to the current production of Iran and Venezuela. The nation will require an additional 4.5 trillion cubic feet per year of natural gas over today's 22 trillion cubic feet – equivalent to current production of the Gulf of Mexico plus Wyoming. By 2030, an additional 650 million tons of coal per year will be required, more than 50 percent more than is now produced. Finally, by 2030, 340 Gigawatts of installed electric generating capacity will be required – equal to 250 nuclear power plants. According to the U.S. Census Bureau, population could approach 500 million persons by 2050.

B. The Background: World Energy Competition

The world energy situation has changed. In the 1970's, threats to America's energy security came largely from the OPEC countries that had developed the means of cooperating to keep world oil prices at levels they desired. Occasional episodes of political instability threatened America's external sources of oil; most notable was the Iranian revolution during the administration of President Jimmy Carter. Today, while OPEC continues to attempt to regulate the world price of oil, world political instability has become endemic, and threats to world oil supply have become pervasive. The top ten petroleum exporting countries include Venezuela, Saudi Arabia, Nigeria, Iraq, and Algeria, and these six marginally stable or marginally friendly countries account for 45 percent of total world petroleum exports.

The Peabody Energy official also presented at the Kentucky Energy Summit strong evidence of world competition for oil, driven by what he referred to as the "Second Industrial Revolution," the phenomenal economic growth of China, India, and other rising nations, most located in Asia. The industrialization of these nations, especially of China and India, is creating immense demand for energy. The Peabody official pointed out that this explosion in demand is only getting underway as the industrial revolution in China moves from the coastal areas to the vast interior. In 2004, China's oil consumption increased by nearly 16 percent. China currently has per capita annual energy consumption of 46 million Btu. If the 1.2 billion people in China had per capita oil consumption equal to that of Mexico, demand would increase by 45 million barrels per day. Today, the world production of oil is about 80 million barrels per day. India has over one billion people whose per capita energy consumption is only 14 million Btu, less than one-third China's. Growth in energy demand there can only increase at an explosive rate. Both China and India are building a large part of their industrialization on their abundant resources of coal. Daniel Yergin, President of Cambridge Energy Resources Associates and author of Energy Future and The Prize, testified before a Senate committee this year that, whereas, in the 1970's North America consumed twice as much oil as Asia, in 2004 and 2005, Asia's oil demand exceeded that of North America.

World demand for natural gas is also growing rapidly. As America's reliance on external sources of natural gas increases, the result will be, in Yergin's terminology, the international commoditization of natural gas. Gas will increasingly be traded on international energy markets and producers will have the same kind of power over the economies of gas import-dependent countries as OPEC countries now have over the economies of the oil import-dependent ones.

Kentucky's Response

Kentucky's Senator Jim Bunning, opened the conference with a description of how the United States is becoming increasingly dependent on foreign sources of petroleum, petroleum products, and natural gas and discussed S. 3325, the Coal-to-Liquid Promotion Act of 2006 that he introduced this year with Senator Barack Obama (IL) to provide financial incentives for development of coal-to-liquids plants. Speakers from the nation's leading coal company and the nation's leading producer of fuels derived from agricultural materials agreed that technology is available to reduce the nation's growing dependence on foreign sources of transportation fuels and natural gas and to meet America's growing need for electricity in ways that are environmentally sound. A panel of state officials described the roles of their agencies that affect the development of advanced technologies for producing coal-to-liquids, coal-to-gas, and biofuels. Representative Rocky Adkins explained to the summit his concerns for America's energy security and how his vision of how Kentucky can help the nation meet its challenges through the Commonwealth's fossil and agricultural material energy resources and university capabilities. Consequently he introduced House Bill 299, the Kentucky Energy Security National Leadership Act, which was enacted by the General Assembly and signed by Governor Fletcher on April 21, 2006. Representative Adkins outlined how House Bill 299 requires the Governor's Office of Energy Policy to develop a strategy for developing coal-to-liquids, coal-to-gas, and biofuels industries in Kentucky.

The Technological Focus

Technology is central to the federal and Kentucky efforts to use coal and agricultural materials to produce transportation fuels and synthetic natural gas. This is significant. To the extent that America develops technologies to reduce its increasing dependence on foreign energy resources, the nation benefits through new investment and employment. And, technology is exportable. As China, India, and other developing countries build the thousands of power plants, coal-to-liquids plants, and other energy producing facilities to meet their burgeoning energy demands, it is imperative that they adopt the best technology. The U.S. Department of Energy has had an active program for finding ways to export America's clean coal technologies to create business opportunities for American manufacturers and to improve the world environment.

Coal, the nation's most abundant energy resource, and agricultural materials are the feed stocks to be used by the new technologies. There are two coal conversion technologies. One, direct liquefaction, converts coal at high temperature and pressure in the presence of hydrogen and a catalyst, producing a synthetic crude oil that can be refined into transportation fuels. Direct liquefaction plants are not being planned in the United States; however, there are large direct liquefaction projects underway in China. The second technology is indirect liquefaction. This process, known as Fischer-Tropsch technology, was developed in Germany before World War II. It has been further developed and perfected by South Africa where today the giant SASOL Fischer-Tropsch complex produces nearly one-third of the nation's total gasoline requirements. In the Fischer-Tropsch technology, coal is converted into a gaseous product stream called "syngas," made up primarily of hydrogen and carbon monoxide. This gas can be used in many ways – converted to Fischer-Tropsch super clean diesel fuels and other fuels, it is burned to power electricity generating turbines, made into chemicals, fertilizers, hydrogen, carbon dioxide for Enhanced Oil recovery, and synthetic natural gas.

The Fischer-Tropsch technology offers great environmental benefits. It can remove virtually all emissions of sulfur dioxide, nitrous oxides, and mercury, reducing these far below levels permitted under current regulations, in some instances to nearly immeasurably low levels. At present no requirements exist in the U.S. to manage carbon emissions from fossil fuel sources. However, should carbon management be required, carbon dioxide produced during the conversion process can be captured for subsequent storage in deep geologic formations or sold for use in enhanced oil recovery operations, a use for which there is substantial demand. Electricity generating units using coal gasification and Fischer-Tropsch technology, known as Integrated Gasification Combined Cycle (IGCC), can operate with virtually no emissions of sulfur dioxide, nitrous oxides, mercury, or carbon dioxide.

A partnership of industry and the U.S. Department of Energy is developing a full-scale demonstration co-production facility (a facility that generates electricity while producing Fischer-Tropsch transportation fuels, hydrogen, or chemicals), called FutureGen. The federal government will contribute $750 million and industry will contribute $250 million to construct FutureGen which will be the world's first zero-emissions plant for producing hydrogen and 275 Megawatts of electricity from gasified coal. The plant will emit no sulfur dioxide, nitrous oxides, or mercury. The carbon dioxide will be captured and sequestered permanently in deep geologic formations. Thus, FutureGen will produce hydrogen, the fuel for the future hydrogen economy in which hydrogen fuel cells will power vehicles, and it will demonstrate the use of coal for production of transportation fuels, chemicals, and electricity with no emissions.

The fuels produced by gasification and Fischer-Tropsch technology are also super clean. Because the catalysts used in Fischer-Tropsch would be damaged by sulfur, all sulfur is cleaned from the syngas. Thus, the diesel fuel produced in the Fischer-Tropsch process is far cleaner than conventional diesel fuel. Since the fuel contains no sulfur, it greatly exceeds the EPA standards for diesel fuel including the new standards for ultra-low sulfur diesel fuel. Recent tests by the US Department of Energy showed that Fischer-Tropsch diesel fuel also reduced emissions of NOx, particulates, carbon monoxide, and hydrocarbons when substituted for high-quality California diesel fuel in a test engine by 12 percent, 24 percent, 18 percent, and 40 percent, respectively.

Implementing the Strategy

Kentucky is heavily involved in development of technologies for production of super clean fuels and electricity through gasification of coal. The development of such technology squarely meets the three guiding principles of Kentucky's comprehensive energy strategy. It also helps meet the nation's goals of energy independence and security. And, it contributes greatly to Kentucky's economic growth. The FutureGen Alliance estimates that the FutureGen plant will cost about $1 billion to construct and will employ about 1300 persons at peak construction, generating a total construction pay of approximately $250 million. A permanent workforce of 150 persons will operate the plant. The plant will use about 1 million tons of coal per year, providing employment for about 130 miners. As substantial as these economic benefits are, FutureGen is a relatively small plant. A 30,000 barrels per day coal-to-liquids plant would likely cost about twice as much to build, would employ about twice the number of construction and plant operation workers, and would use about 5 times the tonnage of coal. Two major reports have recently been issued that call for replacing all or most of America's imports of oil by a combination of strategies centering on converting coal to liquid or gaseous fuels and including in various degrees development of oil shale, tar sands, and enhanced oil recovery. The National Coal Council presented its report, "Coal: America's Energy Future," to Energy Secretary Bodman in March, 2006. The Southern States Energy Board issued its report, "The American Energy

Security Study," this past July. Both reports analyze the economic benefits of their proposed strategies and find that, in essence, a new American industry would be created, generating hundreds of billions in investment and well over 1 million new jobs for Americans. In addition, the Strategic Unconventional Fuels Task Force, a federal-state group established by the Energy Policy Act of 2005, will report to the Congress this November its recommendations for reducing America's oil imports by development of oil shale, tar sands, enhanced oil recovery, and coal-to-liquids. That report will likely show similar massive positive economic benefits. As a major coal-producing state and with large steel and aluminum industries, Kentucky could expect to share extensively in the creation of such industry. As HB 299 points out, the development of these industries could greatly increase employment in Kentucky coal mining and in agriculture and stabilize the markets for coal and agricultural products.

A number of programs and activities are underway to further the goals of Kentucky's comprehensive energy strategy relating to production of liquid fuels from coal and agricultural products and synthetic natural gas from coal.

Commercialization. Governor Fletcher's Executive Budget for the 2007-2008 biennium appropriates about $3 million each year to the Office of Energy Policy for support of energy research and for commercialization of technologies for producing transportation fuels and synthetic natural gas from fossil energy resources and biomass resources.

House Bill 299 Strategy Development. The Governor's Office of Energy Policy (OEP) has taken several actions to directly carry out the mandates of HB 299. The Office has initiated memoranda of agreement with the Center for Applied Energy Research (CAER) at the University of Kentucky for assessment of the various types of equipment for gasifying coal and their operating characteristics with various Kentucky coals. The CAER is also under agreement with the OEP to prepare information and materials for use in explaining the processes and technologies used in converting coal to liquid and gaseous fuels and chemicals. The OEP has also initiated a memorandum of agreement with the Martin School of Public Policy and Administration and the Gatton School of Business and Economic Research for an analysis of the opportunities for Kentucky in the new coal and biomass conversion industries and analysis of incentives that Kentucky can offer to nascent industries that would be of the greatest utility to the industries and, consequently, most effective in attracting the industries to the Commonwealth. The OEP is working with the Kentucky Geological Survey to further identify and assess the opportunities Kentucky has for sequestering carbon dioxide or capturing and selling the carbon dioxide for enhanced oil recovery or other purposes. The OEP has issued a Request for Proposals for providing financial assistance to coal and biomass conversion projects that are at or near commercialization. The OEP has contracted with a firm to develop a site bank in which 4-6 sites, with both Eastern and Western Kentucky being represented, will be identified in terms of their suitability for large coal-to-liquids or coal-to-gas plants and will be comprehensively described in terms of characteristics required for such plants and environmental and other requirements.

Senate Bill 131. Senate Bill 131 was introduced by Senator Robert Stivers in the 2006 Regular Session of the Kentucky General Assembly. The bill was enacted by the General Assembly and was signed by Governor Fletcher on March 28, 2006. The bill enables natural gas distribution companies to purchase a portion of their wholesale gas supplies on long-term contracts from entities that produce synthetic natural gas from coal. The long-term contract mechanism is designed to provide another mechanism by which natural gas utilities can control the recent severe spikes in the price of the natural gas that they purchase to provide to their customers. The Kentucky Public Service Commission has statutory responsibility relating to this policy.

Strategic Unconventional Fuels Task Force. Governor Fletcher, along with the Governors of Colorado, Mississippi, Utah, and Wyoming, was appointed to the Strategic Unconventional Fuels Task Force, which was created by Section 369 of the Energy Policy Act of 2005. Also on the task force are representatives of local governments and officials from the Departments of Energy, Interior, and Defense. This task force is charged with assessing the resources of oil shale, tar sands, and how to enhance oil recovery and production of liquid transportation fuels from coal. The task force will report to the Congress in November, 2006, on recommendations for programs and incentives for developing these resources.

FutureGen site proposal. Kentucky was one of eight states that submitted a proposed site this year for the FutureGen project. Submittal of a site proposal involved an extensive site search and analysis of the suitability of the proposed site, in Henderson County, in terms of location, size, environmental requirements, access to various coals, proximity to electricity transmission lines, and location at or near geologic formations in which carbon dioxide could be sequestered. Of the twelve sites proposed by eight states, four were

> selected for further consideration by the government/industry FutureGen Alliance. Two are in Illinois and two are in Texas. Kentucky was one of only four states that submitted a site that met all of the required criteria. Although Kentucky's site was not selected for further consideration, the process of site selection and analysis will be valuable for attracting to the Commonwealth in the future additional FutureGen plants or similar plants for converting coal into liquid or gaseous fuels and producing electricity.

In addition to these programs and activities, the Governor's Office of Energy Policy is working actively with several entities that propose to develop plants to produce coal-to-liquids, coal-to-gas, or biofuels. Already, a biodiesel plant is in operation in Kentucky and two more are proposed, one of which would produce 45 million gallons per year.

In sum, Kentucky has an aggressive energy policy, one that can reassert Kentucky's leading role in ensuring the energy independence and security of the United States by making use of Kentucky's abundant coal and agricultural resources and doing so with concern for Kentucky's environmental quality. The increased use of coal and agricultural materials will increase and stabilize markets for Kentucky's coal and agricultural production and create new industry and opportunity in the Commonwealth. The challenges are large, but the opportunities must be and can be seized for the Commonwealth.

William H. Bowker presently serves as Director, Division of Fossil Fuels and Utility Services, Kentucky Governor's Office of Energy Policy.

Energy: Past, Present, and Shaping the Future.

Michael A. Mulheirn, Executive Director, Facilities and Transportation
Tommy L. Brown Sr., Retired Director, Mechanical and Electronic Maintenance
Kevin F. Stoltz, Energy Auditor

The Jefferson County Public School District, located in Louisville, Kentucky, was established by an act of the state legislature in 1838. The Louisville and Jefferson County school districts merged in 1975. Today, Jefferson County Public Schools (JCPS) is the largest school district in Kentucky and the 26th largest school district in the United States with more than 97,000 students in 87 elementary schools, 23 middle schools, 20 high schools, and 22 other learning centers. JCPS has approximately 13,600 full-time employees and 5,800 teachers. The annual budget is approximately $950 million, with 96 percent of the budget directly funding programs and schools. JCPS has the 19th largest transportation department in the country, transporting 60,000 students daily, traveling 85,000 miles using 842 buses, making 46,260 stops each day (8 million stops yearly) – traveling enough miles daily to go around the world over three times.

JCPS enjoys national recognition evidenced by the following recent awards:

- Three JCPS high schools (Eastern, Louisville Male and DuPont Manual) made Newsweek magazine's 2005 List of America's Best High Schools.
- JCPS earned a 2004-05 Super System for Quality Schools designation for having all schools accredited by the Southern Association of Colleges and Schools.
- JCPS was a national finalist for the 2003 Broad Prize for Urban Education and received $125,000 for student scholarships. This prize rewards public school systems that use creative, results-oriented approaches. An independent panel of educational leaders analyzed the performance of more than 100 U.S. urban school districts and determined that JCPS was in the top five.
- In late 2005, backed by a $25 million grant from the GE Foundation, JCPS embarked on an exciting plan to restructure the district's math and science curriculum to implement world-class standards. Beginning with the current school year, a common science curriculum for kindergarten through eighth grade was implemented. In conjunction with Pearson Publishing, JCPS is currently developing world-class instructional materials for mathematics. JCPS will field test the world-class math curriculum during the 2007-08 school year, with full implementation in all schools during the 2008-09 school year.
- JCPS received a 2006 ENERGY STAR Award for Isaac Shelby Elementary, the first ENERGY STAR school in Kentucky and the first in the entire southeastern United States region.

Departments/Equipment

The JCPS Facility Planning/Construction Department manages over 14.5 million square feet of enclosed building space, including 152 school facilities and 3,723 classrooms. This department is responsible for managing all capital projects for construction, remodeling and renovation of educational and support facilities. Department personnel are actively involved from the time of the district needs assessment through post occupancy of the facilities.

The Mechanical Maintenance Department is responsible for heating, ventilation, air conditioning (HVAC), and refrigeration systems, as well as the energy management systems (EMS) and security systems throughout the district. There are approximately 40,000 tons of air conditioning, 800 pressure vessels (boilers, water heaters, cookers, and hot water storage tanks), over 800 freezers and refrigerators, and over 12,000 pieces of HVAC related equipment. There are 40 persons responsible for these duties, including service technicians, control technicians, pipe fitters, welders, pump technicians, sheet metal technicians, insulators, water treatment technicians, and security technicians.

The Mechanical Maintenance Department maintains a variety of mechanical equipment in the district including high efficiency condensing boilers, cast iron sectional boilers, and fire tube boilers; reciprocating, scroll, and screw compressors, (both air and water cooled); variable volume multi-zone air handlers, and single-zone air handlers (some with energy recovery wheels); circulating pumps that include variable volume and constant flow; and terminal equipment that includes unit ventilators, fan coils, re-heat boxes, radiators, and a few window air conditioners.

Most of the buildings use natural gas-fired boilers to heat water that heats the building and a centralized chiller plant that cools water used for air conditioning. Typically, there are two-pipe systems that allow selection of heating or cooling, as opposed to four-pipe systems that allow both heating and cooling at the same time.

Control Systems Evolution

With the advent of EMS(Energy Management Systems), energy savings have been considerable. Pre-1980, when temperatures dropped below freezing, service technicians worked around the clock checking buildings. The procedure was to employ full heat to the building, which actually produced the problem of control valves closing, stopping water flow and creating freeze conditions as room temperature setpoints were achieved. EMS has provided the capability of reducing night setback temperatures of hot water loops and keeping control valves open during freeze conditions, as well as alarms indicating when high volumes of water are entering the heating system, such as when a pipe has broken. EMS has also given us the ability to monitor walk-in freezer and refrigerator temperatures so that dispatch receives an alarm when they are out of parameters saving countless dollars in food loss, as well as preventing disruption to the school day.

