

LIFE AFTER OIL: THE AMERICAN TRANSITION FROM OUR FAVORITE FUEL

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ABSTRACT

JEFFREY S. SOPLOP: Life After Oil: The American Transition From Our Favorite Fuel

(Under the direction of Chris Roush, Richard Cole and James R. Cox Jr.)

This three-chapter series of articles considers the way that rising oil prices have created a new energy crisis in the United States. The articles focus on differences between the current crisis and previous oil shocks, as well as the dichotomy of choices that the crisis has created for the country: whether to develop new fuel supplies, such as biofuels, or to focus on oil conservation and efficiency.

For my soon-to-be wife, Julia. My parents. Krista, Tim, Ella, William and Jane.

Family is the greatest blessing.

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Introduction

When Henry Ford began production of his Model T automobile in 1908, he changed the future of American transportation. By laying the groundwork for the development of the assembly line, Ford helped make automobiles a product of mass consumption rather than a trinket of the rich. While Ford's innovation contributed to making automobiles ubiquitous in American society, his achievement also created another ancillary effect: the rapid expansion of the oil industry to provide fuel for all those new cars.

Ford halted production of the Model T in 1927 after churning out more than 15 million of them since its inception.¹ During that same period, sales of gasoline surpassed those of kerosene and lighting oils,² and to meet rising demand driven by the burgeoning auto market, U.S. crude oil production grew by more than 400 percent.³

But even with oil production booming, Ford remained unsure about whether gasoline was the best fuel for his vehicles. When the Model T was first introduced, it had an adjustable carburetor that allowed the vehicle to run on gasoline, kerosene or even alcohol.⁴ Ford, who grew up on a farm in rural Michigan, believed making cars that could run on alcohol, which was distilled from agricultural products, would provide new markets for American farmers.⁵ With this vision in mind, Ford made the following prediction to *The New York Times* in 1925: "The fuel of the future is going to come from

fruit, like that sumac out by the road, or from apples, weeds, sawdust – almost anything. There is fuel in every bit of vegetable matter that can be fermented.”⁶

Despite Ford’s hopes, oil dominates the global fuel market a century after the Model T’s introduction. Today products derived from crude oil, also called petroleum, include gasoline and diesel for cars and trucks, fuel oil for ships and high-grade kerosene for airplanes.

But oil is a finite natural resource, and the world’s dependence on it has created immense problems. In recent years, global demand for oil has leapt, boosted by increased need from large developing nations, such as China and India. At the same time, researchers and industry experts warn that the world’s oil supply is limited and production will eventually peak. Some contend that it already has. In response to these shifts in supply and demand, along with geopolitical instability in some oil-producing nations, such as Iran and Iraq, the price of a barrel of oil has skyrocketed. On just the second day of 2008, oil marked a new record by hitting \$100 per barrel.⁷ Soon after, new warnings were issued that expensive oil could slow economic growth in the United States and the rest of the world.⁸

With the price of oil climbing, U.S. policymakers have been searching for solutions to the emerging fuel dilemma. A favored solution of politicians is to encourage the production of fuels made from agricultural products, known as biofuels. This validation of Ford’s prediction has, so far, focused mostly on the distillation of alcohol from corn, which yields a product called ethanol. Buttressed by the government’s support, U.S. ethanol production more than doubled from 2002 to 2006, by which time the country produced almost 5 billion gallons of ethanol annually.⁹ But even the sharp

increase in ethanol production is only a drop in the fuel-supply bucket, since the United States consumes more than 140 billion gallons of gasoline annually.¹⁰

As biofuel production grows, the issue turns on whether that production can expand quickly and affordably enough to supplant the U.S. oil addiction. And that addiction shows no signs of abating. Although domestic oil consumption has slowed in recent years, it still continues growing despite rising oil prices. And while politicians remain fixated with biofuels, noticeably absent from the debate are serious policy options embracing the conservation of oil.

This thesis will explore how the United States is beginning to cope with a post-oil world. The work focuses on the currently favored policies and technologies to deal with the situation as well as those being dismissed. Specifically, the dichotomy of finding new fuel supplies versus conservation of resources is addressed by analyzing ongoing market mechanisms, technology development and policy decisions as oil prices continue to climb.

Literature Review

Because oil has a long and complex history as a fuel supply, understanding its current predicament requires a thorough review of the related academic, trade and government literature. To grasp the issue, much of the literature can be divided into four categories: how the economics of oil from a supply-and-demand perspective shed light on the market mechanisms at work behind rising oil prices; how oil prices impact the U.S. and global economies; what policy decisions are being implemented in response to

expensive oil and what are the observed effects of those decisions; and how media coverage of these issues has evolved. This literature review will analyze these topics and demonstrate gaps that need to be filled in the research and the popular media's coverage.

The era of scarce oil

While it's been easy to observe rising oil prices during the last few years just by going to a gas station, determining exactly how much more expensive oil will get is more complicated. Only a few years ago it seemed like oil would stay relatively cheap for years to come. In 2002, Lounnas and Brennan wrote an oil outlook for the Organization of Petroleum Exporting Countries (OPEC), in which they assumed that oil would remain in the lower price range of \$22 to \$28 per barrel until 2010.¹¹ Their assumptions quickly turned out to be wrong. The world price of oil rose to more than \$36 per barrel by the end of 2004 and continued to rise to almost \$90 per barrel by the end of 2007.¹² After those volatile and unexpected price jumps, an updated OPEC oil outlook in 2006 refrained from making further projections about the price of oil.¹³ While other predications have been made, analyses from industry experts, scholars and the media indicate a consensus that oil prices are expected to continue fluctuating upward and will remain high for the foreseeable future.