One result of all this is that, even with an increase in square footage over the last 25 years, the consumption of gas has dropped 45 percent. On the flip side, the electrical consumption has increased 103 percent, mainly because of demand for centralized air conditioning and the need to run it throughout the summer months.

The control systems that have evolved over the last three decades are as different as night and day. In the early 80's, JCPS had pneumatic systems that used master and sub-master controllers to control variable outputs. These were replaced by solid state "front ends," which converted electronic signals to pneumatic pressure with the aid of transducers. JCPS now has Direct Digital Controls (DDC) that are Web-based with elaborate animated graphics that communicate across miles of local and wide area networks and that basically have the same results as opening/closing, speeding up/slowing down, and turning off/on mechanically controlled devices to maintain desired temperatures throughout the buildings. Today's controls are much more precise with algorithms that predict, optimize and streamline to accomplish near perfection while obtaining energy efficient results.

Recent Cost/Recovery

The total cost for gas, electric, and all water-related bills for calendar year 2005 was $18,932,538. With everyone feeling the impact of rising energy costs, it has become imperative to search for the most efficient energy-saving means available, including the tracking of all energy consumption. Lou Pawley, former director of Mechanical and Electronic Maintenance, played an instrumental role in implementing "Project 85," an energy management program. Since that time, Jefferson County Public Schools has employed an Energy Auditor who has recorded the consumption and cost of natural gas, electricity, and water-related billings for every building in the district. The JCPS energy database also tracks the monthly electrical demand. Several reports are available using this Access- based software, written exclusively for JCPS. These records go back as far as 1977. This matrix has become an excellent tool for discovering abnormalities in monthly consumption and, also, for tracking building modification and mechanical renovation results. In 2005, $154,978 was recovered from our utility bills as a result of Energy Auditor review.

JCPS also tracks degree days. The degree day totals are used for year-to-year or month-to-month outside temperature comparisons (A Heating [Cooling] degree day [HDD and CDD] is the difference between the average daily temperature and 65° F. The HDD season begins July 1; the CDD season begins January 1.).

Below is an example of consumption/cost comparisons (between 1980 and 2005) using our database for the 249,716 square foot facility, which comprises a single building. The Ahrens Educational Resource Center houses adult education and the Brown School houses kindergarten through twelfth grade.

Optimization of hot water heating loops

Below is the hot water reset schedule as specified by JCPS:

Occupied periods

0° Outside Air Temperature (O.A.T.) ………………………..180° water in our heating loops.

70° O.A.T. …………..….80° water in the heating loops.

A change of 1.43 per degree, therefore
180 - (O.A.T. x 1.43) = heating water setpoint.

Unoccupied Periods

0° O.A.T…………….180° water in our heating loops.

32° O.A.T. …….………80° water in the heating loops.

A change of 3.12 per degree, therefore
180 – (O.A.T. x 3.12) = heating water setpoint.

Since the computer age has arrived, we now have the ability to incorporate building average (determined by an average temperature of a group of rooms that best represent the area being served by the corresponding zone valve) into the formula. For every 1° the building average zone temperature travels from 70° (65° during unoccupied periods), JCPS offsets the heating loop water temperature 5° above or below the calculated heating water setpoint. This algorithm assures that the water is not too hot or cold going out to the terminal units, which keeps the building more comfortable and saves energy as well. Also, with DDC systems, we lower the night setpoint considerably. These formulas can be modified to meet individual loop characteristics, engineering flaws, or engineering marvels as well.

Jefferson County Public Schools
Shaping the Future

Summary of Energy Management Efforts Instituted Since 1980

* In 1979/1980 the District implemented an Energy Management Program that was to be completed by 1985 ("Project 85") the cost was approximately $5,000,000
* In 1981 we developed a very unique method of conserving natural gas by optimization of the heating water loops. This method is still being used today and is one of the main reasons we have reduced our consumption of natural gas by more than 50 percent.
* Between 1985 and 1989 we were in search of a vendor for a continued energy management program. During that period the industry was changing at a very rapid pace In 1990 the decision was made to implement a 100% "digital" control application instead of pneumatic control with an energy management interface.
* Somewhere in the mid 1980's the decision was made to run air conditioning for custodial staffs all summer.
* There are only 128 School buildings used to determine the cost avoidance in this report. These buildings have had some additions (gyms, library's, classrooms) chiller and boiler replacements, water heater replacements, HVAC renovations, etc. but they existed in 1980 and are still in use today.
* In 1980 about 55% of the District was air conditioned by a central plant. Since that time the entire District has been centrally air conditioned.

* ***Estimates are based on the amount of energy consumed during the "Base Year" (A base line of energy use before any energy saving efforts were instituted)***
* ***Cost Avoidance, (Is an estimate of savings calculated based on consumption increase/decrease for the same period of time)***
* ***Degree Day Information, (A measurement of how hot or cold the comparison year is to the base year)***
* ***Inflation is factored in by calculating unit cost each year based on actual cost for that period.***

	Base Year-> 1980	
	Cost Avoidance Compared to Base Year With Degree Day Difference Calculated	Cost Avoidance Compared to Base Year With Degree Day Difference Calculated
	Estimated Cost Avoidance	
	For Electricity	For Natural Gas
1981	($254,492)	($308,517)
1982	($59,637)	($292,456)
1983	($98,770)	($394,981)
1984	($65,866)	($263,502)
1985	$116,573	($570,650)
1986	$266,071	($606,494)
1987	$452,369	($596,541)
1988	$638,544	($556,678)
1989	$780,188	($669,740)
1990	$1,236,412	($698,320)
1991	$2,526,262	($736,528)
1992	$1,399,776	($754,947)
1993	$2,295,615	($857,562)
1994	$2,430,909	($760,987)
1995	$2,775,320	($951,938)
1996	$2,742,273	($783,675)
1997	$2,141,092	($1,142,552)
1998	$2,544,036	($1,630,202)
1999	$3,055,201	($1,443,909)
2000	$2,602,729	($1,647,211)
2001	$2,949,514	($2,133,450)
2002	$3,847,677	($1,981,282)
2003	$2,679,817	($2,387,891)
2004	$3,610,655	($2,894,478)
2005	$6,024,582	($3,455,560)
	$46,636,850	($28,520,051)

	Electricity		Natural Gas
Total Avoidance	$46,636,850		-$28,520,051

Buildings Used in the Summary					
1	AHRENS	44	GREENWOOD	87	PERRY
2	ATHERTON	45	GUTERMUTH	88	PORTLAND
3	AUBURNDALE	46	HARTSTERN	89	PRICE
4	AUDUBON	47	HAWTHORNE	90	PRP H
5	BALLARD	48	HAZELWOOD	91	PRP V
6	BARRET	49	HIGHLAND	92	RANGELAND
7	BATES	50	HITE	93	RUTHERFORD
8	BLAKE	51	INDIAN TRAIL	94	SANDERS
9	BLOOM	52	IROQUOIS H	95	SCHAFFNER
10	BLUE LICK	53	JEFF CO TRAD MID	96	SEMPLE
11	BOWEN	54	JOHNSON	97	SENECA
12	BRECKINRIDGE METRO	55	JOHNSONTOWN	98	SHACKLETTE
13	BUECHEL METRO	56	J-TOWN E	99	SHAWNEE
14	BUTLER	57	J-TOWN H	##	SHELBY
15	BYCK	58	KAMMERER	##	SHRYOCK
16	CAMP TAYLOR	59	KENNEDY ALEX	##	SLAUGHTER
17	CANE RUN	60	KENNEDY JF	##	SMYRNA
18	CARRITHERS	61	KENWOOD	##	SOUTH PARK
19	CENTRAL	62	KERRICK	##	SOUTHERN H
20	CHENOWETH	63	KING	##	SOUTHERN M
21	CHURCHILL PARK	64	KLONDIKE	##	ST MATTHEWS
22	COCHRANE	65	KNIGHT	##	STONESTREET
23	COLERIDGE-TAYLOR	66	LASSITER	##	STUART
24	CONWAY	67	LAUKHUF	##	THOMAS JEFFERSON
25	CORAL RIDGE	68	LAYNE	##	TRUNNELL
26	CROSBY	69	LIBERTY	##	TULLY
27	CRUMS LANE	70	LINCOLN	##	VALLEY
28	DIXIE	71	LOWE	##	WAGGENER
29	DOSS	72	LUHR	##	WATSON LANE
30	DUNN	73	MALE HIGH	##	WATTERSON
31	DUVALLE	74	MANUAL	##	WELLINGTON
32	EASTERN	75	MCFERRAN	##	WESTERN H
33	EISENHOWER	76	MEDORA	##	WESTERN M
34	ENGELHARD	77	MEYZEEK	##	WESTPORT M
35	FAIRDALE E	78	MIDDLETOWN	##	WESTPORT TAPP
36	FAIRDALE H	79	MILLCREEK	##	WHEATLEY
37	FAIRDALE V	80	MINORS LANE	##	WHEELER
38	FERNCREEK E	81	MOORE	##	WILDER
39	FERNCREEK H	82	MYERS HALL	##	WILKERSON
40	FIELD	83	MYERS MIDDLE	##	WILT
41	FRAYSER	84	NOE	##	YOUNG
42	FROST	85	NORTON	##	ZACHARY TAYLOR
43	GILMORE LANE	86	OKOLONA		

Buildings "Not" Used in the Summary	
1	ATKINSON
2	BLACK ACRE
3	BLAKENBAKER GARAGE
4	BLUE LICK BUS COMPOUND
5	BRANDEIS
6	BRECKINRIDGE-FRANKLIN
7	BUS TERMINAL
8	CARTER
9	CB YOUNG CENTER
10	CENTRAL STADIUM
11	CHANCEY
12	COCHRAN
13	DAWSON ANNEX
14	FARNSLEY HOUSE
15	FARNSLEY MIDDLE
16	FOSTER ACADEMY
17	FOSTER E
18	FRANKLIN
19	GHEENS
20	HAZELWOOD N P
21	IROQUOIS M
22	JACOB ANNEX
23	JACOB ELEM
24	LEES LANE BUS
25	LEES LANE N P
26	LYNDON
27	MALE OLD
28	MANUAL STADIUM
29	MAUPIN
30	NEWBURG
31	NICHOLS GARAGE
32	NUTRTION SERVICE CENTER
33	ORMAN
34	RIVERPORT DAYCARE
35	SHELBY NEW
36	VANHOOSE
37	VANHOOSE ANNEX
38	WALLER
39	WAREHOUSE
40	WAREHOUSE 2
41	WILHOIT BUS
42	WKPC

Ahrens Educational Resource Center / Brown School
Energy Consumption / Cost Comparisons (1980 - 2005)

Kilowatts used in 1980	1,307,634	Cost $ 61,680
Kilowatts used in 2005	2,503,587	$152,825
CCF's of Natural Gas used in 1980	128,994	$ 35,397
CCF's of Natural Gas used in 2005	57,048	$ 61,738
Total Heating/Cooling Degree Days in 1980	HDD 4,836	CDD 1,730
Total Heating/Cooling Degree Days in 2005	HDD 4,064	CDD 1,782
Cost per square foot	1980 . . . . . $ 0.39	2005 . . . . . $ 0.86

The chart below shows how the loop water changes as the zone average temperature changes. This formula has also become a very good tool to bring a building out of a night-time lower temperature very quickly, reducing the time it takes to bring a building zone to the required occupied temperature.

OAT = Outdoor Air Temperature
LWT = Loop Water Temperature
AZT = Average Zone Temperature

AZT>	60	62	64	66	68	70	72	74	76
	LWT	*LWT*	*LWT*	*LWT*	*LWT*	*LWT*	*LWT*	*LWT*	*LWT*
OAT = 0	180	180	180	180	180	180	170	160	150
OAT = 10	180	180	180	180	176	166	156	146	136
OAT = 20	180	180	180	171	161	151	141	131	121
OAT = 30	180	177	167	157	147	137	127	117	107
OAT = 40	173	163	153	143	133	123	113	103	93
OAT = 50	159	149	139	129	119	109	99	89	80
OAT = 60	144	134	124	114	104	94	84	80	80
OAT = 70	130	120	110	100	90	80	80	80	80

Energy Savings Performance Contract

In October 2001, JCPS entered into an Energy Savings Performance Contract with LG&E Enertech, which was eventually bought by Ameresco. This $5.2 million project guaranteed nearly $400,000 in savings per year. The project included lighting replacement in 14 buildings and window replacement in 11. As of January 2006, the actual savings were $1,251,590; an additional savings of $140,309 (12 percent more than guaranteed).

Energy Savings Summary – Project History

In summary, by entering into an Energy Services Agreement with Ameresco, the Jefferson County Public School District has saved $1,251,590 over the past five years in utility expenditures and O&M costs, which is $140,309 (12%) more than guaranteed.

New Construction Energy Efficiency Initiatives

In August 2007, JCPS will open two new elementary schools that are designed by Voelker, Blackburn, Niehoff Architects and mechanically/electrically engineered by LSE Engineering. A new middle school will open in August 2008, that is designed by McCulloch Associates Architects and mechanically/electrically engineered by CMTA Engineering. The new schools will include many of the following energy initiatives: Solarban® 80 windows, R-20 roof insulation, R-18.3 wall insulation, daylight harvesting reflectors and dimming fluorescent light ballast systems, high efficiency motors, fully condensing 95% efficient boilers, higher efficient chillers, solar domestic hot water, variable flow heating/cooling pumps, variable speed air handling units, a separate fresh air system with an energy recovery wheel, used in conjunction with individual room fan powered variable air volume boxes. These boxes are similar to reheat boxes with the ability to induce forced air hot water heat upon demand. The rooms will have occupancy sensors that turn off the fresh air supply and lighting when the room is unoccupied. We plan to develop our building system into an electronic format to allow student access for use as an instructional tool.

Partnership for a Green City – Energy Use Partnership

In August 2004, Jefferson County Public Schools, Louisville Metro Government and the University of Louisville entered into the Partnership for a Green City, which represents a collaborative effort to improve Louisville's environmental education, environmental health, and processes for waste reduction and energy management by Louisville's three largest public entities.

From the beginning all partners, along with support of the Kentucky Pollution Prevention Center, Kentucky Institute for the Environment and Sustainable Development, the University of Louisville Speed School of Engineering, and the Kentucky Office of Energy Policy recognized the challenge of developing the partnership. The sheer size of the three entities could threaten to derail the project before it got started. However mutual respect, cooperation, and determination have already generated much success. Together, these three institutions employ some 25,900 people, about 5 percent of the entire labor market in the community. JCPS and UofL enroll 120,000 students, more than 75 percent of all students in the community. They own more than 500 buildings, 7,000 vehicles, and 25,000 acres of land in Metro Louisville. Together they consume a significant amount of energy.

Report Number	Reporting Period		Guaranteed Savings	Actual Savings	Difference
-	Construction Period	10/23/01 - 1/09/03	$0	$86,696	$86,696
1	2004 Annual Report	1/10/03 - 1/09/04	$398,871	$416,742	$17,871
2	2005 Annual Report	1/10/04 -1/09/05	$399,321	$417,192	$17,871
3	2006 Annual Report	1/10/05 -1/09/06	$399,785	$417,656	$17,871
Performance Contract Totals			**$1,197,977**	**$1,251,590**	**$140,309**

Scope of Work for 2001 Performance Contract

Energy Conservation Measures (ECMs)	Doss High School	Sam Meyer Hall	Noe Middle School	Rutherford Elementary	Semple Elementary School	Seneca High School	Southern Middle School	Stonestreet Elementary	Thomas Jefferson Middle	Western MST Magnet High	Westport Middle School	C.B. Young Service Center	Young Elementary School	VanHoose Education Center
Lighting														
T-8 Lighting Retrofit	X	X	X	X	X	X	X	X	X	X		X	X	X
Exit Sign Retrofit	X	X	X	X	X	X	X	X	X	X		X	X	X
Compact Fluorescent Retrofit	X	X	X	X	X	X	X	X	X	X		X	X	X
Gym Lighting Retrofit	X		X	X	X	X	X	X	X	X				
Lighting Controls	X													
Windows														
Replace Single Pane Windows	X	X	X	X	X	X		X	X	X	X	X		
Replace Existing Single Pane Sidelights	X			X	X	X			X	X	X	X		
Replace Transom Windows	X	X		X	X	X			X	X	X	X		

The Energy Use Partnership (EUP) subcommittee is providing an ongoing mechanism for knowledge exchange and demonstration of proven energy efficiency (E^2) methods and technologies. The EUP established eight objectives for improving the energy and environmental performance at the three organizations involved:

- Develop proposals for funding of energy efficiency projects/energy education programs.
- Identify a standardized electronic format for utility data to better track energy usage in buildings.
- Perform E^2 audits at all organizations
- Identify and highlight successful energy programs
- Develop E^2 technology training for facilities personnel
- Promote alternative financing mechanisms, such as energy savings performance contracting
- Develop E^2 awareness training programs for all three Green City Partners by 2006
- Work with engineering firms to incorporate E^2 language into new building specifications

Some Energy-Saving Measures Being Taken by JCPS Today

1) Incorporate DDC systems that optimize all mechanical devices with time schedules, optimal start/stop, and constant temperature analyses.
2) Install occupancy sensors in classrooms used to turn the fresh air supply and the lights on and off, and trigger the associated HVAC mechanical systems for that area.
3) Solar collectors are scheduled to be used to heat the domestic water in one building with others to follow. A real time visual display for students to monitor the results will be in place.
4) Daylight reflectors that project free sunlight into classrooms are being installed. Used in conjunction with daylight harvesting dimming fluorescent light ballasts, the reflectors reduce electrical consumption.
5) Replacement of lighting, windows, insulation, and roofs with higher efficient types.
6) High efficiency condensing gas boilers are being used for heat.

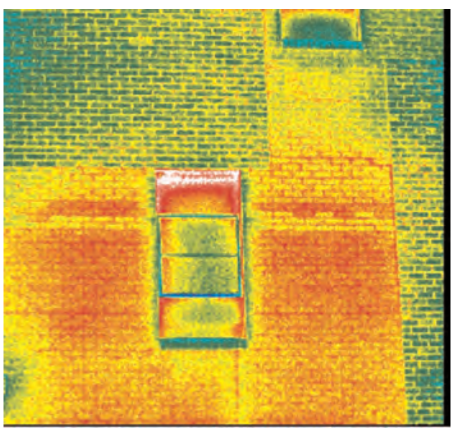
The above pictures show before replacement (left) and after (right). Not only do they now operate freely and save energy, they are also draft free, maintenance free, and are much better looking.