Booming growth in the world economy drives the global rise in demand for oil and its corresponding price increase. "Exceptionally strong and synchronized economic growth, not experienced for almost three decades, brought about a surge in demand," noted an OPEC report.¹⁴ That growth has happened most acutely in developing nations. From 1996 to 2006, demand for oil within the Organization for Economic Co-operation

and Development (OECD), composed of nations with developed economies, grew at the modest pace of 7.4 percent.¹⁵ By contrast, during that same time period demand for oil in all non-OECD nations, most of which are considered developing nations, grew at the much faster clip of 27.6 percent.¹⁶

Among developing nations, China and India in particular have become progressively thirstier for greater shares of the world's oil supply.¹⁷ In 1996, China consumed an average of 3.6 million barrels of oil per day, according to the U.S. Energy Information Administration (EIA).¹⁸ A decade later, China's consumption has more than doubled, making it the second-largest oil-consuming nation in the world, using about 9 percent of the world's total oil supply.¹⁹ Similarly, India's oil consumption has also risen considerably in recent years, though not as sharply as China's. From 1996 to 2006, India's oil consumption increased by 49 percent, and India became the sixth-largest oil consuming nation in the world.²⁰ While China and India are leading the demand surge, the rest of the world is following suit. Based on research by the EIA, total world oil demand is projected to grow another 42 percent by 2030, raising the question of whether oil production can keep pace with demand.²¹

Even as demand for oil has increased, a plethora of oil experts have asserted that the world's oil supply will soon peak and begin to decline. The predominant theory guiding this view is known as Hubbert's Peak Theory, which was introduced by the American geophysicist Marion King Hubbert in 1956.²² According to Hubbert, the possible oil production of any country, or even the world, could be predicted with a formula based on the rate of oil discovery, the rate of production and the cumulative production total. Hubbert utilized these metrics to predict that U.S. oil production would

peak sometime around 1970, and that world oil production would peak around 2000.²³ By using the term “peak,” Hubbert did not mean that oil reserves would be exhausted, but that the rate of oil production would have reached a maximum and, therefore, would start to slowly decline. Half a century later, an ongoing debate continues about the accuracy of Hubbert’s predictions.

On one side of the peak oil controversy are those who believe oil production has already or will soon reach its maximum. Among this group, the direst prediction for the future of oil was by Deffeyes, who utilized Hubbert’s model and predicted world oil production would peak in 2004 or 2005.²⁴ A few years later, Deffeyes updated his prediction to include a specific date when he said oil production had peaked: Dec. 16, 2005.²⁵

Others have warned of an impending peak without setting a specific date, such as Zittel and Schindler, who noted:

[T]he question of the exact timing of peak oil is less important than many people think. There is sufficient certainty that world oil production is not going to rise significantly anymore and that world oil production soon will definitely start to decline.²⁶

Similarly, Hirsch, et al., noted that a number of experts and researchers have predicted an oil production peak in the relatively near future, but that:

Such projections are fraught with uncertainties because of poor data, political and institutional self interest, and other complicating factors. The bottom line is that no one knows with certainty when world oil production will reach a peak, but geologists have no doubt that it will happen.²⁷

With this in mind, the consensus indicates that world oil production has little room left to grow and may already have reached its peak.

Despite pessimistic predictions that oil will soon peak, other experts argue that there is still plenty of oil left. At the forefront of this group is Daniel Yergin, chairman of

Cambridge Energy Research Associates (CERA). The risks of oil are not below ground, such as in shortages of reserves, Yergin argues, but above ground in terms of political dissonance, natural disasters and price volatility.²⁸ Based on CERA's estimates, global oil reserves are approximately 3.74 trillion barrels – almost triple the amount estimated by peak oil proponents.²⁹

While the evidence indicates the world has more oil reserves than the amount endorsed by the peak oil theorists, much of this oil is harder to get at than conventional oil reservoirs. New technologies, such as the steam flooding of oil reservoirs, allow more oil to be extracted than was previously possible, thus extending the life of some oil fields.³⁰ And oil can also be extracted from non-conventional resources, such as oil sands and oil shale, which are both sources of crude that are beginning to be explored by major oil companies.³¹ But these methods are considerably more expensive than traditional oil pumping. So even if technology makes more oil recoverable and a peak is not as near as some believe, the cost of recovery, and therefore the price of the oil, will remain elevated. As a result, the era of expensive oil has begun.

Oil's economic impact

As one of the United States' primary energy supplies, oil significantly affects the U.S. economy. Historically, this impact has been most clearly demonstrated during times of unexpected spikes in oil prices, or what economists refer to as oil shocks. Hamilton noted that such shocks preceded nine out of the 10 recessions after World War II, and that this relationship has been repeatedly confirmed as more than a statistical coincidence.³² A similar observation was made by Jones, et al., who concluded that

“post-shock recessionary movements of GDP are largely attributable to the oil price shocks.”³³

But the ongoing oil dilemma is substantially different from past episodes of price shocks. Current oil prices are driven by the combined effect of rising global demand and emerging constraints on production. So it is unlikely that oil prices will decrease in a relatively short time, as in previous shocks such as during the 1973 Arab-Israeli War or the 1979 Iranian revolution.

Unfortunately, because shocks have been the norm in the past, the body of research considering the ramifications of long-term high oil prices is sparse. However, some researchers are making non-empirical projections. Hirsch, et al., asserted that sustained high oil prices “will cause protracted economic hardship in the United States and the world.”³⁴ Likewise, Fenton described the impact on the global economy of any long-term high oil prices as serious.³⁵ And Rogoff noted that even though the global economy has proven somewhat resilient to higher oil prices so far, at least some of that resilience is an illusion.³⁶ In particular, Rogoff stated that the United States has deferred the effects of higher oil prices by running up a higher current account deficit, meaning that higher oil prices have resulted in greater spending on exports of foreign oil rather than reduced domestic consumption, which could prove a serious long-term problem for the U.S. economy down the road.³⁷

Because of the lack of research into the economic effects of sustained high oil prices, making specific predictions of how oil’s decline will affect the U.S. economy is virtually impossible. Still, the prevailing lessons of history and economics point to several likely scenarios: The United States reacts slowly to higher oil prices and pays for

it with lower growth in gross domestic product (GDP); alternative fuels are quickly developed that can supplement oil's increasing scarcity; or conservation methods are implemented that significantly reduce national demand for oil. Whether any one of these scenarios comes about, or whether some mix does, depends largely on decisions of the U.S. government.

Tough decisions: developing new fuels or embracing conservation

Permanently higher oil prices present a novel set of challenges for U.S. policymakers. Unlike oil shocks of the past, the current situation of sustained higher oil prices isn't likely to be solved simply by loosening monetary policy, which was suggested by Bernanke, et al.³⁸ While a looser monetary policy could help encourage investment in new technologies, and so partially alleviate the problem, to prevent oil from becoming a significant drag on U.S. economic growth a more comprehensive strategy will need to be developed and implemented with the federal government's backing.

At this time, U.S. energy policy is primarily focused on developing new fuel supplies to supplement oil usage. The 2007 Economic Report of the President reports a goal to reduce gasoline consumption by 20 percent within a decade in the light-duty vehicle sector, which is comprised of cars and light trucks.³⁹ "About three-fourths of this goal will be met by greatly increasing and expanding the Renewable Fuel Standard," the report states. "The new standard will mandate that 15 percent of transportation fuels come from alternative fuels."⁴⁰

The original Renewable Fuel Standard (RFS) was enacted in 2005 and required gasoline blenders to use 7.5 billion gallons of renewable fuels such as ethanol by 2012, with specific goals set incrementally each year.⁴¹ In addition to passing the RFS, Congress has also allocated a variety of subsidy and support programs to add incentives for producing and blending renewable fuels.⁴² These programs have substantially boosted production of renewable fuels, ethanol in particular. In 2005, total U.S. ethanol production was 3.9 billion gallons.⁴³ Less than two years later, ethanol production had almost doubled. And with dozens of new plants currently being built or expanded, U.S. ethanol production capacity is projected to surpass 13 billion gallons per year in 2008.⁴⁴ But even while ethanol production took off, many critics argue that ethanol is a poor alternative to oil.

Perhaps the most heated controversy surrounding ethanol is the debate about whether it truly is a renewable fuel. For a fuel to be considered renewable, it must be produced from a resource that can be replenished and must yield more energy than is required to produce it. In the United States, most ethanol comes from corn, which can be grown each year and so meets the first criterion. But whether corn-based ethanol really yields more energy than is required to produce it, a factor known as its energy balance, remains a matter of intense debate.

Pimentel has consistently criticized the use of corn-based ethanol as a fuel source.⁴⁵ Pimentel's research found that corn-based ethanol production has a 29 percent negative energy balance, meaning that 29 percent more energy is required to produce ethanol than it yields.⁴⁶ An even worse energy balance was recorded by Patzek, who found that ethanol production had a 65 percent negative energy balance.⁴⁷ The findings of

Pimentel and Patzek have been contradicted several times, most notably by Shapouri, et al., who found that corn-based ethanol production has, on average, a 34 percent positive energy balance.⁴⁸ That positive energy balance value is also the one endorsed by the U.S. Department of Energy.⁴⁹ Patzek responded to the findings of a positive energy balance, arguing that the results violated “the fundamental laws of mass and energy conservation.”⁵⁰

Disagreement among researchers about the energy balance of ethanol production stems from disagreement over the inputs required to grow corn. In some locations, corn crops require large amounts of fertilizer and irrigated water. So corn requires more energy to produce in these locations, and the energy balance of ethanol made from that corn is more likely to be negative. In other locations, corn growth requires fewer inputs, so the energy balance of ethanol is more likely to be positive. This makes the prospect of determining a national energy balance for corn-based ethanol extremely difficult. But based on the research, the national energy balance for corn-based ethanol is unlikely to be much greater than neutral, and may even be negative, indicating that it is not a high quality renewable fuel.

Ethanol’s questionable energy balance isn’t the only complaint lodged by critics. Some also contend that ethanol produced from corn will drive up food prices, a matter known as the food-versus-fuel issue. The underlying premise of this view suggests that increasing ethanol production requires a greater share of the U.S. corn crop, thus elevating the price of corn. In addition, rising corn prices could have a ripple effect on other foods as farmers switch fields to grow more corn and less of other crops.

“In the United States, the growth of the biofuel industry has triggered increases not only in the prices of corn, oilseeds, and other grains but also in the prices of seemingly unrelated crops and products,” observed Runge and Senauer.⁵¹ They argued that the ripples will spread, affecting other nations around the world with rising food prices. This would be a devastating problem for many developing nations, where people spend 50 to 80 percent of their budgets on food.⁵² Others, such as Rajagopal and Zilberman and Msangi, et al., voiced concerns about the impact of biofuels on world food prices.⁵³ At this time, however, it is too soon to tell whether the boom in ethanol and other biofuels will significantly affect domestic or world food prices.