7) Chillers with high efficient “screw” compressors that modulate to very low percentages to reduce start/stops all the while maintaining constant chill water temperature during low load conditions. (New environmentally safe refrigerants are being implemented.)
8) Research of “frictionless” chiller compressors that claim to be 32 percent more efficient than screw compressors.
9) Energy recovery wheels on “fresh air” air handler units that control humidity and re-use airborne energy that would normally be exhausted.
10) Variable drive systems that slow down air handler motors and pump motors on low load conditions.
11) Variable air volume room controls to efficiently modulate room temperatures.
12) E^2 student involvement includes posting “When not in use, turn off the juice” stickers in classrooms throughout the district.
13) JCPS and the Kentucky Pollution Prevention Center have worked together to develop energy savings tips that are displayed in the Monday Memo newsletter that goes out to all school district personnel at least once a month.
14) Incorporate findings from Kentucky Pollution Prevention Center E^2 audits that have been performed on several buildings as renovations and building changes occur.

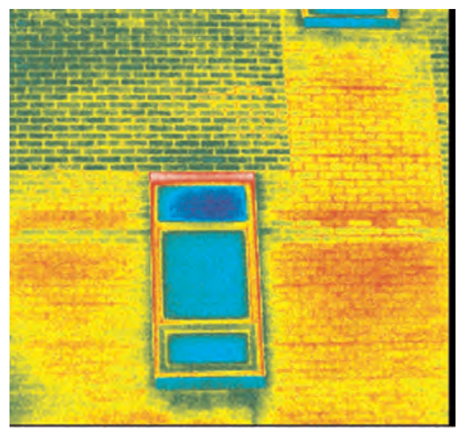
Energy Conservation Philosophy

The JCPS energy conservation philosophy is to tackle the issue from many different angles. Our goal is that these initiatives be cost effective, practical, replicable, and maintainable. This applies to new construction, renovations and existing facilities. In addition to the initiatives described above, on a systemwide basis, we studied our entire waste disposal system and worked on improving the conservation culture within the district. This includes our “*When not in Use, Turn off the Juice*,” stickers above light switches, energy conservation tips in the district newsletter, systemwide recycling, and the removal of automatic dishwashers from school kitchens.

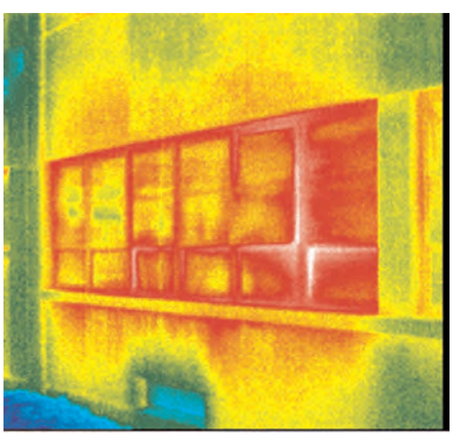
JCPC Western High School Pre/Post Retrofit



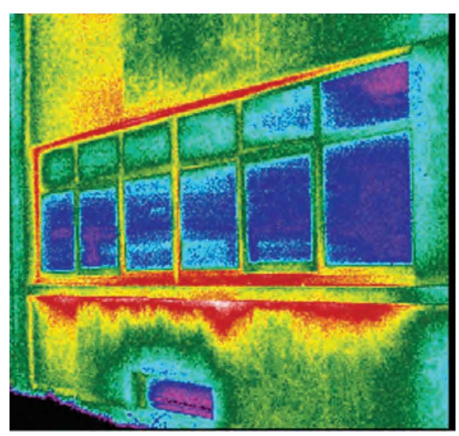
Window 1 - before - Date: 1/22/02 - ambient temp 53.6F



Window 1 - after - Date: 3/27/02 - ambient temp 46.4F



Window 2 - before - Date: 1/22/02 - ambient temp 53.6F



Window 2 - after - Date: 3/27/02 - ambient temp 46.4F

The pictures above show the heat loss on the left frames (Pre Retrofit) and the improvement made on the right (Post Retrofit).

Since our recycling program was implemented systemwide six years ago, we have increased recycling awareness, as well as reduced solid waste disposal cost from $710,000 per year to less than $500,000 per year. This initiative saves approximately 1,000 tons of paper per year, which equals 17,000 trees and 24,000,000 gallons of water saved per year.

The removal of automatic dishwashers from school kitchens is an ongoing process; namely worn out machines are not replaced, nor are they included in new construction. The dishwashers were replaced with disposable trays. This action reduced our labor intensity, reduced equipment cost, and reduced utility costs by $800,000 per year and chemical costs $500,000 per year. The disposable trays cost a fraction of the savings, and we are currently working on a program that will recycle these disposable trays.

JCPS is proud of our energy initiatives to date, but we realize that we are on a never ending journey that will excite and amaze us for many years to come.

Michael Mulheirn, FCIOB, REFP, joined JCPS seven years ago as the executive director for Facilities and Transportation. Michael is a construction engineer, Fellow of the Chartered Institute of Building, and a Recognized Educational Facility Planner. A highlight of Michael's 33-year career was being named the Planner of the Year, the highest individual honor from the Council of Educational Facility Planners International.

Tommy Brown Sr., a licensed Master HVAC technician, worked for 40 years as an employee of the JCPS Mechanical and Electronic Maintenance Department and retired as director. Tommy played a tremendous part in the implementation of energy conservation and new design concepts in the JCPS district and received many accolades.

Kevin Stoltz, a licensed Boiler and Master HVAC technician, has worked for JCPS for 22 years in the Mechanical and Electronic Maintenance Department and is currently the energy auditor for JCPS. Kevin continues the initiatives started by Lou Pawley and Tommy Brown Sr. and plays a critical role in our new initiatives and our Energy Use Partnership.

SOLAR ENERGY – A POWERFUL RESOURCE IN A CHANGING WORLD

Andy McDonald, Co-coordinator
Kentucky Solar Partnership

Solar energy is an abundant yet underutilized resource in Kentucky and throughout much of the world. As the mainstream media, politicians, business and community leaders, and the general public finally come to recognize the reality of global warming, its causes, and the gravity of its consequences, we are beginning to hear serious conversations about how to wean ourselves off of fossil fuels and radically reduce our carbon dioxide emissions. Dramatic improvements in energy efficiency and conservation and the rapid deployment of renewable energy technologies are among the key strategies we must pursue if we are to avoid the worst consequences of climate change. (The other main strategy is carbon sequestration, achieved primarily through tree planting/reforestation and the halting of deforestation and forest burning). Solar energy stands as one of the key renewable energy resources available to us in this critical effort.

While solar energy currently supplies a small fraction of the world's energy supply, the global solar industry has grown at a tremendous pace over the past decade. "Annual global production of solar cells has increased six-fold since 2000, exceeding 1,700 MW in 2005, and the industry plans to continue its dramatic expansion."[1] Germany, Spain, and Japan are at the forefront of this movement. Each of these countries have made large investments in solar energy and have implemented powerful policies and incentive programs to drive the growth of solar and bring down its costs. While the United States was a leader in the manufacturing of solar photovoltaics 10 years ago, today Germany and Japan have become the world's leading manufacturers and markets for photovoltaics. Japan's policies have driven down PV system costs by 80 percent since the early 1990's, to the point where solar power is now competitive with conventional electricity prices in Japan.[2]

While the United States has fallen behind these other nations, great advances have still been made here in the US. Today, many states offer valuable incentive programs to help reduce the costs and other barriers that limit the use of solar technologies. In 2005 the Federal government made tax credits for solar energy available for the first time since the 1980's, when the Reagan Administration cut off numerous important renewable energy programs, a key event that may have set back the development of renewable energy by decades.[3] Despite the loss of major funding and support from the US government, the solar energy industry continued to advance and in recent years, states and local governments have stepped in to take local action to develop solar energy, other renewables, and energy efficiency programs.

In this article we will look at the policies and incentives used to advance the use of solar energy. We will discuss a number of specific regional initiatives, and then we will explore what's been happening in Kentucky in recent years. Although there has been little support from the State government, a solar industry is beginning to develop in Kentucky, supported by the efforts of individual citizens, non-profit organizations, local governments, colleges, private businesses, and the US Department of Energy's Million Solar Roofs Initiative. Before delving into these topics, let's get an overview of solar energy technologies and some basic concepts that are important for understanding the real potential for solar energy.

Solar Technologies and Applications

The energy of the sun can be harnessed in several ways and used for a variety of purposes. The simplest and most direct ways use ***passive solar design*** methods for heating, cooling, and lighting. Passive solar design integrates the building with local site conditions to take advantage of the sun for heating in the cold months; to minimize solar heat gain during the cooling season; to promote natural ventilation and passive cooling; and to provide natural ***daylighting***. Passive solar building methods have been used around the world for millennia, and are applied to modern buildings to significantly reduce the need for external energy inputs for heating and cooling. Here in Kentucky, passive solar design strategies can reduce the energy needs of a home or commercial building by 50 percent or more.

Solar thermal systems such as passive solar design take advantage of the sun's heat energy. Solar water heating, solar pool heating, and solar space heating are other important applications for solar thermal energy. Water heating accounts for 15 – 25 percent of the energy use in a typical home and can be a major energy expense for many businesses, such as hotels, food processors, and Laundromats. A solar water heater can supply 50 – 80 percent of a home or commercial facility's hot water needs on an annual basis. A solar space heating system can provide 25 – 50 percent of a home's space heating needs.

Solar thermal systems are normally installed with a back-up heating system. A solar water heater will normally include a conventional electric or gas water heater to ensure that hot water is always available, and a passive solar home will have a furnace or wood stove, for instance, for supplemental heating. It's generally not feasible to meet 100 percent of your heating needs in our climate with a solar thermal system, but if we can supply 50 – 80 percent of our needs with the sun, we have made significant progress.

There are two general types of technologies for generating electricity with solar energy – ***solar photovoltaics (PV)*** and ***concentrating solar collectors***. Concentrating solar collectors use solar thermal energy to generate steam which is used to turn a turbine to generate electricity. They are used in large solar power plants in regions with excellent solar resources, such as the southwestern US. Acres of concentrating solar collectors can produce enough electricity to power whole towns. According to the US Department of Energy, concentrating solar collectors are the most cost-effective means of producing solar electricity on a large scale. "As a result, government, industry and utilities have formed partnerships with the goal of reducing the manufacturing cost of concentrating solar power technologies."[4] "Since the first 14 MW trough plant was installed in California in the early 1980's, generating costs have dropped from 45 cents/kWh (in 2005 dollars) to 9-12 cents/kWh….Costs are expected to drop to 4-7 cents/kWh by 2020."[5] Most of the work with CSC is taking place in arid regions such as the southwestern United States with solar resources superior to what we have here in Kentucky.

Solar PV cells use sunlight, not solar heat, to generate electricity. The more intense the sunlight, the more electricity a PV cell will generate. For this reason, the electrical output of a PV cell is significantly affected by shading and cloud cover. The great advances in PV technology, the rapid growth of the PV industry, the sharp drop in costs, and the effectiveness of government incentives in other countries lead the Solar Energy Industries Association to conclude that, with the proper incentives and government support, PV cells could become cost competitive with coal-generated electricity by 2015.[6]

Does Solar Really Work in Kentucky?

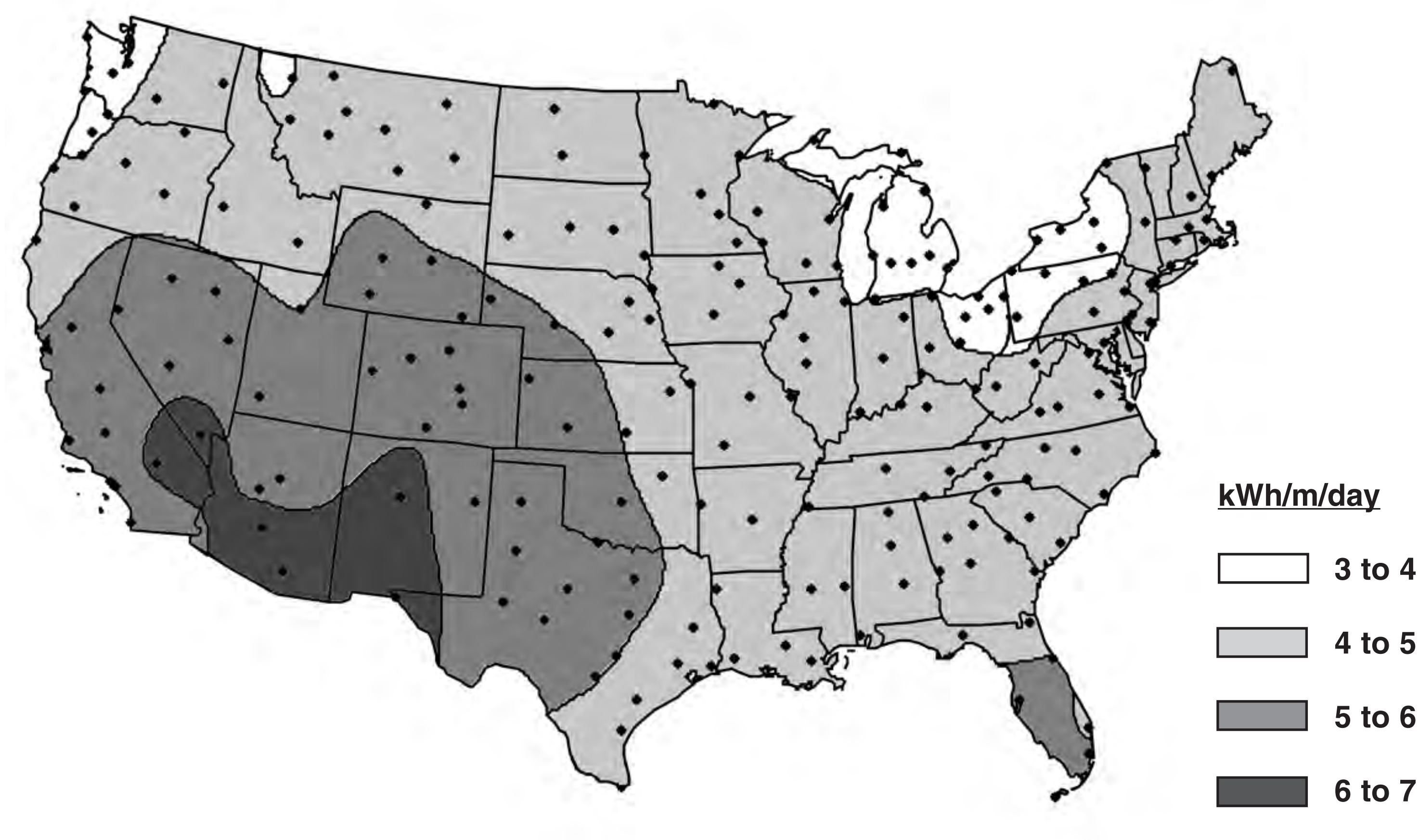
Some people believe that "solar doesn't work in Kentucky" because we have periodic stretches of cloudy weather throughout the year. As the map of US average daily solar radiation in Figure 1 illustrates, Kentucky's solar resource is actually quite good.

Kentucky's average daily solar radiation is comparable to places as diverse as east Texas and central Wisconsin, and is better than New York's and New Jersey's. When you consider that each of these other states provide substantial financial incentives for solar (not to mention Germany, which is not known for its sunny climate) you realize that Kentuckians could profit from this resource as well.

Applications for Solar Energy

Solar electric systems have a wide variety of applications, ranging from remote site electrification to powering entire homes and entire communities. For many years, "off-grid" applications were the most common use of solar PV systems. With the development of utility-interconnection technology and regulatory frameworks that allow small producers to sell power onto the electricity grid, grid-intertied or net-metered PV systems have become a very common application

Average Daily Solar Radiation Per Month



for solar PV. They give homeowners and businesses that are already on the grid an easy way to use solar electricity, with a number of important advantages.

First, grid-intertied PV systems don't have strict power limits the way off-grid systems usually do. If the customer uses more power than the PV system can provide at a given moment, the power is simply taken off the grid (and the customer billed for that usage). When the customer uses less power than the PV system is producing, the excess power flows onto the grid, and the customer gets credited for that power generation. This is what "net metering" refers to. Customers are billed for their net consumption during the billing period, and when the PV system is producing power onto the grid, the utility meter can actually flow in reverse. This arrangement opens the door for "Renewable Energy Production Incentives" which can provide actual income to a solar energy producer based on kWh sold onto the grid.

Grid intertied systems also have the advantage of using the PV generated power more efficiently. In stand-alone systems with a battery back-up, much solar energy can go unused when batteries are fully charged during sunny conditions. In a grid-intertied system, all potential solar generation is either used immediately on-site or flows onto the grid, where it will be used by someone (like the next-door neighbor), while the homeowner's bill gets credited for the PV production.

Solar water heating systems are used for heating household hot water, swimming pools, home space heating systems (such as radiant floor systems), and also have a wide range of commercial applications. Solar swimming pool heaters are the largest single application for solar thermal systems in the US.[7] In November 2004, the International Energy Agency (IEA) reported that global capacity of installed solar thermal systems was equivalent to 69,320 Megawatts (MW).[8] This compared with 23,000 MW of global wind capacity and 1,100 MW of solar photovoltaics, and is equivalent to over 300 coal power plants. (The average US coal power plant has a capacity of about 200 MW.)[9] The IEA's report reveals that solar thermal technologies are proven, are already making a substantial contribution to the world's energy needs, and are poised to make a significant contribution to our future energy needs.

Current Solar Energy Costs

The price for solar PV modules dropped from around $27/Wp (Watt peak) in 1982 to around $4/Wp in 2003, and as of September 2006 had risen to about $5/Wp. The cost of the PV module accounts for about 50 – 60 percent of the installed cost of a PV system, so for a residential PV system the average installed cost runs about $10,000 - $12,000/kWp installed.[10] For a home that uses 500 kWh/month (one-half of the average Kentucky home), a PV system to power 100% of the home's needs would cost around $45,000.[11] Put another way, PV generated electricity costs around $0.30/kWh, about five times the cost of coal-generated electricity in Kentucky.[12]

The rise in costs for PV modules in recent years is attributable to high global demand coupled with a shortage in the supply of silicon used in the manufacture of PV cells. The industry expects this shortage to be relieved in coming years, and with ongoing support from government programs, prices are expected to continue to fall.