Although current U.S. policy is heavily focused on increasing the production of ethanol and other biofuels to supplement oil supplies, conservation hasn't been entirely overlooked. The predominant policy vehicle for conserving oil has been the Corporate Average Fuel Economy (CAFE) standard. CAFE was passed by Congress in 1975 and mandates a minimum miles-per-gallon requirement for auto manufacturers' new lines of cars and light trucks.⁵⁴ At the end of 2007, President Bush signed into law the first revision to the CAFE standard since it was passed. The revision raised mileage standards by 40 percent for cars and light trucks to 35 miles per gallon by 2020.⁵⁵

While raising CAFE standards is likely to have some impact on national oil consumption, better mileage also makes gas relatively cheaper on a per-gallon basis. This leads consumers to drive more miles than before the gains in efficiency, thereby reducing CAFE's benefits. Greene, et al., dubbed this phenomenon the “rebound effect” of the CAFE standard.⁵⁶ In a later study, Small and Van Dender found that the rebound effect declined throughout the 1990s and early 2000s.⁵⁷ But, the authors note, the decline of the

rebound effect during that time period was due to cheap gas prices and rising income. This meant consumers cared less about their vehicles' fuel efficiency, because driving was relatively inexpensive regardless. Now that oil prices, and subsequently gas prices, are so much higher, consumers are more likely to change their behavior based on their vehicles' fuel efficiency. So raising the existing CAFE standard might have a rebound effect, whereby consumers drive more than they did before the higher standards took effect. This rebound effect could mean that the oil savings from CAFE will not be as high as many politicians claim.

So while politicians hail the new CAFE standards as an important victory for the conservation of oil, the long-term benefits remain uncertain. But the support and enthusiasm of politicians has made one thing clear: They currently favor the development of new fuel sources to the conservation of oil. This preference has vast implications for the future of the United States.

A view of oil from the popular press

In addition to considering the fate of oil from the academic and policy perspective, it is also important to understand how the media cover the apparent end of the oil age. The media often function as interpreters, through which current events are synthesized and presented to the public. Therefore, reviewing the media's interpretation of oil provides insight into how the issue is being framed, as well as what gaps in coverage exist.

Much of the media's coverage of oil has, so far, focused on narrow, temporal events, such as oil's daily closing price in the futures market. To some degree, this type

of narrow coverage is aligned with the daily newspaper model of presenting information on a timely basis – there isn't always room for considering broader trends. At the same time, when the press presents an issue too narrowly, without providing the necessary scope, the story can be misleading. For example, the media covered the announcement by the International Energy Agency that global demand for oil in 2008 would be slightly higher than previously anticipated.⁵⁸ But while attention was given to that relatively small adjustment in the demand estimate, and the immediate reaction of oil prices on the futures market, the coverage failed to mention how the revised estimates would mean total world oil demand had increased by more than 10 percent in five years.⁵⁹

Although this limited style dominates news coverage, several publications produce more in-depth articles on the state of oil. Some of the most comprehensive coverage has come from *The New York Times*, which has regularly published articles on oil and biofuels.⁶⁰ In one of the most notable *Times* articles on rising oil prices, Mouawad noted, “Unlike past oil shocks, which were caused by sudden interruptions in exports from the Middle East, this time prices have been rising steadily as demand for gasoline grows in developed countries.”⁶¹ While this observation is accurate, the article fails to address rising prices from a supply standpoint. In a separate *Times* article, Mouawad does consider the supply side of the equation but dismisses the peak oil theory. Instead, he argues that technological advances will greatly expand the supply of oil.⁶² Although new technology developments are changing the methods used to extract oil, dismissing the possibility that the world oil supply will soon peak – a theory endorsed by many experts – presents an inaccurate view of the issue.

Not all publications view the peak oil issue the same way. In an article for *The Christian Science Monitor*, Francis presented evidence from several industry experts on both sides of the issue.⁶³ Writing for *The Guardian*, Seager covered a recently released German study saying that world oil production peaked in 2006.⁶⁴ The differing opinions and coverage show the media have a difficult time grasping the turbulent oil market from either a supply or demand perspective. The coverage also shows that opinions vary among experts, and so achieving proper depth requires drawing from a variety of sources.

Beyond oil, biofuels have also been heavily covered by the media. Much of the attention focuses on ethanol because of its rapid production growth. Birger wrote in *Fortune* that the frantic rush to grow more corn for ethanol production could potentially create a “dot-corn” bubble.⁶⁵ If ethanol fails as a fuel, Birger wrote, farmers who invested in new equipment and local ethanol plants will be hurt the most. Hagenbaugh wrote for *USA Today* about how ethanol prompts farmers to grow more corn than ever before, which, in turn, means growing fewer acres of other crops.⁶⁶

Along with its effects on farmers, ethanol’s potential impact on food prices also garners significant media attention. Martin wrote for *The New York Times* on the food-versus-fuel debate, noting that the impact of ethanol on prices at the grocery store isn’t yet firmly established.⁶⁷ An article from *The Economist* argued that rising world food prices are due in part to U.S. ethanol subsidies and also to rising incomes in developing nations.⁶⁸ A similar conclusion was reached by *The Christian Science Monitor*, which also noted the U.N. Food and Agriculture Organization has issued warnings about turning too much food into fuel.⁶⁹

Corn-based ethanol isn't the only biofuel being covered by the media. Several other biofuels based on feed stocks other than corn are also starting to attract attention. A number of news stories have focused on the research and development of cellulosic ethanol, which can be made from agricultural waste products such as corn husks, wood chips and wheat stalks. Woodyard wrote in *USA Today* about several potential cellulosic ethanol feed stocks and surveyed the processing plants that are under construction to use these feed stocks rather than corn.⁷⁰ Algae is also being considered as a potential source for biofuel production. Keefe reported in *The Atlanta Journal-Constitution* that Royal Dutch Shell PLC, a large oil company, is building a refinery in Hawaii to test production of biofuels from algae.⁷¹ "Algae is promising as a biofuel because it grows quickly, is rich in vegetable oil and can be cultivated in sea water, reducing the use of land and fresh water," Keefe noted.⁷²

Although these potentially new biofuel feed stocks are being covered, discussion of their viability and of other solutions to the oil problem has been limited. This tendency of the press to cover the developments without contextualizing them skews the information available to the public about biofuels. Many of the reported "breakthroughs" will take years of research and development before contributing to the fuel supply, if they ever do. In addition, the media have covered the conservation aspect of oil supplies only sparsely. Some articles have been written about technological developments that would help conserve oil, such as plug-in hybrid vehicles, which utilize both electric and internal combustion engines. But these articles lack contextualization and are few in comparison to the expansive coverage of biofuels.