PV systems can be the most cost-effective electricity option in certain situations. For example, on sites that are more than 1/4 mile from the utility grid, the cost of running the power line to the site can exceed the cost of a PV system. In situations where cables would need to be buried and roads dug up, like for street lights, PV systems can be the least-cost option.

A solar water heating system for a typical home in Kentucky costs around $3,500 - $4,500 installed. Such a system can save a family $150 - $400 or more per year, depending on the type of conventional water heater being replaced, cost of energy, amount of hot water used in the home, and other factors. Solar water heaters are less expensive than PV systems per unit of energy produced, and can generate thousands of dollars of tax-free income for homeowners over their 25+ year lifespan. Most homes will recover their investment in a solar water heater within 10-15 years, without any financial incentives. When incentives are available, the payback period can be significantly reduced.

Assessments of the economic value of a solar energy system must take into account the rising cost of energy over time. An investment in a solar energy system fixes one's energy costs (or at least a portion of those costs), providing security against future price increases.

The costs of passive solar design strategies can vary widely because they are the result of a host of design decisions and construction options. Generally speaking, passive solar strategies do not necessarily increase the cost of a building, but even when they do, those costs will often be recovered within a few years through energy savings.

The Importance of Energy Efficiency and Conservation

The Intergovernmental Panel on Climate Change has proposed that industrialized nations need to reduce carbon dioxide emissions by 80% by 2050 in order to minimize the consequences of climate change.[13] To achieve such an ambitious goal, we must invest both in the development of renewable energy sources and in radically improving energy efficiency and conservation efforts. For both the individual and the nation as a whole, efficiency and conservation are the first, most economical step, and should be pursued vigorously.

Efficiency and conservation allow us to meet our needs at a lower cost and with less pollution. On the national level, investing in energy efficiency is like building power plants that don't pollute, at a fraction of the cost. For example, a report from the Alliance to Save Energy states that if all homes in America used the most energy efficient refrigerators available, the electricity savings would eliminate the need for about 30 power plants.[14] Those energy savings would translate into pollution not produced and money saved by American families.

Achievements of the Federal Energy Management Program (FEMP) illustrate the enormous potential of energy efficiency. According to the Alliance to Save Energy, the FEMP has saved taxpayers more than $8 billion through energy efficiency in government buildings. The further installation of currently-available, cost-effective technologies could save U.S. taxpayers an additional $1 billion per year.[15]

Energy efficiency offers tremendous opportunities at the personal level, as well. Compact fluorescent light bulb's (CFL) produce the same amount of light as standard incandescent bulbs, but use 25 percent as much energy.[16] High-efficiency models are now available for most appliances, and can be identified by the Energy Star label. The benefits to consumers from the move to efficiency are illustrated by the air conditioner efficiency standards approved in 2004, which are expected to save American consumers $5 billion in energy costs over the next 25 years.[17]

Focusing on efficiency and conservation alongside solar facilitates the expansion of the solar industry by enabling consumers to more readily afford the technology. As efficiency and conservation enable us to do the same work while using less energy, they also enable us to do that work using a smaller, and thus less expensive solar energy system. This makes solar more feasible for a greater number of people, and increases society's possibilities of meeting a significant portion of our energy needs with a mix of solar and other renewables.

Policy and Incentive Programs that Support Solar

Numerous financial incentives, rules, regulations, and policies are used to encourage the use and development of renewable energy and energy efficiency. These incentives and policies vary around the country and the world. Each state has its own mix of incentives and policies, and while some states offer strong incentives, others offer very few. Incentives and policies can be derived from the Federal government, state governments, local governments, utility companies, and private non-profit organizations.

Governments use incentives and policies as tools to reach their renewable energy and efficiency goals. In recent years many states have established goals to meet a certain percentage of their energy needs from renewable sources by a specific date. Table 1 shows the goals established by the six states with the highest standards. As there is now widespread recognition of global warming and the need to take serious action to mitigate it, it is likely that more states will be implementing policies to increase the use of renewable energy, and that these policies and incentives will become stronger.

Financial incentives for renewable energy include tax incentives, grants, loans, rebates, industry recruitment, bond programs, and production incentives. These incentives can be made available to the residential, commercial, and industrial sectors, as well as public entities (like schools and municipalities) and non-profit organizations. Table 2 charts the types of incentives available in every state, and whether those incentives are sponsored by the State or Local governments, private agencies or utility companies.

Table 1 – Renewable Portfolio Standards – Top Six States

State	Target Year	Percent Renewables
California	2010	20%
	2020	33%
Maine	2017	30%
New York	2013	24%
New Jersey	2021	22.5%
Hawaii	2020	20%
Nevada	2015	20%

Source: www.dsireusa.org, October 1, 2006.

Rules, regulations, and policies that support solar energy include public benefits funds, renewable portfolio standards, net metering, interconnection standards, line extension analysis, generation disclosure, contractor licensing, equipment certification, solar/wind access laws, construction and design standards, requirements to offer green power products, and green power purchasing policies. Table 3 charts the regulations and policies available in each state.

Where does Kentucky stand in relation to other states in offering incentives for solar and other renewables? According to the Database for State Incentives for Renewable Energy (DSIRE), the State of Kentucky offers no financial incentives for solar energy and has only two policy mechanisms that support solar. These are a statewide net metering law and a solar access law, which allows landowners to obtain a solar easement to guarantee access to direct sunlight. The net metering law applies to all investor owned utilities and rural electric cooperatives, requiring them to make net metering available to customers with solar PV systems of 15 kW or smaller.

There are financial incentives available in Kentucky from the Tennessee Valley Authority (TVA) and from a partnership of several non-profit and public organizations. TVA's Generation Partners Program offers a $500 payment upon installation of a PV system or wind generator, and will pay a production incentive of $0.15/kWh for the renewable electricity produced onto the grid. This program is technically available through each of TVA's distributors in Kentucky, but according to the program's website, there are no Kentucky distributors participating in the program, and participation is at their discretion.[18]

The Kentucky Solar Partnership, a project of Appalachia - Science in the Public Interest, has partnered with the Mountain Association for Community Economic Development (MACED) to offer low-interest loans to residents of Eastern Kentucky for solar water heating systems. MACED also offers loans for businesses to purchase renewable energy equipment or for the development of renewable energy businesses. KSP has also partnered with the University of Louisville and the Partnership for a Green City to create a pilot rebate program for solar water heaters, using funding from the US Department of Energy. This program has offered $500 rebates for residential solar water heaters installed in Kentucky, but has funding to provide only 25 rebates.

Tables 2 and 3 show that Kentucky is far behind many other states in supporting solar energy. Kentucky is one of only three states in which the State government offers no form of financial incentive for renewable energy. Meanwhile 19 state governments offer a rebate program for renewables, and in 20 states utilities or local governments offer rebate programs. Table 4 offers examples of the rebates offered in several states.

In regards to policies and regulations, Kentucky is one of 35 states that have passed net metering laws, an important regulation for helping the PV market expand. Around the nation there are many instances of utilities taking the initiative to offer net metering. Despite this progress, Kentucky remains one of 15 states that have implemented two or fewer of the suite of policies reviewed by DSIRE. Notably absent in Kentucky are Public Benefits Funds (PBF) (also known as Clean Energy Funds or Sustainable Energy Funds) and a

TABLE 2 - DATABASE OF STATE INCENTIVES FOR RENEWABLE ENERGY
Financial Incentives – Source www.dsireusa.org

State/Territory	Personal Tax	Corporate Tax	Sales Tax	Property Tax	Rebates	Grants	Loans	Industry Recruit.	Bonds	Production Incentive*
Alabama	1-S					1-S	1-S			1-U
Alaska							2-S			1-U
Arizona	3-S	1-S	1-S	1-S	4-U					
Arkansas										
California	1-S			1-S	2-S, 19-U, 2-L	1-L	2-U, 1-S			1-S
Colorado					4-U, 1-L		1-U, 1-L			1-L
Connecticut				1-S	1-S	5-S	4-S			
Delaware					1-S	2-S				
Florida		2-S	1-S		1-S, 2-U	1-S				
Georgia			1-S							1-U
Hawaii	1-S	1-S			3-U		2-U, 1-L	1-S	1-L	
Idaho	1-S		1-S			2-P	1-S		1-S	
Illinois				1-S	1-S	1-S, 1-P				
Indiana				1-S		1-S				
Iowa	1-S	1-S	1-S	3-S	3-U	1-S	2-S			
Kansas				1-S		1-S				
Kentucky					1-P		1-P			
Louisiana				1-S			1-S			
Maine					1-S	1-S				
Maryland	2-S	2-S	1-S	2-S	1-S, 1-L		2-S			
Massachusetts	3-S	5-S	1-S	1-S	1-S, 1-U	3-S	2-S, 1-U			1-S, 1-P
Michigan				1-S		4-S		2-S		
Minnesota			2-S	1-S	1-S, 11-U	2-U	3-S			1-S, 3-U
Mississippi							1-S			1-U
Missouri		1-S				1-S	1-S			
Montana	2-S	1-S		3-S		2-P, 1-U	1-S			
Nebraska		1-S			3-S		1-S			
Nevada				3-S	1-S					1-S
New Hampshire				1-S	1-S, 1-U		1-S			
New Jersey			1-S		1-S	2-S	1-S			1-S
New Mexico	1-S	1-S	1-S						1-S	1-U
New York	2-S	1-S	1-S	2-S	3-S, 2-U	1-S	2-S	1-S		
North Carolina	1-S	1-S		1-S			1-S			1-U, 1-P
North Dakota	1-S	1-S	1-S	2-S						
Ohio		1-S	1-S	1-S		2-S	2-S	2-S		
Oklahoma		1-S						1-S		
Oregon	1-S	1-S		1-S	2-S, 7-U	2-P, 1-S	1-S, 5-U			
Pennsylvania					1-L	2-S, 4-L	2-S, 5-L			1-U
Rhode Island	1-S		1-S	1-S	1-S, 1-U					1-P
South Carolina	1-S	2-S			1-S					
South Dakota				2-S						
Tennessee				1-S			1-S			1-U
Texas		1-S		1-S	4-U			1-S		
Utah	1-S	1-S	1-S							
Vermont			1-S		1-S	1-U				1-U
Virginia				1-S		1-S		1-S		
Washington			1-S		8-U	2-P	6-U	1-S		3-U, 1-S
West Virginia		1-S		1-S						
Wisconsin				1-S	1-S, 2-U	2-S, 1-U	1-U			2-U
Wyoming			1-S		1-S					
District of Columbia						1-S				
Palau										
Guam										
Puerto Rico	1-S		1-S							
Virgin Islands										
N. Mariana Islands										
American Samoa										
Totals	**25**	**27**	**20**	**37**	**104**	**53**	**60**	**10**	**3**	**27**

* In addition to these incentives, some private renewable energy credit (REC) (also know as green tag) marketers provide production-based incentives to renewable energy project owners. See http://www.eere.energy.gov/greenpower/markets/certificates.shtml?page=2 for more information about REC marketers.
Note: This table does not include incentives for renewable fuels and vehicles. For these incentives, go to http://www.eere.energy.gov/afdc/laws/incen_laws.html

TABLE 3 - DATABASE OF STATE INCENTIVES FOR RENEWABLE ENERGY

Rules, Regulations & Policies – Source www.dsireusa.org

State/ Territory	PBF	Disclosure	RPS	Net Metering	Inter-connection	Extension Analysis	Contractor License	Equipment Certification	Access Laws	Construction & Design Standards	Green Power Purchase	Required Green Power
Alabama												
Alaska									1-S			
Arizona			1-S	2-U	1-U	1-S	1-S	1-S	1-S	2-S, 1-L	1-L	
Arkansas				1-S	1-S			1-S		1-S		
California	1-S	1-S	1-S	1-S	1-S		1-S		2-S, 8-L	2-S, 2-L	4-L	
Colorado		1-S	1-S, 1-L	1-S, 6-U	1-S, 1-U	1-S			1-S, 2-L	1-S, 3-L	2-L	
Connecticut	1-S	1-S	1-S	1-S	1-S		1-S				1-S, 1-L	
Delaware	1-S	1-S	1-S	1-S	1-S							
Florida		1-S	1-U	2-U	1-S		1-S	1-S	1-S, 1-L	1-S		
Georgia				1-S	1-S				1-S			
Hawaii			1-S	1-S	1-S		1-S		1-S	2-S		
Idaho				2-U	2-U				1-S			
Illinois	1-S	1-S	1-S	1-U	1-U					1-L	1-S	
Indiana				1-S	1-S				1-S			
Iowa		1-S	1-S	1-S	1-S				1-S		1-S	1-S
Kansas					1-S				1-S			
Kentucky				1-S					1-S			
Louisiana				1-S	1-S			1-S				
Maine	1-S	1-S	1-S	1-S				1-S	1-S	1-S	1-S	
Maryland		1-S	1-S	1-S	1-S				1-S	2-S	1-S, 2-L	
Massachusetts	1-S	1-S	1-S	1-S	1-S				1-S		1-L	
Michigan	1-S	1-S		1-S	1-S		1-S			1-S		
Minnesota	1-S	1-S	2-S	1-S	1-S			1-S	1-S	1-S		1-S
Mississippi												
Missouri			1-L		1-S				1-S			
Montana	1-S	1-S	1-S	1-S, 1-U	1-S				1-S			1-S
Nebraska									1-S			
Nevada		1-S	1-S	1-S	1-S		1-S		1-S	2-S		
New Hamp.				1-S	1-S				1-S			
New Jersey	1-S	1-S	1-S	1-S	1-S				1-S	1-S	1-S	
New Mexico			1-S	1-S	1-S	1-S			1-S	1-S		1-S
New York	1-S	1-S	1-S	1-S	1-S				1-S		1-S, 1-L	
N. Carolina				1-S	1-S				1-L	1-L		
North Dakota				1-S					1-S			
Ohio	1-S	1-S		1-S, 1-L	1-S				1-S			
Oklahoma				1-S								
Oregon	1-S	1-S		1-S, 1-L	1-S				1-S, 2-L		1-L	
Pennsylvania	1-S	1-S	1-S	1-S	1-S						1-S	
Rhode Island	1-S	1-S	1-S	1-U	1-S				1-S	1-S		
S. Carolina											3-L	
South Dakota												
Tennessee									1-S			
Texas		1-S	1-S, 1-L	1-S, 2-U	1-S	1-S				1-S		
Utah				1-S	1-S		1-S		1-S		1-L	
Vermont	1-S	1-S	1-S	1-S	1-S							
Virginia		1-S		1-S	1-S				1-S, 1-L			
Washington		1-S		1-S, 1-U	1-S				1-S	1-S	2-L	1-S
West Virginia												
Wisconsin	2-S		1-S	1-S	1-S		1-L	1-L	1-S, 1-L	1-S	1-S, 1-L	
Wyoming				1-S	1-S							
D.C	1-S	1-S	1-S	1-S	1-S							
Guam										1-S		
Puerto Rico								1-S				
Totals	**19**	**25**	**28**	**56**	**41**	**4**	**9**	**8**	**50**	**31**	**29**	**5**

Renewable Portfolio Standard (RPS). Seventeen states now have Public Benefits Funds and 22 have Renewable Portfolio Standards.[19]

Public Benefits Funds are usually state-level programs created to provide resources for the development of renewable energy resources, energy efficiency initiatives, and low-income support programs. These funds are usually supported by surcharges on electricity consumption assessed to all electricity customers in the state or jurisdiction. These can be expressed as a flat fee on each utility bill (ie. $0.05/month), a percentage of each utility bill (i.e. 3%), as an added charge per kWh used (i.e. $0.002/kWh), or by other means. While these funds were typically established through the electric utility restructuring process, they can be used in any state as a means to create a substantial pool of funds for developing solar and other sustainable energy initiatives.

Table 4 – Solar and RE Rebate Offerings in Selected States

State or Utility	Incentive Amount	Eligible Technologies
Delaware	50% installed cost	Solar Water Heat, Photovoltaics, Wind, Geothermal Heat Pumps, Biodiesel Manufacturing Facilities, Fuel Cells (Renewable Fuels)
Florida – Jacksonville Electric Authority (JEA)	Residential: $400 - $800 Commercial: 15% - 30%	Solar Water Heaters
Maine	Varies by system type and size, PV Maximum: $7,000 Solar thermal max: $1,250	Solar water heaters, solar space heat, PV
Maryland	20% equipment cost	Solar water heating, solar thermal process heat, PV
Minnesota	$2/watt DC	PV
New Jersey	$0.15 - $5.00/W DC (varies by technology, capacity and applicant type)	Photovoltaics, Landfill Gas, Wind, Biomass, Anaerobic Digestion, Fuel Cells (Renewable Fuels)

Source: www.dsireuse.org, October 1, 2006

"Renewables Portfolio Standards (RPS) require that a certain percentage of a utility's overall or new generating capacity or energy sales must be derived from renewable resources."[20] California's RPS is 33% renewables by 2020; New York's standard is 25% renewables by 2013. By establishing a goal that utilities know they will have to meet, an RPS motivates utilities to invest in renewable energy and is one of the most important policy measures for expanding the use of renewables, along with Public Benefits Funds.

Renewable Energy Production Incentives, also known as Feed-In Tariffs, are payments made to producers of renewable energy per kWh generated. TVA's Generation Partners Program provides a production incentive of $0.15/kWh. Unlike rebates and tax credits, which are usually based on the size of the system installed, production incentives are based on the performance of the system and "can often be a more effective mechanism for ensuring quality projects."[21]

Germany has been using several mechanisms to promote renewable energy since the early 1990's, including "tax incentives, below-market-rate loans, and feed-in tariffs that guarantee payment for renewable energy fed into the electricity grid."[22] Germany's system guarantees payment for renewable energy production with long-term contracts (20 years for most technologies), providing security for investors. A recent report concluded that "Europe's experience reveals that feed-in tariffs may promote renewable energy most quickly and at least cost in the long run."[23] The same report notes that Germany's renewable energy policies had generated up to 170,000 jobs as of 2005.

Regional Solar Efforts

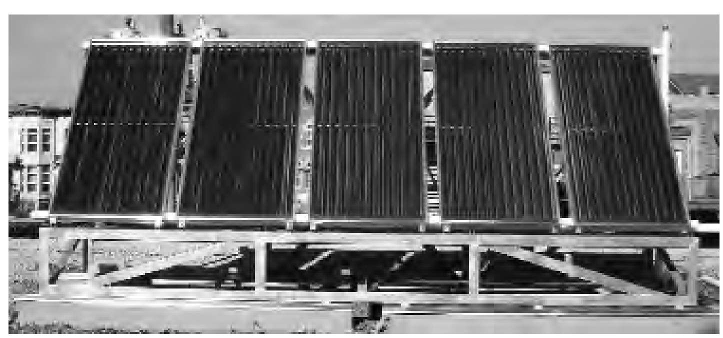
Going Solar in Chicago

A number of regional efforts illustrate some of the exciting progress being made to advance the use of solar energy. In 2001 the City of Chicago announced the goal to provide 20% of its energy from renewable sources by 2005. As part of this plan, the City agreed to install solar thermal systems on over 100 City buildings by 2006 and committed $5 million to the effort. A key element of the City's plan was working with Solargenix, a manufacturer of solar thermal collectors, to support the opening of a manufacturing facility in downtown Chicago. The City provided a $1.7 million loan to Solargenix and committed to purchasing $5 million of solar collectors for City buildings.

Chicago's initiative provided economic development while expanding the use of solar energy, and is expected to save Chicago almost $7 million in energy costs over the next 30 years. Since opening their manufacturing facility, Solargenix has been training local contractors in the design and installation of solar thermal systems, building the City's knowledge base about solar energy. The solar water heating systems are being installed on fire stations, swimming pools, and other appropriate public facilities. The establishment of a solar factory in Chicago complements rebates available throughout Illinois, which cover 30% of the installation cost for solar PV and solar water heating systems.[24]

Citizen's Energy Cooperative of Wisconsin

The Citizen's Energy Cooperative of Wisconsin (CEC) presents a noteworthy model for expanding the use of solar energy. Drawing on the resources of its members, CEC owns and operates multiple large scale renewable energy systems in Wisconsin. These systems are housed in YMCA's, schools, hospitals, multi-unit housing facilities, correctional institutions, and industrial and commercial facilities. To-date, most of the systems CEC has installed have been solar water heaters.



Solar hot water collectors on the roof of a fire station in Chicago. Photo: Andy McDonald

The renewable energy produced at these facilities is metered and sold to the host. CEC enters into contracts with each host, linking the price of the energy produced to a point lower than the market rate of the displaced conventional fuel (usually natural gas or electricity). CEC retains ownership of the equipment for 20 years. The host benefits by guaranteeing energy costs lower than the conventional alternative. The CEC profits from the sale of the energy and distributes profits to its members.

"The monies received by CEC via energy production contracts with its members, are dedicated to the expansion of renewable energy systems throughout the state. After joining, the member is able to contract with CEC each year to produce a specific amount of renewable energy. CEC then guarantees that it will build systems that will produce enough energy to satisfy the members' energy contracts. CEC then sells the renewable energy to the end user/member that is located at the installation site. CEC funds the installation of the system, then recoups its investment by billing the facility for the cost of energy used based on the market price for that energy. When the Cooperative is profitable from the sale of the renewable energy, the members receive dividends based upon their patronage (energy production contracts) with CEC."[25] (http://www.cecofwi.com/commercial-systems, October 1, 2006)

CEC also offers the sale and installation of residential solar water heating systems. By working as a cooperative and buying equipment in bulk, CEC is able to offer lower prices to its customers.

Solar Energy Developments in Kentucky

A network of individuals and organizations has been working for many years to develop the use of solar energy in Kentucky. The organization I work with, Appalachia - Science in the Public Interest (ASPI), has been using and demonstrating passive and active solar energy systems at our demonstration centers in Rockcastle County, Kentucky for over 25 years. We have publications in our library produced by the Kentucky Division of Energy in the 1980's featuring numerous passive solar homes built in Kentucky, along with directories of Kentucky's solar energy professionals published over 20 years ago. The use of solar energy is not new to Kentucky, but through the efforts of many people, it may be gaining momentum and be ready for application on a much broader scale.

ASPI formed the Kentucky Solar Partnership (KSP) in 1999 as a partner of the US Department of Energy's Million Solar Roofs Initiative. ASPI is a non-profit organization that works out of Mt. Vernon and Frankfort, Kentucky. Our mission is to work for healthy land and sustainable communities in Kentucky and Central Appalachia.

The Kentucky Solar Partnership's goals are to identify the barriers to the use of solar energy in Kentucky and work to remove those barriers. Since its formation, KSP has installed the first net-metered PV system in the state at ASPI's Small Town Demonstration Center in Mt. Vernon; installed a demonstration solar water heater, also in Mt. Vernon; worked with community partners to help pass the state's net metering law in 2004; and helped install other demonstration solar energy systems around the region. For many years ASPI and KSP have hosted the National Tour of Solar Homes in Central and Eastern Kentucky, organizing groups to tour ASPI and numerous solar buildings in the region.

In 2005 KSP published *The Kentucky Solar Energy Guide* and unveiled two new websites to bring regional solar information to a wider audience. The Kentucky Sun Pages at www.greenprofessionals.org/ky provides an online directory of renewable energy and green building professionals serving Kentucky. This free directory allows solar and other "green" professionals to register their business and describe the services they provide. By creating a searchable online directory, KSP sought to make it easier for people interested in using solar and green technologies to find professional contractors. KSP's other website, www.kysolar.org, provides information about solar energy, KSP's programs and upcoming events, and a downloadable version of *The Kentucky Solar Energy Guide*.

KSP initiated two incentive programs to support the installation of solar water heaters in 2005. In partnership with the Mountain Association for Community Economic Development (MACED), a low-interest loan program was created and made available to residents of MACED's service area (51 counties in Eastern Kentucky). Loans are available for residential solar water heating systems. MACED also offers loans for businesses to install renewable energy equipment and for renewable energy business development. As of September 2006, eleven loans had been issued for residential systems, along with two business development loans.

Through a partnership with the Energy Center at the University of Louisville, KSP also established a $500 rebate program for solar water heaters installed on residences in Kentucky. This pilot program, funded by the US Department of Energy, provided funding for 25 rebates. The program specifies that each system installed should be inspected to ensure the it meets program guidelines and equipment specifications, and that it is working properly. As of September 2006, 23 rebates have been approved.

One of the barriers to the expanded use of solar energy in Kentucky has been a shortage of skilled contractors trained in solar electric and solar water heating systems. To address this issue, KSP has held two trainings for solar water heater installers. Over twenty five people attended each of these two-day trainings, and Kentucky now has a growing number of trained solar contractors. Further workshops covering PV design and installation are planned for the coming year.

A major regional effort for educating the public and building the market for solar has been the Bluegrass Energy and Green Living Expo, first held in 2004 in Lexington. This has become an annual event, organized by ASPI and KSP to bring together the business, education, government, and non-profit sectors to educate Kentuckians about healthy living, energy conservation and renewable energy solutions, and connect consumers with marketers of related products and services. Attendance at the Expo increased by 32% from 2004 to 2005, with over 1,100 people attending the tradeshow, workshops, and other events in 2005.

Another regional advocate for solar energy is Berea College and its Sustainability and Environmental Studies (SENS) Program. The Ecovillage at Berea College includes student-housing for 50 married and single parents with children. These housing units incorporate passive solar design as well as other green building features. The

Commons House in the Ecovillage uses a solar water heater for domestic hot water and radiant floor heating. Another house includes a solar water heater and a net-metered PV system, installed with the assistance of Joshua Bills and the Kentucky Solar Partnership. Berea College is recognized around the state and beyond for its leadership on sustainability issues, and has been a strong supporter of the Bluegrass Energy and Green Living Expo, as well.

Another significant effort to support the development of solar in Kentucky has been the formation of the Energy Center at the University of Louisville. The Energy Center was founded with a three year grant from the US Department of Energy with a mandate to develop the use of solar technologies and build the local capacity of solar energy professionals. Their projects have included the installation of demonstration solar water heating systems at a number of schools in Jefferson County; a research and demonstration project of daylighting technology in schools; research into solar street lighting in downtown Louisville; research into solar heat pipe technology; professional trainings for PV and solar water heater installers; creation of the solar water heater rebate program administered by KSP (described earlier); and the production of educational solar exhibits at the Kentucky State Fair in 2006.

Numerous schools around Kentucky have also installed solar PV systems as educational and demonstration projects. The KY NEED Project, Kentucky Office of Energy Policy, and American Electric Power have co-sponsored these projects and developed educational programs to accompany them. KY NEED has also organized annual "High Performance Schools Workshops" directed towards school administrators, decision-makers, and building designers. These workshops cover a wide range of topics which include passive solar design, and especially daylighting. With the support of the Kentucky Department of Education and the Kentucky Office of Energy Policy,

Solar Water Heater

many Kentucky schools are now looking at high performance building strategies for their new construction and renovation projects. Daylighting in particular has become an important strategy whose benefits are becoming more widely recognized.

Looking Toward the Future

Kentucky has a broad foundation of experience with solar energy which demonstrates that the technologies work and that solar is a valuable resource in our state. While there is a growing base of professionals skilled with solar energy, the industry is still in its infancy here. Meanwhile, the demand for clean, secure energy sources and meaningful responses to the crisis of global warming point to the need to rapidly develop solar energy along with a variety of other clean energy sources and strategies.

The need to widely expand the use of solar in Kentucky runs up against basic economic facts that solar electric and solar water heating systems are still more expensive than their conventional alternatives, which in Kentucky primarily means coal generated electricity. Cheap electricity is a barrier to both efficiency and solar energy. But this economic relationship does not reflect the true cost of mining and burning coal, nor the true value of solar. People are beginning to recognize these true costs, however, and beginning to demand solutions from government and industry.

Government has a responsibility to serve the common good and this requires shifts in our state energy policy. Widespread use of solar energy, along with aggressive energy efficiency and conservation programs, and the development of other renewable energy resources, could dramatically reduce carbon dioxide emissions, promote energy independence, diversify our energy supply and make the grid more resilient, reduce peak loads, eliminate the need for new power plants, reduce air pollution and the health costs it imposes, and promote economic development. This last point should not be overlooked as the global market for efficiency, renewables, and carbon-neutral technologies seems poised to take off.

With this in mind, the State of Kentucky should step forward and develop a suite of policies and incentives to strongly support solar, other renewables, efficiency, and conservation. These should include a Renewables Portfolio Standard, a Public Benefits Fund to generate the resources needed to invest in new initiatives, a Renewable Energy Production Incentive, rebate programs, and high performance construction and building design standards.

The vision behind these policies should be grounded in a recognition of how our energy use drives global warming and our need to dramatically reduce global emissions of greenhouse gases – an 80 percent reduction by 2050 according to the Intergovernmental Panel on Climate Change. Such a vision will shift how we perceive costs and benefits, and can provide the motivation, courage, and political will to achieve ambitious and necessary goals.

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Kentucky's Energy Future

Nick Comer
East Kentucky Power Cooperative

In the past century, the availability of reliable, affordable electricity has profoundly improved Kentuckians' lives. Our daily routines start with alarm clocks. For many of us, workdays revolve around computers and other electronic equipment. We go home to our refrigerators, washers and dryers, televisions and numerous other electric appliances. On a grander scale, many of the most significant advancements of the past century, including revolutions in medical treatment, transportation and communications, have been made possible by electricity. Clearly, reliable, affordable energy has been fundamental to improving lives. So it is exciting to ponder what the future holds and how our lives will change in the coming decades.

East Kentucky Power Cooperative generates and transmits the power that is distributed by 16 member cooperatives to nearly 500,000 homes, businesses, industries and farms in 89 Kentucky counties. Although cooperatives' roots are in providing power for rural areas, this is changing as suburbs, retail developments and industries move farther from city centers. In fact, demand for electricity among EKPC's member cooperatives is growing at nearly twice the rate of the rest of the nation. Likewise, demand is growing statewide. The state Public Service Commission estimates that Kentucky will need to add 7,000 megawatts of new generation capacity by 2025 in order to meet anticipated demand growth.

It is important to keep in mind that Kentuckians pay some of the lowest electric rates in the nation, even as energy rates have risen. According to the U.S. Energy Information Administration, 2005 average retail rates in Kentucky were 40 percent below the national average. This is due, in large part, to the fact that Kentucky is blessed with abundant, affordable coal, the same fuel that generates more than half of the nation's power. Besides being a plentiful domestic energy resource and less expensive than its competitors, coal claims a brighter future with the development and demonstration of cleaner and more efficient technologies. As East Kentucky Power Cooperative implements such technologies, the cooperative supports a valuable natural resource, produces cleaner electricity and meets the power needs of the cooperative's members efficiently and affordably.

Since the passage of the Clean Air Act more than three decades ago, utilities have taken major steps to reduce their impact on the environment. And that costly investment will continue into the future. In fact, the greatest transformation Kentuckians are seeing in power generation today is reduced emissions from the power plants that produce their electricity. As a result, the generating units coming online today bear little resemblance to those of 50 years ago or even 20 years ago. East Kentucky Power Cooperative has been a pioneer of clean-coal technologies. In 2005, the cooperative brought online Kentucky's first coal-powered generating unit in 15 years, the E.A. Gilbert Unit at Spurlock Station in Mason County. The 268-megawatt unit is powered by a clean-coal technology known as circulating fluidized bed (CFB).

In the CFB boiler, a coal/limestone mixture burns at significantly lower temperatures than in conventional coal boilers. Ash and unburned coal are recirculated through the boiler on a bed of air and continue to burn until a very low volume of particles remains. Lime from the limestone absorbs 98 percent of the sulfur dioxide, and the lower boiler temperature means that significantly less nitrogen dioxide is produced—about 20 percent of conventional coal units. East Kentucky Power Cooperative's new CFB unit ranks as one of the cleanest coal units in America and is the cleanest in Kentucky. And the cooperative plans to construct two additional CFB units in the next four years, an investment of more than $1 billion.

For East Kentucky Power Cooperative, the decision to implement CFB technology was a strategic one. Comparisons with another emerging clean-coal technology—integrated gasification combined cycle (IGCC)—show that CFB matches or exceeds IGCC in almost all emissions categories. It should be noted that commercial utility applications of IGCC are still in development and face years of pilot projects. In 2004, the president of the Pew Center on Global Climate Change characterized IGCC technology as "nowhere near prime time" in terms of its readiness for commercial utility applications.

Because of CFB technology's low emissions, East Kentucky Power Cooperative can continue to fuel its units with affordable coal and still meet increasingly stringent clean-air standards. In fact, CFB technology reduces emissions to levels that allow the use of very affordable grades of coal, including waste coal, while meeting strict clean-air standards. This is a benefit to Kentucky ratepayers because market prices for low-sulfur "compliance" coal have increased steadily in recent years as utilities strive to cut emissions. The CFB unit also can be fueled with other supplemental fuels such as waste tires and biomass. It is important to note that CFB is a proven technology, with commercial applications in operation at the time the technology was needed by East Kentucky Power Cooperative. As a result, projects can be financed easier for the cooperative.

As the cooperative constructs some of the cleanest coal units in the nation, East Kentucky Power Cooperative is also taking steps to reduce emissions from its existing conventional generating units. This year, construction began on a pair of flue-gas desulfurization units, known as scrubbers, that will reduce sulfur dioxide and particulate emissions from the cooperative's two largest generating units. These scrubber units will cost approximately $300 million to install and will complement other environmental compliance steps East Kentucky Power Cooperative has taken in the past 15 years at a cost of $250 million to $300 million. In recent years, for example, East Kentucky Power Cooperative added selective catalytic reduction (SCR) equipment to the same generating units. Operating like catalytic converters on your automobile, this equipment is designed to reduce emissions of nitrogen oxide by nearly 90 percent.

Great strides have been made throughout the United States in lowering emissions. According to a September 2004 report from the U.S. Environmental Protection Agency, total nationwide annual emissions of six principal air pollutants (nitrogen dioxide, ozone, sulfur dioxide, particulate matter, carbon monoxide, and lead) dropped an incredible 51 percent between 1970 to 2003, from 301.5 million tons a year to 147.8 million tons. This is especially impressive when you consider that during the same 33-year period, the overall economy grew 150 percent, the gross national product increased by 176 percent, energy consumption was up by 45 percent and the population grew by 39 percent.

There still is work to be done to further reduce emissions. That is why East Kentucky Power Cooperative has partnered with Western Kentucky University's Institute for Combustion Science and Environmental Technology to produce cutting-edge research on clean-coal technology. Led by noted chemist Dr. Wei-Ping Pan, the institute is working to help utilities reduce mercury emissions in order to meet caps on these emissions starting in 2010 as part of the EPA's Clean Air Mercury Rule. In addition, the institute conducts research to make coal units more efficient and environmentally friendly, and conducts emissions analysis. East Kentucky Power Cooperative, along with Warren RECC, is supporting the institute's effort to install a gasifier to study the fate of mercury and other chemicals in the gasification process. The cooperative also contracts with the University of Kentucky's Center for Applied Energy Research to study the use of fly ash for fuel, including ash from CFB boilers.

East Kentucky Power Cooperative has also been a Kentucky pioneer in energy alternatives, particularly power from landfill gas. As landfill waste breaks down, it produces methane, a greenhouse gas. East Kentucky Power Cooperative was the first Kentucky utility to develop power plants fueled by methane gas. And this year the cooperative broke ground for its fifth such plant, this one in Pendleton County. Others are located in Boone, Greenup, Hardin and Laurel counties. When its newest plant is operational, the cooperative will have the capability to produce enough electricity from landfill gas sources to power nearly 9,500 Kentucky homes. The power produced by these landfill gas plants is marketed by 14 Kentucky electric cooperatives under the EnviroWatts program, giving cooperative customers the option to power their homes or businesses with electricity generated from renewable sources. In addition, East Kentucky Power Cooperative has studied the feasibility of wind energy. Reliable wind-producing sites in the commonwealth are scarce and tend to be located in environmentally sensitive areas, making this technology economically unfeasible at this time.

A key component of ensuring the reliable delivery of power for Kentucky consumers is the transmission grid–the high-voltage power lines that deliver electricity from generators to distribution points. As new electric generating units come online to accommodate our state's rapidly growing demand, East Kentucky Power Cooperative is acutely aware of the need for additional transmission facilities. The cooperative has more than 2,800 miles of transmission lines in service and is planning projects that will add more than 260 additional miles of line in the next five years. Meanwhile, federal officials have pushed in recent years for more regionalized power markets, with power transfers occurring over longer distances. While broader power market means more options for backup power, which increases reliability, it also places much greater demands on transmission systems that, for the most part, were designed for local or state consumers.