Summary

While much has been written about oil and biofuels in the academic literature and the popular media, few articles have considered the broader societal implications of permanently expensive oil. What seems clear is that world oil demand is expanding, and supply is at best growing slowly or at worst falling. So a relapse to the relatively cheaper oil prices of the past is unlikely. As expensive oil's impact on the U.S. economy becomes more pronounced, the public will look to policymakers for answers.

At the moment, the favored policy solution is to develop new fuel supplies rather than emphasize and enforce conservation. But what are the inherent tradeoffs in such a solution? Can new fuel types be developed and produced quickly enough to supplement oil and avoid severe economic and environmental consequences? Why is conservation being overlooked? This thesis seeks to begin answering these critical questions.

Methodology

This thesis project is comprised of a series of three print articles. Each article focuses on a different facet of how the decline of oil is affecting the United States energy supply. The articles are designed to connect and have some overlap, but each article covers a unique topic.

Human Sources

As is the custom in good journalism, human sources provided critical information for the articles' composition. Many of these sources were interviewed by phone. But

some travel was also done to collect essential details firsthand. The information gathered from these sources was synthesized, and opinions from various perspectives were sought.

Drawing from a wide variety of sources helped provide depth to the articles and a diverse array of ideas and comments. Researchers, members of academia and industry experts provided vital background information and understanding of technically difficult concepts. Members of non-profit foundations and other advocacy groups were interviewed to capture the various competing interests that are at stake. Finally, some snapshots of ordinary people were used to provide anecdotal evidence as to how the oil crisis affects U.S. citizens.

Documents and Research

Much of the information for this thesis came from documents and research papers. Government documents and reports from non-governmental organizations contain a wealth of data and other relevant information that added depth to the piece. Scholarly articles provided information about the latest research and how existing data were interpreted. Some documents and research articles that were used in this thesis have already been discussed in the literature review and are also cited in different parts of the articles.

Analysis

This thesis drew information not only from outside human sources and documents but also from personal analysis. This analysis focused on interpreting the information available from other sources and providing added scope and depth to that information.

While every attempt was made to keep this work unbiased, it is important to recognize that no article is ever perfectly objective because no author is able to write from a perfectly objective point of view. Rather than attempt to hide this reality behind a false pretense of objectivity, it is better to admit that the author's analysis shaped the final product. The author sought to ensure that this analysis was as transparent and well-supported as possible.

Limitations

Like any project, this thesis had limitations. The primary limitation for this project was the sheer scope of the subject matter being covered: oil and the future of the U.S. fuel supply. No series of articles, no matter how long or well-researched, could fully cover this subject and investigate every important historical event, policy concept, economic impact or potential technological breakthrough. Nevertheless, this thesis addressed what the author found to be the most significant of these subjects and discussed how they are changing the future of the U.S. energy supply.

Other limitations on this project were time, money and the author's breadth of knowledge. A project such as this could easily take years of research and writing. The time allotted for this thesis was less than three months, a limit that undoubtedly affected the final product. Additionally, to fully understand the issues firsthand, extensive travel would be required to interview sources in person as well as to directly observe the work being done in the fields of biofuels and oil conservation. But the funds for this project were limited, and so the amount of travel was restricted to the available budget.

Chapter Breakdown

This thesis is broken down thematically into three chapters. A basic overview of each chapter is given here:

1. **The Permanent Oil Crisis:** This article considers oil's past, present and future in the United States. Historical narrative is used to consider the role oil has played in the past century of U.S. history. The ongoing challenges of both supply and demand in the current oil market are summarized from the perspective of current research and the oil industry. This information is considered alongside policy decisions and legislation.
2. **A Harvest of Biofuels:** This article considers the legislation and political support driving the current biofuel boom and the ramifications of this support. The impact of the boom is addressed and discussed with a focus on how such government intervention in the fuel market tends to create winners as well as losers. A firsthand account of ethanol's impact on farmers provides anecdotal evidence about the consequences of policy decisions. Effects of the boom are used to consider how the biofuel market will grow, what the most promising new technologies and feed stocks are, and how long it might take for a robust biofuel industry to have a substantial impact on the U.S. fuel supply.
3. **Getting Plugged-in to Conservation:** The final article discusses what the potential savings from conserving oil are. It focuses on one of the most promising

new technologies being developed for oil conservation – the plug-in hybrid vehicle. The status of the technology and its potential impact on the U.S. fuel supply are discussed, alongside a view of how the country could proceed toward the electrification of the transportation system.

Chapter 1

The Permanent Oil Crisis

Joe Neuhof is frustrated with oil. It isn't sky-high pump prices at gas stations that are bothering him; it's what high oil prices are doing to Western Colorado. "Basically, you have the industrialization of one of the most beautiful places in the country," he says.

The beautiful place that Neuhof, a field director for the Colorado Environmental Coalition, worries about is the Roan Plateau. Located a few miles northwest from the town of Rifle, Colo., the plateau rises above the Colorado River valley and is home to wildflower meadows, forest glades of juniper, fir and aspen trees, and some of the most diverse wildlife in all of Colorado.