As regional power transfers increase and as East Kentucky Power Cooperative's members' demand for electricity continues to grow at nearly twice the national rate, congestion on power lines builds. As a result, it is necessary to constantly improve, upgrade and add to the transmission grid. Without improvements, reliability and the cost to serve members suffers as power line congestion leads to the risk of blackouts and the uneconomic dispatch of generating units. The widespread blackouts that struck the northeastern United States and Canada in August 2003 demonstrated the risk posed to large areas when blackouts cascade across the power grid.

Utilities are facing, and will continue to face, increased challenges to constructing transmission facilities. Property owners and other concerned parties are mounting increasing opposition to transmission projects, citing such concerns as aesthetics and the perceived impact to the environment. A key challenge for transmission owners is balancing such concerns and minimizing overall impacts while making necessary improvements to ensure the reliability of the transmission grid. With these goals in mind, East Kentucky Power Cooperative has begun implementing a new transmission line siting methodology for significant projects. Developed by the Electric Power Research Institute and Georgia Transmission Corp., this methodology incorporates the use of aerial photography and vast amounts of data concerning land use and land cover. This information is analyzed to identify the most suitable routes for a transmission line between two given points. The analysis includes a suitability scoring system that was developed with input from Kentucky stakeholders representing interests ranging from environmental activists to homeowners groups to agricultural associations. In addition, East Kentucky Power Cooperative has implemented a formal program to reach out to property owners and other interested parties to keep them informed and to gather information as the cooperative plans and constructs new, significant transmission projects.

Generating and transmitting power to serve more than a million Kentuckians is a risky and capital-intensive endeavor, and will continue to be so. These formidable costs and risks have increased in recent years as growing economies in Asia have sparked a power plant building spree there, driving up the costs of fuels and building materials around the globe. In the future, we can expect to see similar far-ranging repercussions in all kinds of markets, as local markets increasingly become global markets. Developments in other states, nations and continents will have an increasing impact on the job of ensuring rates and reliability here in Kentucky.

The task of generating electricity and delivering it to homes and businesses has changed immensely in the past century. Without doubt, the next century will see similar transformations. Perhaps, a hundred years from now, we won’t even recognize power plants and transmission lines as we know them today. One thing that is unlikely to change is the importance of affordable, reliable power to our lives.

The Connection between Energy Use and Air Quality

Michelle Stites
Environmental Coordinator
Louisville Metro Air Pollution Control District

View the Louisville skyline from across the Ohio River on a clear night and you see all the hallmarks of a vibrant city. Tall buildings light up the night as cars and trucks carry residents and visitors alike to an untold number of destinations. Spend a day in the city and observe a thriving community with people living, working and enjoying their leisure time. During these daily activities, the role of energy often goes unnoticed. Unfortunately, on occasional days, the result of our energy use does not. Smog and other air pollutants are the more undesirable results of the energy that sustains our community.

Air pollution emissions associated with energy use in the Louisville Metro area result almost entirely from the combustion of fossil fuels. These fuels, which include coal, natural gas, and petroleum products such as oil, diesel, and gasoline, are the decomposed and compacted remains of once living organisms. Through various extraction techniques, these fuels are pulled from their geologic deposits and burned to unleash the stored energy. Extraction techniques tend to be very energy intensive themselves and are often incredibly polluting, as are the processes sometimes necessary to refine these fuels into the products that we use daily. Thus begins the impact of energy use on air quality.

What are the sources of energy-related pollutants?

The combustion of fossil fuels creates byproducts, or pollutants, many of which are harmful to our health and to the environment. There are two broad categories of sources for these pollutants – point sources (this includes the regulatory nomenclature of "stationary" and "area" sources), which are those sources that are generally at a fixed location, and mobile sources. These varied sources release emissions into the ambient air, which is to say into the surrounding atmosphere, where they begin to take their toll on human health and the environment.

The image of the tall stacks of power plants with smoke-like puffs billowing from them is a familiar sight to most in the country, certainly to denizens of Kentucky where the majority of our electricity is derived from coal fired plants. In fact, the utility that serves much of Metro Louisville, Louisville Gas & Electric (an E.On company) (LG&E), has an electric service area that is 97.75% supplied by fossil fuel derived electricity. In more recent times, thanks to the installation of pollution controls required by Clean Air Act amend-

One of LG&E's coal-fired power plants - Cane Run Station

ments, most of the visible emissions from power plants are actually steam from “scrubbers” that remove the majority of the sulfur dioxide and much of the particulate matter as well. This is certainly true at LG&E’s three coal-fired power plants, Trimble County Station, Cane Run Station and Mill Creek Station.

The other 2.25% of the electricity supplied by LG&E is generated by the Ohio Falls Hydroelectric Station (OHFS), one of the 5 hydroelectric facilities on the Ohio River. OFHS, which has a capacity of 80MW (based on nameplate ratings), is a run-of-river facility, meaning that it operates only when water level and flow conditions permit. This often means that during summer’s peak hours, when electricity demands are at their highest, OFHS is not operating due to low river levels.

In addition to these workhorses of the electric grid, LG&E also maintains six combustion turbines, which are powered by natural gas. Some of these use fuel oil for “cold starts,” meaning that they are able to start operating and generating electricity in blackout conditions. These facilities are not in constant operation; rather they are put into use at times when energy demand is at its highest. Those peak hours of need generally occur during the summer when heavy use of air conditioning is occuring across all sectors.

Many industrial and commercial facilities use fossil fuels to generate steam for heat as needed on site. This steam may be used for heating a facility, such as the boilers that heat the University of Louisville Belknap Campus through steam distribution. Or, this steam heat could be a necessary input at some point in an industrial process. For instance, such steam heat is necessary in the chemical production cycles at the American Synthetic Rubber and the Oxy Vinyls plants in Louisville’s Rubbertown area. The fuel used for these purposes can vary from facility to facility. Several facilities use coal fired boilers to fulfill their needs, but other more unique solutions can be found as well. Rohm and Haas’ Louisville production facility, for example, uses hazardous waste generated by their production activities as a fuel for its burners. This method of waste disposal also provides the necessary heat input for their manufacturing processes. Also, General Electric Company’s Appliance Park has for many years made use of methane collected from Waste Management, Inc.’s Outer Loop Recycling and Disposal Facility as a fuel for heat and steam.

LG&E also supplies natural gas for consumers in the industrial, commercial and residential sectors. Industrial uses comprise roughly a third (32%) of the natural gas use in the U.S. In many areas of the nation natural gas is used to fuel power plants, making electric generation the second largest user (29%) of natural gas. Residential users account for nearly a quarter (24%) of the consumption for uses such as home heating, cooking and water heating. The remaining portion of natural gas use is mainly by the commercial sector with a small fraction (less than 1%) going to fuel for vehicles running on compressed natural gas.

Natural gas is primarily comprised of methane, a relatively simple carbon molecule, and combusts much more cleanly than other fossil fuels. Consequently, the quantity of emissions resulting from the use of natural gas is much lower than the amount of corresponding emissions from the use of coal or oil. The production, storage and delivery of natural gas can also result in air pollution as small amounts of methane may leak out at any number of points in the supply chain. While not a regulated pollutant, methane is a potent greenhouse gas so these comparatively small releases can add up when considered on a national or global scale.

The number of vehicles on the road has increased by 112% since 1970.

Along with these fixed locations for fuel consumption, the other major source of emissions associated with energy use is the myriad of mobile sources that the advent of the internal combustion engine has given rise to. Americans are in their cars more than ever and the trend is continuing upward. Each year since 1970 the vehicle miles traveled in America has far outpaced the corresponding growth in population. This transportation sector is only a portion of the mobile source category, which is comprised of two basic groups: On-road and non-road.

As one would imagine, on-road vehicles are those traveling along our highways and avenues in numbers that grow by the day. They are automobiles, motorcycles, SUV’s, pickup trucks, heavy-duty trucks, minivans and buses, the things that most of us rely on to get us and our consumer goods to where we need to be on a daily basis. Petroleum products, chiefly gasoline and diesel, fuel the vast majority of these vehicles. However, there are alternatives to these traditional mobile source fuels that are becoming more available. Ethanol and biodiesel are both renewable fuels manufactured from agricultural products. Each of these fuels has roots dating back to the invention of the internal combustion engine. Although they have seen an impressive increase in attention in recent years, biofuels still constitute only a small fraction of the fuel used in this country.

Since 1970, on-road emissions have decreased in almost every category despite increased numbers of vehicles on the road. One sector in which this does not hold true is the heavy-duty diesel truck, where emissions of oxides of nitrogen have risen significantly since 1970. In January 2001 EPA finalized its 2007 Clean Diesel Rule. By addressing fuel and engine technology at the same time, the EPA is anticipating that when the current, in-use heavy-duty diesel fleet is replaced, around 2030, the reduction in emissions will be equivalent to removing 90% of today's trucks and buses from the road. In the meantime, ultra low sulfur diesel (ULSD), which became widely available at the pump this fall and will be fully phased in by 2010, will reduce emissions from existing vehicles and will allow for the use of pollution control technologies on all heavy-duty diesel engines starting with the 2007 model year.

Emissions have also grown from the other type of mobile sources, non-road engines. Also referred to as off-road, this group includes equipment for lawn and garden, construction, agriculture, marine and aeronautical applications as well as railroad engines. These sources went largely unregulated until the Clean Air Act was amended in the 1990s and still lag behind regulations for on-road sources. The larger equipment's engines are predominantly diesel and have not been subject to the same regulations that have kept on-road emission in check. That, however, is beginning to change as the 2007 Clean Diesel Rule also contains requirements for the fuel and engine technologies used in this market with phase-in periods that are staggered behind the on-road requirements by only a few years.

What is happening in Metro Louisville to lower emissions associated with energy use?

On April 22, 2005, Earth Day, Mayor Abramson signed the U.S. Mayor's Climate Protection Agreement, which was later unanimously endorsed by the U.S. Conference of Mayors. A year and a half later 313 mayors had signed on to the agreement and the number is still growing. Under this agreement participating cities seek to reduce their greenhouse gas emissions and to encourage the adoption of policies and legislation at the state and federal level to address the growing problem of climate change. Reductions are possible from a variety of approaches, including land use policies, transportation options, building code and maintenance choices and fleet fuel efficiency. To meet these goals and to improve the overall quality of the city's air, Louisville has expanded its efforts using interdepartmental collaborations and partnerships with organizations outside of Metro Government.

The Metro Green Team is a body of volunteer Metro employees from multiple departments that has met for several years (under varying committee names before and after the city and county governments' merger) to discuss the various environmental impacts of our local government and ways in which they could be mitigated. Through this group, ideas and information are exchanged between departments and many success stories have hinged on its members. Early progress has been made in the area of resource conservation through the implemented practices of double-sided copying, the use of recycled content paper for both the office and for city publications, and recycling of toner and inkjet cartridges. With these policies and others like it in place, Metro government has turned its attention to another critical area of its operations, energy use.

Through the formation of a Sustainable Buildings and Energy Efficiency Committee, Metro Louisville has undertaken a review of its Environmental Management Systems Manual, looking specifically to update those sections dealing with energy efficiency. This team has also been tasked with making specific recommendations for ways in which Metro Government operations can conserve energy and move to a more sustainable state. Metro Government has already begun to take steps toward more energy efficient operations and practices. For instance, occupancy sensors have been installed at many locations to switch off lights in areas that remain unused for stretches of time, including restrooms and stairwells, and energy efficient lights and ballasts are being put into use. Also, in an effort to reduce the vehicle miles traveled by its employees, Metro Government has provided free TARC (Transit Authority of River City, the public transportation system in Louisville) bus service to its workforce.

Bike Louisville, an initiative of Louisville Metro Planning and Design Services, is an ongoing project aimed at creating a bicycle friendly environment in the city. To meet this goal, Louisville is providing safer on-road facilities for bikes, education for both cyclists and drivers and is raising community awareness of the health benefits of an active lifestyle. This movement was propelled forward in 2005 with the Louisville Metro Bicycle Summit, an event that brought together city officials, transportation professionals and bicycling advocates and enthusiasts. From this Summit emerged the Bicycle Friendly Louisville Plan, a road map for the city's efforts to encourage cycling as both a recreational choice as well as a non-polluting mode of transportation. Since that time Mayor Jerry Abramson has hosted several "Hike and Bike" events, which help get riders out onto city streets in a safe and controlled environment in hopes of encouraging them to continue on their own. It is a testament to the commitment of city officials and the work of Planning and Design Services that Louisville was recently designated a "Bicycle Friendly Community" at the Bronze level by the League of American Bicyclists, two years ahead of the goal set forth in the Bicycle Friendly Louisville Plan.

In another effort, a new committee called "Community of Trees" has been formed to coalesce the efforts of a diverse group of Metro and community specialists in increasing Louisville's urban forest. Healthy urban forests offer a myriad of benefits for cities and their inhabitants. First, trees are nature's air filters. By filtering out NO_2, SO_2, CO, and PM, trees help clear the air of otherwise harmful pollutants. Additionally, trees sequester CO_2 by taking it up through the leaves and storing it as biomass. Trees even prevent the release of energy related emissions by reducing the need for air conditioning. This occurs through direct shading of a building, as well as through prevention of the urban heat island effect, the occurrence of elevated ambient temperatures in urban areas due to the prevalence of darker surface areas (e.g., roads, parking lots, and roofs).

The Community of Trees effort builds on the success of receiving a grant provided by Duke Energy (then Cinergy) for planting 1000 seedlings and 200 caliper trees over three years. These plantings will be distributed among various public lands in the urban services district of Louisville. The grant was the result of a collaborative effort among departments with a shared interest in trees, specifically planning for the life-cycle and eventual replacement when needed. This includes considering what species are selected, where they are planted, and how they will be maintained.

Louisville has nearly completed a city-wide project to convert all Metro-owned traffic lights from incandescent bulb to light-emitting diodes (LEDs). These LEDs are energy efficient and reduce consumption by an average of 80%. Additionally, they save time and money by lowering maintenance costs significantly. LEDs last six or more years instead of an incandescent bulb's lifespan of eight to twelve months. This retrofit project is expected to save 7.5 million kilowatt hours, enough to power 750 homes for a year. A retrofit of all state-owned traffic lights has already been completed, making Kentucky the second state, only behind Delaware, to complete a statewide conversion.

Metro Parks employees plant a tree along one of Louisville's Parkways.

Louisville encourages individuals to help clear the air as well. In 2001 the Louisville Metro Air Pollution Control District (APCD or District) created the Lawn Care for Cleaner Air (LCCA) program. LCCA is a public awareness program that recognizes property owners for minimizing their air emissions from lawn maintenance by re-landscaping, or by switching to cleaner yard maintenance equipment. APCD started small by giving workshops at libraries, and at garden club, neighborhood and community meetings where staff explained the public benefits to reducing gasoline powered lawn maintenance equipment use. Participants were surprised to learn that one-hour's use of a 4-stroke lawnmower produces almost as much smog forming compounds and carbon monoxide as driving 200 miles in a typical car. Gasoline powered string trimmers and leaf blowers generate even higher levels of VOCs. Using native trees, shrubs, perennials and other plants, property owners can create a low maintenance yard that requires up to 50% less work. The program's honorees reduce tons of potential emissions annually in Louisville's ambient air. For example, as of the beginning of 2006 the property owners recognized under this program cut potential emissions of CO_2 by 748 tons and VOCs by 44.2 tons.

The LCCA program was broadened in 2003 with the introduction of a rebate program. APCD offers Louisville Metro residents rebates when they buy new electric-powered lawn equipment or push reel mowers. Additionally, in conjunction with Metro Solid Waste Management, APCD issues a bonus rebate to residents who also recycle a gasoline-powered lawnmower, string trimmer, leaf blower, or batteries for rechargeable models. Participants receive up to $100 depending on the combination of items. Rebates are funded by monies from the assessment of penalties on those violating the District's regulations. By collecting data on how many hours of gasoline-powered yard maintenance activities were avoided, emission reduction calculations at the beginning of 2006 included 521 tons of CO_2 and 30.8 tons of VOCs.

In the winter of 2004-5, APCD was awarded one of two inaugural EPA grants for innovative approaches to reducing air pollution. With this grant APCD held a Low-Maintenance Landscaping Design Competition. Participants submitted designs in four categories and were required to include two additional plant lists for greater reproducibility. First and second place monetary prizes were awarded in each of the categories by a group of professionals who volunteered their time to judge the competition. The 1st place winner in each category received an additional stipend for plant materials to help implement their design on new or existing landscapes.

A Louisville intersection outfitted with energy-saving LED taffic lights.

Winning designs are posted on the District's website (www.louisvilleky.gov/APCD) and free to anyone to incorporate into their property.

The outreach arm of APCD, Kentuckiana Air Education (KAIRE), focuses on educating the public on mobile source issues. Funded by federal transportation dollars, KAIRE raises public awareness in Louisville Metro and the surrounding counties in Kentucky and Southern Indiana. Its primary mission is to educate the public as to the impact of its daily choices and provide information to make better ones. Through advertising campaigns, event sponsorships, booths at diverse public events, a website (www.helptheair.org), and giveaways such as t-shirts and tire gauges, KAIRE works to saturate the community with the message that all individuals can do their part. KAIRE also maintains a notification network and works with the local media to broadcast Air Quality Alerts on those days when the Air Quality Index is forecasted to enter or exceed the "Unhealthy for Sensitive Groups" range.

TARC has been actively pursuing ways to make the energy efficient and less polluting choice of riding the bus an even more environmentally friendly one. As early as 2001 TARC installed throttle modulators on their older diesel engines to reduce emissions from jackrabbit starts and to conserve fuel. In addition to providing cleaner rides, TARC is also making it easier for cyclists to commute further by outfitting its buses with bike racks. These racks have been such a success that TARC is seeking ways to mount more than two bikes at a time on a bus. Also, by voluntarily switching its own fleet to ultra low sulfur diesel years before its use was mandated nationwide, TARC reduced emissions of CO, VOCs, NO_X, and PM. In pursuit of a greener fleet, TARC has already added 5 hybrid diesel buses to its fleet and is actively pursuing the purchase of several more. Those buses achieve 20-25% greater fuel efficiency than the standard diesel bus.