But the plateau also happens to sit on some large oil-shale deposits. Oil shale is a type of sedimentary rock that contains a chemical called kerogen, which, after it is extracted, can be refined into crude oil. Although extracting kerogen from oil shale is akin to squeezing water from a rock, some major oil companies are still giving it a try. And, despite the inefficiency of the process, it's not hard to understand why.

These days, heading to the gas station for a fill-up is a costly experience. Gasoline prices have more than doubled in just five years. Filling up a 20-gallon tank now costs more than \$60, based on average U.S. pump prices. And thanks to Americans' love affair

with gas-guzzling SUVs, many people now find themselves in a financial pickle just trying to keep their behemoth autos on the road.

Expensive oil is no novelty for Americans. Spikes in oil prices have occurred sporadically during the past four decades and have always subsided. So while drivers are getting gouged at the pump now, expectations remain high for some relief in the near future.

But recent predictions of declining oil prices have persistently proved optimistic and wrong. The reason is the impetus behind the ongoing oil crisis comes from different sources than similar fluctuations in the past. This new species of energy crisis is sending both consumers and oil companies scrambling for solutions.

Hurricane Katrina is often considered the tipping-off point for oil's dollar-per-barrel ascension. But prices had already risen by more than 50 percent in the two years leading up to the storm. Katrina's decimation of the Gulf Coast refineries may have crimped the U.S. oil supply, causing a classic price spike. But the storm's effects on oil supplies have long since subsided, and today's high prices are the result of a gradual climb rather than any sudden jolt.

"Historically, food and energy prices were very volatile," says James Hamilton, a professor at the University of California, San Diego and a researcher on oil's economics. "If they went up one quarter, they were just as likely to go down the next. But that's not an accurate statement of what we've seen the last three years."

Not your parents' oil crisis

In the past, dramatic swings in oil supplies and prices manifested themselves as an unpredictable boom-and-bust pattern, which plagued the energy industry. In particular, the 1970s stand out as a decade of volatile oil prices resulting from turbulent geopolitical events.

The first major oil crisis began in 1973 and was precipitated by hostilities between Israel and an alliance of Arab nations, in what is now called the Yom Kippur War. Although the fighting lasted only three weeks, key oil producers such as Saudi Arabia and Kuwait utilized the “oil weapon” to apply pressure on supporters of Israel.

The methods of these oil-rich nations included a series of embargos, production cutbacks and price hikes, mostly targeted at the United States. “We want the consuming countries to know how we feel, and I think they are beginning to feel it,” said Kuwait’s Petroleum Minister, Abdel-Rahman Atiqi, after the crisis began.

While the embargo’s tactics caused an immediate jump in world oil prices, the actual drop in global oil supplies was relatively minor – only about 5.5 percent of world oil consumption.

But even that small drop in oil supply was enough to cause widespread energy hysteria. After the embargo started in 1973, oil prices tripled in just a few months. Panic resulted from uncertainty over how much oil was actually available. “The figures we have now are gobbledygook, and we don’t know if they’re real or not,” bemoaned a New York state official in early 1974. Without solid information, neither oil companies nor government officials felt the energy supply was secure.

In the United States, lines formed at gas stations as the government tried to manage the predicament via price controls and rationing systems – actions that only served to stoke the public’s fears. Although the embargo by Arab nations quietly ended in 1974, global anxiety continued pushing up oil prices even as supplies became more available.

Europeans experienced the worst consequences of the energy crisis. When the turmoil began, Western Europe was heavily dependent on oil-based energy supplies and imported 80 percent of its oil from the Middle East and North Africa.

Faced with supply shortages and price hikes, vulnerable European nations started experimenting with the first serious attempts to develop alternative energy supplies. According to *The New York Times* in 1973, these efforts included dabbling with such “exotic” technologies as windmills, solar power and gas derived from plants.

While the alternative energy projects never made much progress during the crisis, European nations also began imposing high taxes on oil to curb domestic consumption. These higher taxes remain in place today and have kept the price of oil in Europe much higher than in the United States, says Olivier Blanchard, a professor of economics at the Massachusetts Institute of Technology. “Europe’s higher oil taxes have clearly affected the way things are produced on both sides of the Atlantic,” he says. “They also give the European countries an economic tool that the U.S. doesn’t have. If European governments think prices will remain high, they can actually smooth the economic effect by lowering their taxes.”

After remaining in place for decades, Europe’s higher oil taxes have profoundly affected their consumption level – the average European now uses about 8 barrels of oil

per year; the average American uses more than 25 barrels per year. In addition to consuming less oil, European nations have also had more success in developing alternative energy supplies, such as Germany, which has a nation-wide solar program.

By contrast to Europe's situation, the United States imported only 5 percent of its oil from the Middle East in 1973, and so was less vulnerable to the embargo. Although President Nixon capitalized politically on the crisis by calling for "energy independence," his rhetoric was "a public relations exercise, rather than a serious response," Leonardo Maugeri notes in his book, "The Age of Oil." Indeed, American oil consumption remained mostly unfazed by the crisis.

But fears that the world's oil supply was running out continued to plague the public mindset. Predictions of scarce oil abounded. In 1977, a dire report by the CIA warned that "in the absence of greatly increased energy conservation, projected world demand for oil will approach productive capacity by the early 1980s and substantially exceed capacity by 1985."

Other energy agencies fanned the flames by supporting the CIA's conclusion with equally pessimistic oil demand forecasts. A day of reckoning seemed just over the horizon. The public's fears came to a head in 1978 with the beginning of the Iranian Revolution and, consequently, the world's second great oil crisis.

Due to pressure from Ayatollah Khomeini and his millions of revolutionary followers, the Shah of Iran fled to Egypt in January 1979. Before to the revolution, Iran produced about 5.5 million barrels of crude oil per day, which amounted to 10 percent of the world's oil production. After the Shah's departure, Iranian oil output fell precipitously and came to a virtual halt before slowly ramping back up.

The supply disruption prompted by the Iranian Revolution, and the ensuing Iran-Iraq War, caused another shock to oil prices. The cost of a barrel of crude oil went from the inflation-adjusted price of \$44 in 1978 to \$79 in 1981.

Once again, the U.S. government attempted to implement price controls, and panicked drivers flooded gas stations. Gas lines formed across the country, similar to the previous oil crisis. In an ironic twist, the gas lines themselves begat more gas lines. Thousands of idling motorists squandered loads of oil – about seven-tenths of a gallon an hour – while they waited to fill their tanks. By some estimates, waiting motorists wasted about 150,000 barrels a day during the spring and summer of 1979.

Although oil prices began descending in the early 1980s, several years passed before prices reached some semblance of stability again. While other events, such as the start of the Persian Gulf War in 1990, have also caused leaps in oil prices, most other spikes were relatively minor compared to the shocks of the 1970s. And after decades of turbulence in oil supplies, the United States has developed a familiarity with volatile oil prices.

But the ongoing elevation of oil prices is the result of different forces than previous crises. Despite U.S.-led wars in Iraq and Afghanistan, the rising price of oil is being driven by surging demand rather than uncertain supplies.

“In the present situation, there is no supply disruption particularly, but a demand response caused mostly by China and India,” economics professor James Hamilton says. China’s oil consumption has more than doubled in the past decade, propelling China to the position of the second-largest oil-consuming nation in the world. In that same time

period, India's thirst for oil also rose considerably, making it the world's sixth-largest oil-consuming nation.

While China and India are leading the demand surge, the rest of the world isn't far behind. Projections from the U.S. Energy Information Agency and the International Energy Agency both conclude that by 2030 the world will demand about 30 million more barrels of oil per day than at present. Such portents call into question whether oil production can keep pace with ballooning demand.

For the United States, demand-driven growth in oil prices presents a different set of challenges from previous price shocks. In the past, once events calmed down, prices fell. But the current demand-centered oil crisis indicates sustained high oil prices rather than temporary spikes. As that reality sinks in, the oil industry finds its dominance of the U.S. energy market in a state of jeopardy.

Desperate times call for fuel from rocks

The oil situation has become so desperate that companies like Shell Oil Co. are trying to develop cost-effective methods for squeezing the kerogen out of oil shale. The process might seem wasteful, but it's going to be a while before other energy sources can really fill the energy void, says Tracy Boyd, communications and sustainability manager for Shell's exploration and production division. "It's going to be a long time before alternative and renewable energy sources really come into being," Boyd says. "In the meantime, something has to bridge the gap."

That something, Boyd believes, could be oil shale extracted from rock formations like those found in the Roan Plateau. The plateau lies within a geological area known as

the Green River Formation, which spreads across parts of Colorado, Utah and Wyoming. The U.S. Geological Survey estimates that the formation holds more than 800 billion barrels of viable oil supplies. “At our current consumption rate, that’s 110 years of oil,” Boyd says. “It’s three times the size of Saudi Arabia’s oil reserves. It’s just not so easy to get at.”

The difficult and energy-intensive oil shale extraction process has undermined previous efforts to develop the Green River Formation’s resources. After World War II, a Bureau of Mines program researched the potential for oil shale development but never went further.

Renewed interest came about during the 1970s oil crises. The idea gained federal backing when Congress created a synthetic fuels program to encourage development of unconventional fuel resources. In 1975, two researchers from Colorado State University, LeRoy Carlson and Alexander Cringan, predicted that “rich deposits of oil shale in northwestern Colorado probably will be mined in the near future.”

But when oil prices crashed in the 1980s, most efforts to develop oil shale were dropped – until recently. In the U.S. Energy Policy Act of 2005, oil shale was identified as a strategically important domestic resource and thrust back into the energy world’s limelight.

Previous attempts to recover oil shale involved operations similar to strip mining combined with high-temperature processing, known as retorting, to separate the oil from the rock. Because the mine-and-retort method has proved economically inefficient and environmentally damaging, Shell is developing new technology for extracting oil shale.

The Shell method, called an in-situ conversion process, involves gradually heating several thousand feet of shale formations underneath the earth's surface to temperatures around 700 degrees Fahrenheit. Over time, oil separates from the rock formations and can be pumped to the surface similar to traditional oil field operations.

So far, Shell has tested its process on a 30-by-40-foot testing area and recovered 1,700 barrels of oil and gas. "The challenge now is to scale the process up in a way that's cost effective and environmentally responsible," Boyd says.

But the term "environmentally responsible" can mean different things to different parties. And the environmental impact of oil shale extraction in an area that has already experienced significant natural gas development is simply unknown, says Joe Neuhof of the Colorado Environmental Coalition. "There's no good way to gauge the cumulative impact of what oil shale would look like on top of what's already happened with natural gas," he says.

Neuhof also remembers the negative impact that the oil shale busts of the 1970s and 1980s had on the region. "There are bumper stickers you still see in the area that say, 'The last one out of Grand Junction, turn the lights off,'" he says, referring to one nearby town that was affected when previous oil shale extraction efforts fizzled. "That's how much it affected the economy out here. That's how severe it was."

But Boyd says that Shell started work on its oil shale process when other companies were giving up, so the company isn't planning on halting its research despite what oil prices do. "We're certainly not doing it or undoing it because of what today's price of oil is," he says. "The bigger issue is energy security, supply and demand."

Jesse Smith, an oil and gas contractor for nearby Garfield County, Colorado, agrees with Boyd's assessment of the push for oil shale. "I don't think what's going to happen in the future is going to be driven by economics," Smith says. "It's going to be driven by world politics."