In addition to these and other initiatives by Louisville Metro Government, still more progress is taking place under the guise of the Partnership for a Green City (P4GC, or Partnership). The P4GC is the result of a collaborative effort between Louisville Metro Government, the University of Louisville (U of L) and Jefferson County Public Schools (JCPS). The sheer mass of resources consumed, people employed and land used by these three institutions made it a formidable challenge to form a working partnership between them. Along with this challenge, however, came the possibility of incredible benefits. With more than 500 buildings, 7,000 vehicles and 25,000 acres of land among them, each successful initiative could be multiplied many times over by sharing ideas, savings and bargaining power.

The Energy Use Partnership (EUP), a committee of the P4GC, has been particularly active since its formation. With the goal of reducing energy use in all three institutions, the EUP seeks out new technologies, practices and other opportunities for energy savings and allows for the sharing of information among the participants. To this end the group has benefited greatly from the expertise and guidance of the Kentucky Pollution Prevention Center, which has, among other things, performed audits on 17 Partnership buildings. The purpose of these audits is to identify current building conditions that are not optimal for energy efficiency and to prioritize the correction of these conditions based on cost and payback. KPPC trained students from U of L's J.B. Speed School of Engineering, as well as JCPS students from the J. Graham Brown School and Waggener High School in energy auditing.

The EUP has supported energy efficiency and renewable energy projects by each of the members and, by collecting and analyzing data from each, the committee helps to determine which initiatives merit expanded implementation. In June of 2006, Mayor Abramson announced one such project, the purchase and installation of three solar-powered streetlights in

KAIRE's booth at the Kentucky State Fair, including Claira, the Clean Air Automobile, a game that illustrates how an individual's driving habits can affect how much they pollute.

downtown Louisville. This pilot project will continue through the winter months when solar power will be at its lowest point of availability. U of L faculty and students will monitor the project and will examine whether the downtown location with its tall buildings will be suitable for solar power and which of the three solar panel units, each made by a different manufacturer, is preferable. After this study has run its course the panels will be moved to another location for additional assessments. Some possible uses for this technology include remote locations in Metro Parks; this would alleviate the need for overhead lines or trenching, and for hospitals and other emergency locations where lighting would be vital even during a power loss.

JCPS has also been exploring ways to take full advantage of available solar resources. In addition to testing daylight harvesting ballasts and solar reflectors that throw sunlight from windows further into a classroom, JCPS has already installed and is operating a solar water heater at its Churchill Park Rehabilitation Center. An early starter in the area of energy efficiency, JCPS has been investigating ways to incorporate energy saving technologies into buildings as they are built, a much more cost effective alternative to retro-fitting. This includes improvements to the building's thermal envelope, as well as the solar technologies mentioned previously. Another achievement on the part of JCPS is its "When Not In Use, Turn Off the Juice" pledge. Students and faculty are asked to sign a commitment to conserving electricity by taking responsible steps in their everyday actions, such as turning off the lights when you leave a room or shutting down your computer when the day is over. Stickers bearing this logo have also been placed at strategic points (*e.g*., light switch plates) throughout JCPS facilities.

In addition to its role in providing technical expertise, U of L has also implemented energy-saving projects of its own. One of these projects has been the installation of Vending Misers on beverage machines around campus. The Vending Miser is a device that can be added to any cold beverage vending machine to conserve electricity. By sensing both the ambient temperature around the machine, as well as whether there is anyone in the vicinity of the machine, the Vending Miser will power the machine down when it is not necessary to cool the product or illuminate the sign. U of L will potentially save thousands of dollars a year from reduced electric consumption by these machines, without affecting the quality of the product delivered.

This summer the EUP took a step into another major area of energy consumption and convened a Fleets Subcommittee. Early benefits of this committee's work have included sharing information on the use of biofuels and other alternative fuels. For example, the Metropolitan Sewer District (MSD) has for years been operating a fleet that runs on compressed natural gas. Also, JCPS and Metro Government have both had experience with using biofuels, either ethanol or biodiesel. By sharing this information each Partner benefits from the others' experiences and the group can explore opportunities for increasing alternative fuel use and decreasing overall consumption.

What does the connection between energy and air quality mean to all of us?

Innovative thinking and wise use of existing resources are necessary for sustaining our community's well-being. Regulations will continue to be necessary to protect public health, but there is much that can be achieved through voluntary action on the part of governments, businesses, and individuals. Sometimes that means replacing old equipment with new and improved technology. For instance, simply changing a single incandescent light bulb to an energy efficient compact fluorescent (CFL) will, over the course of its lifetime, prevent 450 pounds of greenhouse gas emissions from a power plant. Other times it may mean changing a habit; making sure that your vehicle is maintained properly at all times or that you change your furnace filter regularly.

No turn of the engine key or flip of the light switch is without its consequences and each person has innumerable opportunities throughout the course of that person's daily life to lessen the impact on the air we breathe. Those opportunities may include weather-proofing your home, car-pooling or using an alternative mode of transportation to get to work, supporting community air quality initiatives, installing energy efficient office equipment at your business, or teaching your children to always turn off the lights when they leave the room; every step is one step closer to a healthier community. After all, it all adds up to cleaner air.

Resources

AIRNow – *http://airnow.gov/*

Kentuckiana Air Education – *http://www.helptheair.org/*

Louisville Gas & Electric Power Plant Information – *http://www.eon-us.com/lge/lge_plant_info.asp*

Louisville Metro Air Pollution Control District – *http://www.louisvilleky.gov/APCD/*

Louisville Metro Government – *http://www.louisvilleky.gov*

Partnership for a Green City – *http://www.jefferson.k12.ky.us/Departments/EnvironmentalEd/GreenCity/*

Pew Center on Global Climate Change – *http://www.pewclimate.org/*

U.S. Department of Energy, Energy Information Agency – *http://www.eia.doe.gov/*

U.S. Department of Transportation Federal Highway Administration, Transportation Air Quality Selected Facts and Figures, January 2006 – *http://www.fhwa.dot.gov/environment/aqfactbk/index. htm*

U.S. Environmental Protection Agency, Office of Transportation and Air Quality – *http://www.epa.gov/otaq/*

U.S. Environmental Protection Agency, Air Topics – *http://www.epa.gov/ebtpages/air.html*

U.S. Environmental Protection Agency, Office of Air and *Radiation – http://www.epa.gov/air/index.html*

U.S. Mayors Climate Protection Agreement - *http://www.ci.seattle.wa.us/mayor/climate/*

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Commonwealth Agri-Energy, LLC – Kentucky's Ethanol Plant

Mick Henderson, General Manager

As we move into the 21st century, ethanol has become a popular alternative to gasoline for the American consumer. Here in Kentucky, Commonwealth Agri-Energy, LLC has answered the call. The demands for energy, carbon-based pollution and resulting environmental problems, global political instability, and dwindling supplies, are all answered by the bio-fuels alternative. In Hopkinsville, with 12 million bushels of Christian County corn, Commonwealth Agri-Energy, LLC, (CAE), processes 33 million gallons of ethanol per year. CAE is a 100% farmer owned business that uses 7% of Kentucky's corn, basically the amount that Christian County grows. The business started production in March of 2004 as a 20 million gallons per year plant. Hopkinsville Elevator Company, a cooperative of 2300 farmer members, along with the Kentucky Corn Growers, with 700 farmer members, developed this ethanol project to provide an added value to their grain merchandising business. Located on an old rock quarry, the site was chosen because it was adjacent to a major railway, adjacent to a state highway, near a metro area with higher education institutions, and supplied by a good water source. With the passing of the Energy bill in August 2005, the business expanded production to 33 million gallons per year as of March of this year. The plant uses the latest technologies to process ethanol as energy efficiently as the best in the industry. We make 198.4 proof, (or 99.2%), ethanol denatured with about 5% gasoline. Denatured means made unfit for human consumption, (or we would be very similar to whiskey distilleries). Louisville, Kentucky has been our biggest market for fuel ethanol.

Commonwealth Agri-Energy, LLC is a corn dry grind ethanol plant. The dry grind process, versus a wet milling process, is a lower capital cost process that a much smaller investor group can afford and still compete. That means that it grinds the whole kernel of corn dry and makes a smaller set of end products. The full blown wet mill may have 10 – 15 different end products. The dry grind plant produces three products, fuel ethanol, CO_2, and DDGS. It is a three-way split of products. For a 33 million gpy ethanol plant, it needs to grind 33,000 bushels per day of corn, or 33 truck loads. This yields 11 truck loads of ethanol, 11 truck loads of CO_2, and 11 truck loads of DDGS per day. CO_2 is processed by another company adjacent to the plant, Pain Enterprises, to make liquid CO_2 for carbonated beverages and dry ice. DDGS, or distillers dried grains with solubles, are various animal feed products sold to the beef, dairy, swine, and poultry industries. CAE also separates about three truck loads per week of animal feed fat corn oil sold to poultry producers. Land O' Lakes markets our DDGS, and Ethanol Products markets our ethanol. This method of ethanol production from corn uses the basic processing design similar to its predecessor, the whiskey distillery, however, the modern corn dry grind ethanol producer is dramatically more energy efficient. Efficiency is critical in the highly competitive petroleum fuels marketplace which is all about energy efficiency. With the dramatic improvements in plant energy efficiencies, and the corresponding improvements in farmer field efficiencies, the fuel ethanol plant can compete in today's marketplace. The plant is also labor effi-

The Ethanol Plant in Hopkinsville, Kentucky.

cient compared to earlier designs. Our plant employees 30 people which is one fourth of the labor requirements of twenty years ago. Computer controls and automated systems have dramatically improved operational efficiency over the years requiring only three people to operate the plant. The process runs 24 hours a day 365 days a year. It takes dedicated people who care about our success and pay attention to the details. We are proud of our employees.

I have been in the business for 25 years and have seen several ups and downs in the price of corn and the price of crude oil. They do not swing together and either can make or break the ethanol business. Recently we have experienced an unprecedented upswing in petroleum prices while corn production in the last few years has been at record levels. This has given the ethanol industry a great boost and chance for future success. I expect that this past volatility will continue in both markets, corn and petroleum. There will be opportunities for profitability that should continue to provide incentives for additional ethanol plants to be built, and the industry should continue to grow. There will also be downturns in this volatile pricing market with periodic contractions, buyouts, and consolidations. My favorite business model for an ethanol plant is farmer owned, like CAE. It allows for the dollar to be turned right close to home. It brings wealth to the farmers who grow the crop, as well as the community where they live in mostly rural America, the backbone of this country. As the industry has matured, Wall Street investors, not just farmers, are investing in the business as well. Even major petroleum businesses are beginning to take part in the bio-fuels business again. The 2005 Energy Bill provides additional protection for the industry which is necessary if it is to survive. The Energy Bill guarantees a market of 7.5 billion gallons per year by 2012; an amount we will exceed by 2008. As we outpace demand, voluntary use will be pushing prices for ethanol down and tightening margins for the ethanol producer. An update on the 2005 bill will be needed to provide incentives to grow this vital industry for our future. The demand for liquid fuel in this country, especially gasoline, has been at unparalleled levels, and correspondingly unparalleled prices. The ethanol alternative is easily added to the fuels distribution network to provide molecules of octane at a reasonable cost. Today, ethanol provides 5 billion gallons per year to the ~150 billion gpy gasoline market, about 3%.

Ethanol is not new. It has actually been around as an automotive fuel for as long as cars have been mass produced. Henry Ford built his Model T to run on ethanol. Prohibition was an attempt to kill America's alcohol drinking problem, but it simultaneously killed the ethanol industry which was just gaining a toe hold. It made a comeback in WWII when beverage distilleries were converted to make fuel for the war effort. When petroleum was very cheap during the next forty years, the industry died once again. During the late 1970's, the advent of OPEC and the oil crisis, ethanol made a resurgence in the US Midwest as a gasoline extender. In the 1990's, and the Clean Air Act, ethanol found its place as an additive in gasoline to reduce air pollution. It proved its worth as a clean burning oxygenate that reduced vehicle tail pipe emissions in major metropolitan areas. However, a petroleum chemical MTBE, (methyl tertiary butyl ether), was the choice of most gasoline blenders to provide an oxygenate to the marketplace. MTBE was later blamed for polluting ground water and recently has been pulled from the gasoline pool this summer. As mentioned earlier, the Louisville market has been using our ethanol as its oxygenate of choice for a few years already after banning MTBE. Ethanol has never seen a greater need in the marketplace. It has seen an unprecedented surge in demand and a corresponding surge in plant construction and expansions. With flexible fuel vehicles entering the marketplace, ethanol is even making Super Bowl commercials (GM's Live Green Go Yellow campaign and Ford's commercial about 250,000 vehicles per year being built). These flexible fuel vehicles will run on anything from regular 87 octane unleaded to 105 octane E-85, (0% ethanol up to 85% ethanol). Although this trend sells new cars, it diverts attention away from the most straight forward use of ethanol. It can be used in basically all domestic and foreign built cars in the US market at a 10% blend in gasoline. At this level, it can triple the present market for ethanol before the US fleet needs to move to flexible fuel technology (this is calculated by taking the present 5 billion gpy and tripling it to 15 billion gpy in a 150 billion gpy gasoline market). A popular program considered today is 15 / 15 / 15, or 15 billion gpy of ethanol with a 15 billion bushel corn crop by 2015, a reachable goal with present technologies. Beyond that, programs like 25 by 25, (25 billion gpy by 2025), will probably require technologies that process cellulosic sources, like switch grass or wood chips, to achieve this goal. By that time other technologies like the hydrogen fuel cell could also be part of the solution.

Ethanol is a good solution to carbon-based pollution and the environmental problems that result from it. As a bio-fuel, ethanol converts biomass that is renewable every year into an automotive carbon based fuel that displaces gasoline that is derived from fossil fuels sequestered millions of years ago. In the food or fuel debate, corn is considered a food that should not be used for fuel, however, the starch portion of the kernel is converted into fuel and the rest of the kernel is fed back into the food cycle as an animal feed (or in some cases directly into food). The issue for use of crops to produce liquid fuel is more a matter of efficiency than an issue of feeding starving populations. The ability to feed the world's needy has more to do with political issues than a lack of sufficient food. Socio-economic and political conditions are the problem, not our use/misuse of biomass. We can grow more. The "energy balance" of corn derived ethanol created considerable debate last year, but was put to rest by various analyses done by reputable experts who defined a positive balance as a ratio where there is more energy available in the finished ethanol than it takes to make it. The US Department of Agriculture placed the ethanol industry at a positive 1.76 to 1. The Argonne Labs with the US Department of Energy has the balance positive at 1.34 to 1, and Berkley has the positive balance at 1.25 to 1. This overall positive balance was debated last year by several academics and government experts and put to rest. The whole flexible fuel program is based on E-85 being less polluting than gasoline and vehicles that can run on it lower the fleet fuel economy requirements for automobile manufacturers. Greenhouse gas emissions are of major concern as nations around the world address the issue of climate change and reducing CO2 emisions as well as the industrial and automotive sources of it. Ethanol reduces greenhouse gas emissions by as much as 30%, and wins hands down in the environmental debate about bio fuels versus petroleum fuels. Commonwealth Agri-Energy, LLC uses technologies that dramatically reduce our stationary source emissions. It requires no industrial sewer discharge because the production process recycles through its own anaerobic digester waste treatment. CAE stack gas emissions are minimized by using a thermal oxidizer that destroys particulate and volatile organic compounds and destroys odors that are associated with these emissions. Noise reduction technologies have been developed to reduce fan noise. We have installed low horsepower cooling water systems that use our quarry lake for cooling rather than chiller water. CAE strives to be a good neighbor and leader in our community. We have showcased our plant by taking high school, college, and business community groups, farmer groups, and groups interested in building their own ethanol plant in the region on tours of the facility.

Global instability and dwindling supplies of petroleum are the reason for high priced gasoline. The US depends on foreign sources of oil for 60% of its supply, and on foreign sources of refined gasoline for 25% of our supply, and of that amount, 25% of our oil supply comes from the Middle East. The US cannot afford to be this dependent on foreign sources for our petroleum based fuels. A better solution cannot be found than ethanol made from corn by farmers in Kentucky. We don't have to depend on anyone except ourselves. Like Henry Ford said in 1906, if we need more we can grow more. America presently processes 1.8 billion bushels of corn to make 5 billion gallons of ethanol per year. That is 16% of the 11 billion bushel corn crop this year. To make the 15 billion gpy of ethanol by 2015 with 15 billion bushels, we will need to convert 36% of the corn crop into ethanol. To do this, we need 16% of our corn crop today processed as ethanol, or 68 million gpy, (another plant of our size or doubling the size of this plant). By 2015, Kentucky should be processing 150 million gpy from 55 million bushels of corn, or three plants the size of our current plant. There is lots of room for growth.

As a performance fuel, ethanol has been showcased by the Indy Racing League. The entire Indy Car fleet ran on 10% ethanol blends this past season. Next season, they will be increasing the ethanol in their fuel to 100%. At speeds exceeding 230 miles per hour, there is no question that ethanol performs. I have my own testimonial to ethanol performance. I have used this fuel since I have lived in the Midwest and driven a lot of miles in many different makes and models of vehicles. I have owned a 1977 Volkswagen Rabbit, a 1982 Toyota Celica, a 1987 Ford Thunderbird, a 1994 Chrysler Concorde, a 1995 Chevy Caprice, and a 2001 Toyota Siena. All have been driven over 80,000 plus miles and each used 10% ethanol blends with equal or improved performance, with no engine problems.

In the June 13, 2005 issue of Time Magazine, our business was showcased in an article describing one possible future. Our "centerfold" caption read: "Mick Henderson, with Kentucky farmers, is producing the fuel that could help the 500-m.p.g. car become a reality." The article described two technologies that are available today, which when coupled together create the 500 miles per gallon of gasoline capability. The hybrid engine, with plug-in technology, can get up to 75 miles per gallon. Flexible fuel technology using E-85 (15% gasoline and 75% ethanol) makes 500 mpg for the gasoline portion of the mix. With innovations like these, we can take the United States, with Kentucky as a leader, into a future by meeting our challenges with alternative sources of energy, while reducing or eliminating our dependence on foreign oil.

Mick Henderson is the General Manager of Commonwealth Agri-Energy, LLC. He has been with CAE since 2003. He has 25 years in agricultural processing experience, mostly in ethanol with Archer Daniels Midland Co.

Looking Down the Road to Energy Independence

Cam Metcalf, Executive Director, Kentucky Pollution Prevention Center
Sri Iyer, Energy Efficiency Specialist, KPPC
Chris Wooton, Marketing and Public Relations, KPPC

What fuels the future of energy in the Commonwealth of Kentucky? Coal? Solar Power? Wind? The truth is Kentucky's energy future will entail a blend of fuels used in energy production while making efforts to conserve energy use in all aspects of our lives.

This article illustrates collaborative actions – not recommendations – that drive energy production and consumption in Kentucky. These actions will hopefully encourage further discussion on how to ensure a better future for Kentucky's energy resources that are critical to sustainable economic growth, a healthy environment and the well-being of society.

Generally, there are four fuels used to produce energy – coal, oil, gas and nuclear. However, there is another option that is increasingly being touted as the "fifth fuel" – energy efficiency (E2), which uses economically viable solutions to reduce energy consumption. With two decades of documented practical and successful applications of E2 programs in homes and businesses throughout the country, the time is right for Kentucky's energy market participants to collaborate on how to blend E2 into Kentucky's mix of energy fuels.

A Case for 'Clean Coal'

Coal is the most versatile and largest source for electricity generation in the United States. Kentucky is blessed with abundant coal, ranking third in coal production after Wyoming and West Virginia. During 2005, Kentucky mined 119.7 million tons of coal, a 4.8 percent increase compared to 2004 and about 11 percent of the nation's total coal production during the same period. Some of the results of massive coal availability in Kentucky are:

- Lowest electricity cost in the nation at an average $0.042 per kilowatt-hour (kWh) compared with a national average of $0.072/kWh.
- Ranks sixth nationally in per capita primary energy consumption.
- Ranks third in electric industrial intensity which is 268 percent above the national average.
- Carbon intensity is 2.5 times national average.

At the current rates of coal production (and no change in reserves), coal reserves in Kentucky could in theory last for another 238 years.

Coal-fired power plants have a major environmental impact, and unfortunately many such plants in Kentucky are old and produce air emissions at higher rates than current emission standards. Regional air quality data show high levels of smog, acid rain and particulate levels in areas upwind of Kentucky's coal-fired power plants. This makes a strong case for more research, development and funding to further develop, demonstrate and deploy clean coal technologies for Kentucky's energy future.

Natural Gas - In and Out

Kentucky's 1.9 billion cubic feet of proven natural gas reserves account for 1 percent of the nation's proven reserves. In 2002, Kentucky produced more than 86 million cubic feet of natural gas, yet the commonwealth is a net importer of natural gas.

Nothing Crude about Biofuels

In July 2006, the United States imported 9.5 million barrels of crude oil per day, which accounts for about 58 percent of the daily U.S. oil consumption. The daily crude oil consumption is forecast to increase from 15.48 million barrels in 2004 to 18.08 million barrels a day in 2030 which is a rate of 0.6 percent annually.

In his 2006 State of the Union Address, President Bush announced a Biofuels Initiative that will improve energy security in the United States by reducing the country's dependence on gasoline made from imported oil by as much as 75 percent by the year 2025. Agriculture is a major user of energy, with energy consumed directly and indirectly, and agriculture is going to play a growing role in meeting the Nation's demand for renewable sources of energy. In 2005, 4 billion gallons of ethanol and 91 million gallons of biodiesel were produced. According to the U.S. Department of Energy's Division of Energy Efficiency and Renewable Energy (EERE), the ethanol fuel industry is growing so rapidly that a national Renewable Fuels Standard (RFS), passed as part of the Energy Policy Act of 2005, is already obsolete. The RFS requires 4 billion gallons of biofuel production in 2006, increasing gradually to 7.5 billion gallons in 2012. But, according to the a recent press release from the Renewable Fuels Association (RFA), there are currently 101 ethanol facilities nationwide with the capacity to produce more than 4.8 billion gallons of ethanol per year - an amount that already exceeds the RFS requirement of 4.7 billion gallons of biofuels for 2007. With an additional 41 ethanol facilities under construction and seven expansions to existing facilities underway, the industry is in the process of adding nearly 2.8 billion gallons of new capacity that will allow the industry to produce 7.6 billion gallons of ethanol per year, which exceeds the RFS requirement for 2012.

Kentucky is right on board with the trend. New biodiesel and ethanol plants are breaking ground in the Commonwealth at a rapid pace. Kentucky agriculture produces 54 million bushels of soybeans annually with 11 pounds of oil processed from each bushel. Currently, Griffin Industries, located in Butler, KY, has the capacity to produce 2 million gallons of biodiesel from soy oil, tallow and yellow grease. Owensboro Grain broke ground for a 50 million-gallon biodiesel facility in Owensboro, KY, which is expected to go operational by 2007.

Commonwealth Agri-Energy LLC in Hopkinsville, KY, and Parallel Products in Louisville, KY, are the two existing ethanol production plants with an annual total production capacity of 35.4 million gallons. There are also about six ethanol plants at various stages of development in Kentucky. Bluegrass Bioenergy LLC in Fulton, KY, recently broke ground for the state's second major ethanol plant, which is expected to produce 55 million gallons of ethanol per year beginning late 2007. Agri Fuels LLC plans to construct a $100 million ethanol production facility in Meade County near Brandenburg, KY. The plant could produce more than 55 million gallons of ethanol per year and is expected to break ground in early 2007. The facility will use 19 million bushels of corn from within a 50-mile radius of the plant.

To put this in perspective, Kentucky consumed about 2,100 million gallons of petroleum gasoline in 2002. Therefore, we would require about 210 million gallons of ethanol for producing a 10% ethanol blended fuel (E10). The expansion of existing ethanol plants and development of new ethanol plants in Kentucky will meet the state's demand of ethanol for ethanol blended (E10) fuel. However, the U.S. Department of Energy forecasts that by 2030 energy consumption in the United States will increase by more than 30 percent from current levels. Energy production must increase by more than 40 percent to meet the needs of the transportation sector alone. Therefore, the supply of renewable energy, such as ethanol and biodiesel, must also grow simply to maintain its current share of the overall energy market, and it must grow even faster if it is to reduce dependence on fossil fuels.

Leadership Buy-In

Now more than ever, state and federal officials must seriously consider the benefits of renewable energy and understand the vital role that colleges and universities play in the research and development of viable renewable energy strategies. U.S. Senators Mitch McConnell and Jim Bunning secured $2 million in funding through a federal appropriation to the University of Louisville (U of L) that established the Kentucky Rural Energy Consortium (KREC), a program that conducts and facilitates research and educates the public about issues that relate to efficient energy use and renewable energy production and other energy activities of importance to Kentucky. With additional support from the Governor's Office of Energy Policy (GOEP), researchers at U of L and the University of Kentucky (UK) are conducting seven research projects that focus on developing resource-responsible technologies and practices specific to the energy sector. The Kentucky Pollution Prevention Center (KPPC) at U of L's J.B. Speed School of Engineering serves as KREC's clearinghouse and provides additional support for ongoing activities of the consortium members as well as state and federal programs that support KREC's goals.

The research goals for the consortium include dramatically reducing the United States' dependency on foreign oil and creating an economically viable bioenergy industry in Kentucky. Nearly $1.5 million in federal funds support KREC's seven research projects with an additional $295,000 in state matching dollars provided by GOEP through a fund passed by the Kentucky General Assembly and signed into law by Governor Ernie Fletcher. KREC's goals are consistent with Kentucky's Comprehensive Energy Strategy, which was introduced by Gov. Fletcher in February 2005 and addresses Kentucky's short- and long-term energy needs. Details about this plan are available online at www.energy.ky.gov/energy.

KREC in Action

The scope of KREC's research embodies a variety of approaches to renewable energy and is building an intellectual base in Kentucky to address the challenges of alternative fuels and energy efficiency technologies.

One project's goal is to reduce the cost of corn stover as a feedstock to a biorefinery by reducing collection, handling and storage costs and increasing the efficiency of pretreatment, enzymatic hydrolysis and fermentation into value-added fuels and chemicals. The project will allow for the evaluation of corn stover, a residue available on Kentucky farms, to be converted to a higher value product in rural communities.

Another project entails the development of a solar heat pipe system particularly suited to climates, such as Kentucky, with moderately cold and moderately sunny winters. Through the use of heat pipes, the system transfers energy into a building on sunny days. and avoids energy losses during the night and cloudy days. These heat pipes have the ability to transfer heat in one direction only with virtually no losses in the reverse direction. This prevents energy loss during the night and on cloudy days when there is little to no sunlight. Compared to traditional passive solar heating systems, the solar heat pipe system provides better energy efficiency in Kentucky's cloudy climate.

Other KREC research projects focus on:

- Adapting bacteria to improve the production of ethanol;
- Improving the production of fuels and high-value chemicals from biomass;
- Developing nanomaterials to produce electricity from the sun that can be used to produce hydrogen from water;
- Developing an economical process to produce biomass briquettes from coal fires and wood waste for industrial boilers; and
- Developing a residential ventilation system that reduces energy use and improves indoor air quality.

More information about KREC initiatives is available online at www.kppc.org/KREC.

Partners for Energy Efficiency

KPPC is a nonprofit environmental technical assistance and outreach center at U of L's J.B. Speed School of Engineering. The center provides free, nonregulatory and confidential technical assistance, training and applied research to improve energy efficiency, reduce waste streams and enhance environmental performance. The center facilitates and promotes the proactive implementation of management systems and technologies to improve the competitiveness of Kentucky's businesses, industries and other organizations.

Since the inception of the center in 1995, KPPC has performed nearly 600 assessments and audits for pollution prevention (P2), energy efficiency (E2), environmental management systems (EMS) and technology diffusion projects. KPPC's E2 services began in 2000. Since then, the center has conducted 83 comprehensive energy assessments for educational, commercial and industrial facilities. The total recommended savings were approximately $3.7 million with an energy savings of more than 266,000 million British thermal units (MMBtu) per year. The total implementation costs were approximately $6.9 million with an overall average payback of about 1.9 years. The total estimated energy costs for the 20 industrial facilities audited were approximately $30 million dollars with cost savings of roughly $3.7 million or an average of $185,000 per year for each facility.

While it is imperative to encourage industrial development in Kentucky to promote economic well-being, it is also necessary to consume natural resources more efficiently and protect the environment. The southeastern United States is economically one of the fastest growing regions in the country. According to the Energy Information Administration's Annual Energy Outlook 2006 for East South Central Region (Kentucky, Tennessee, Alabama and Mississippi), energy consumption in residential, commercial, industrial and transportation sectors is expected to increase annually at the rate of 1.8, 3.3, 1.5 and 1.2 percent respectively from 2004 to 2030 while the gross domestic product is expected to increase 3 percent annually for the same period.

KPPC Energy Efficiency Specialist Sieglinde Kinne works with Steve Michal, Superintendent of Electrical Maintenance, during a recent energy efficiency assessment of Davidson Hall at the University of Louisville.

Among the most energy-intensive industries in the U.S. are those that manufacture aluminum, chemicals, forest products (such as paper and wood products), glass, metalcasting, petroleum and coal products, and steel. Kentucky is one of the top aluminum producing states and ranks as the number one state in the primary aluminum industry for 2001. About 31% of the primary aluminum production capacity in the United States is based in the Ohio Valley. A recent report sponsored by the Kentucky Science and Technology Corporation identified the aluminum industry as 1 of the 4 growing value chain clusters in the state. There are 112 aluminum-related facilities with 15,329 employees located in Kentucky with shipments worth over $2.5 billion in 2001. Kentucky also has a strong presence in the automobile industry and ranks 4th among the 50 states in total light vehicle production. In 2003, 1,164,967 cars and light trucks were produced in Kentucky, which is about 10% of all cars and trucks manufactured in the U.S. The gross state product for the Kentucky automotive industry was over $10.6 billion in 2002.

In the area of resource management, these Kentucky energy-intensive industries are placing a new emphasis on energy use and energy efficiency opportunities. Energy management plans being developed are considering how energy affects every part of the operation and processes. At some point in the near term, procurement of energy sources and their availability may become more important than price when ensuring that the operation is uninterrupted. Also, adding energy efficiency and renewable energy as part of an organization's supply mix should be considered.

Resources Ready for E2

KPPC partners with other organizations, such as the Kentucky Department for Environmental Protection, the Governor's Office of Energy Policy (GOEP), the Kentucky Business Environmental Assistance Program (KBEAP), the Kentucky Energy Services Coalition (KESC), the U.S. Department of Energy and Environmental Protection Agency and others to provide outreach and resources to businesses, industries and organizations that want to realize cost savings through improved environmental performance and energy efficiency. More information about KPPC and its partner organizations is available at www.kppc.org.

New partnerships in Kentucky aggressively pursue E2 opportunities and assist those who want to lead the way in the evolution of E2 practices, technologies and resources. E2 programs provide significant economic and environmental benefits and can be developed, piloted and implemented in just a few years. These programs bring relief where it might be difficult to provide additional funding for energy costs in the short term with tight state and local government budgets.

For example, energy expenses for fiscal year 2005-2006 in Kentucky's K-12 public schools totaled about $154 million according to the Kentucky Department of Education. Over the past four years, energy bills for Kentucky's K-12 and postsecondary schools alone, have increased by more than 30 percent, or nearly $37 million. If all of those schools reduced energy costs by 5 percent (an easily achievable goal), the annual savings would total about $7.7 million – money that could create and maintain programs vital to student development. The new Kentucky Energy Efficiency Program for Schools (KEEPS) helps Kentucky school districts and higher education institutions reduce energy consumption and operating expenses.

This pilot program, funded by GOEP, is being implemented by KPPC in partnership with the National Energy Education Development (NEED) project and the Kentucky School Plant Management Association (KSPMA). KEEPS is educating teachers, students, facility managers and operations and maintenance personnel on how their actions affect energy consumption. KEEPS also educates school board members, superintendents and university presidents on the value of energy-savings policies, programs and facility improvements.

After acceptance to the KEEPS program, the selected school districts and universities must identify an energy manager, commit to the evaluation process, attend training and consider implementing possible energy-savings measures that KPPC identifies. Bullitt County Public Schools, Franklin County Public Schools, Kentucky State University, Russellville Independent Schools, Thomas More College and Western Kentucky University were recently accepted as pilot members of KEEPS. KPPC provides tools that help these schools analyze and understand their energy consumption. The center also provides training and helps KEEPS participants identify and implement low-cost/no-cost energy-savings measures that have short payback periods. Over time, KPPC will help evaluate and determine funding options to implement capital-intensive energy-savings measures with longer payback periods. This approach allows KEEPS participants to ease into the process of reducing energy use and saving money through energy efficiency. It also demonstrates the value of the KEEPS program before the schools and universities invest in more capital-intensive, energy-savings measures.

Energy Efficiency Programs

State and regional studies show that adoption of economically attractive, but as yet untapped, energy efficiency resources could yield more than 20 percent savings in total electricity demand nationwide by 2025. The National Action Plan for Energy Efficiency (NAPEE) points out that it will take concerted efforts by all energy market participants: customers, utilities, regulators, states, consumer advocates, energy service companies, and others, to bring more energy efficiency into the nation's energy mix to slow demand growth in a wise, cost-effective manner. Significant opportunities for energy efficiency are likely to continue to be available at low costs in the future. It is time to take advantage of more than two decades of experience with successful energy efficiency programs, broaden and expand these efforts, and capture the savings that energy efficiency offers.

To expand its E2 efforts, KPPC has partnered with technical assistance programs at the University of Illinois, University of Minnesota, the University of Kentucky and the National Pollution Prevention Roundtable to implement a multi-state Technology Diffusion Initiative (TDI) that promotes the use of innovative E2 and P2 technologies. Technology diffusion and deployment promotes the adoption of solutions that are commercially available but have not achieved widespread market penetration. The overall process requires awareness of the E2 opportunities, identification of barriers to implementation of those opportunities and their solutions, and assessment of new E2 technologies.

TDI identifies barriers to the implementation of innovative E2 technologies and documents how to overcome those barriers to better control energy use and costs. To address the uncertainty associated with how to implement new E2 technologies, KPPC's technical staff conducts pilot trials with TDI clients. The trials lead to full-scale demonstrations and finally adoption of the new E2 technology at the facility. These pilot trials, demonstrations and applied research efforts create additional awareness of innovative E2 technologies and best practices among other change agents and organizations that have not yet adopted them. KPPC and the partners are excited about the potential results and positive impacts that E2 technology diffusion will have on environmental performance and cost savings for organizations. KPPC is realizing that more effort and funding may be required for energy efficiency technology demonstration, deployment and commercialization than for research and development of the technologies.

Still Work To Do

Initiatives, such as KREC, KEEPS, and TDI prove that efforts to improve energy efficiency and develop renewable energy resources in Kentucky are off to a good start. But there is still work to do to secure continual success and sustainability.

More utilities, regulators and partner organizations must improve customer access to energy efficiency programs that help control energy costs, provide necessary funding to deliver these programs, and examine policies that govern energy companies. These policies must facilitate—not impede—cost-effective energy efficiency programs.

The National Action Plan for Energy Efficiency (NAPEE) consists of more than 50 organizations that are dedicated to creating a sustainable, aggressive national commitment to energy efficiency through gas and electric utilities, utility regulators and partner organizations. NAPEE points out that it will take concerted efforts by all energy market participants—customers, utilities, regulators, states, consumer advocates, energy service companies and others—to reduce energy demand in a wise, cost-effective manner. It will also require education on energy efficiency opportunities; review of existing policies; identification of barriers and their solutions; assessment of new technologies; and modification and adoption of policies.

Kentucky Is Ready

This article touches on only a few policies, programs and other resources in Kentucky and across the country that help deliver better energy efficiency in new and existing residential, commercial and industrial facilities that will consume the majority of the energy used for years to come. Numerous other resources, such as the U.S. EPA ENERGY STAR® program and the Leadership in Energy and Environmental Design (LEED®) program, integrate better energy design and management practices into the mainstream.

Experience and results continue to demonstrate that energy efficiency programs help reduce energy use and provide lower costs through energy management systems. Additional investigation and study of the impacts that energy efficiency programs can have is needed. Also, other energy efficiency policies such as building codes, appliance standards, and tax incentives will continue to add value to E2 program efforts. Energy efficiency programs will require consistent and long-term funding to ensure education, outreach and continued implementation of the energy efficiency measures and technologies that have been demonstrated to be cost effective and available commercially.

Kentucky's energy future depends on the experience we gain today. We must continue to investigate the positive impacts that energy efficiency programs and renewable energy resources have on the sustainability of Kentucky's businesses, industries, schools and, most importantly, our quality of life. There are challenges, but, given the resources and technologies that are available now and those that will be available in the near future, Kentucky's energy future is indeed a bright one.

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