Further tests and research on Shell's process are currently under way. But even if testing goes well, it will be many years before Shell begins processing oil shale commercially. "We're hoping that by the middle of the next decade we'll be in a position to make a decision about moving forward on the oil shale project," Boyd says.

So for all the drivers struggling under the burden of high gas prices, the hope of oil shale's boosting domestic energy supplies in the near future remains remote.

Energy independence, one car at a time

With gas prices continuing to climb past record highs, some ambitious motorists are taking the notion of oil independence into their own hands. One emerging trend is for owners of diesel vehicles to convert their cars to run on used fryer grease.

Kevin Maass, the owner of KTM Auto in Plymouth, N.H., heard about using grease in diesel engines and decided to try running his car on it while at the supermarket. "It was during the first fuel crunch that we went into, and the price of oil went through the roof," Maass says. "I was grocery shopping, and saw that vegetable oil was on sale. So I bought three gallons, poured it directly into my car and drove around for three weeks on it."

Many people who convert their vehicles to run on grease also put a switch on the dashboard that allows them to alternate between regular diesel fuel and grease power. In

normal operation, it is easiest to start a car running on diesel fuel for the first couple of miles to let the grease warm up and reduces its viscosity. Once warm, the car can be shifted to grease mode with the flip of a switch. And the grease gets about the same miles per gallon as diesel fuel does.

After his initial experience with grease, Maass worked with some friends to develop a basic conversion kit that allowed diesel cars to run on grease. Nothing about the conversion kit was specially made. “We did it all out of hardware store parts and universal stuff,” he notes. Maass has also made the plans and parts list for the kit available on his Web site: www.ktmauto.com.

After completing the design, Maass started offering the kits to his customers along with assistance in the conversion process. He also converted several cars to run on grease for his own use, but the concept proved so popular that he received purchase offers immediately and sold the cars. “Every time I did a conversion, someone offered me good money for the car,” he says.

Maass also helped establish a network of supply sites across the state so that other grease users could have easy access to fuel. “People help out by picking up the oil from restaurants and bringing it to these areas to get filtered,” he says. The filtered grease is available free for use in converted diesel cars. Last year, Maass gave away 3,000 gallons of grease.

Nationally, enough recycled vegetable oil and other sources of grease are available to provide fuel for about 1.7 billion gallons of biodiesel per year, according to the U.S. Department of Energy. That much biofuel could displace about 5 percent of the nation’s annual diesel fuel use.

But Maass says that even though plenty of grease is available for more people to stop using oil, the government hasn't been very helpful. He contacted state authorities to see what was required to legitimize his grease distribution. In response, he was informed that grease isn't a legal vehicle fuel, and even using it was a violation of New Hampshire state law.

"I think the government needs to get on board and encourage people to use alternative fuels," Maass says. "Right now, that's not happening."

Even if using grease fuel isn't completely within the law, Maass still observes plenty of enthusiasm from his customers. "A lot of people feel like the whole oil gig is so corrupt that they don't want to support it anymore," he says. "They're so tired of being totally energy dependent on a country like Iraq or any of the other Middle East countries."

And in the meantime, Maass says, "We've got to learn to downsize. We have to downsize vehicles. We have to downsize commuting. We have to downsize our waste." But history indicates that's easier said than done.

Chapter 2

A Harvest of Biofuels

At first glance, Byron Weathers of Yuma, Colorado, resembles the quintessential American farmer. A gray-haired, bespectacled man of 54, Weathers pauses from working on his 1,500-acre corn farm to discuss the impact of rising fertilizer prices on his business. “Those are the kinds of things that need to get out there that people don’t understand,” he notes in a soft voice, tinged with a Western accent.

A corn farmer for more than 30 years, Weathers has endured his share of tough times. As his combine, a large machine that plows through fields to thresh and clean corn all at once, rolls over a patch of brown earth, Weathers recalls one Christmas in the late 1980s when the price of corn was so low that he “didn’t have enough money to buy Christmas presents.” Faced with mounting financial problems, Weathers considered selling the same plot of land he’s now harvesting.

But before he went ahead with the sale, a local bank agreed to cut him a break. He was able to hang onto his land. The next season “that quarter of ground produced the most money I’ve ever made in my life,” he says with a grin. But many others farmers in Yuma were less fortunate, he says. They lost their farms after years of low corn prices.

These days, things have changed for Weathers and other corn farmers across the country. The shift isn't due to any newfound love of corn but to a national sense of urgency to develop new fuel supplies.

Without a doubt, the U.S. has fuel problems. Oil prices continue to hover above \$100 per barrel. The cost of a gallon of gasoline has more than doubled in just five years. And rampant demand from rapidly developing nations – China and India in particular – has helped plunge the country into a new oil crisis.

Unlike crises of the past, the current oil dilemma will potentially keep oil prices high for many years to come. Faced with that reality, the race is on to develop alternative fuel supplies to supplement oil. But are these attempts making a difference?

Much of the current effort focuses on corn-based ethanol, the biofuel movement's poster child. In a 2005 energy policy speech, President Bush noted that most domestic ethanol comes from corn, and "we're pretty good about growing corn here in America." He was right. The United States grew 42 percent of the world's corn supply in 2006, or more than 11.1 billion bushels, according to the U.S. Grains Council. The next-largest producer, China, grew less than half that amount.

To make use of so much corn, the president and Congress have enacted a variety of programs to encourage ethanol production during the last few years. One well-known program is the Volumetric Ethanol Excise Tax Credit, which provides a tax credit of 51 cents per gallon to gasoline suppliers who blend ethanol with gas. A variety of other programs exist, such as loan guarantees, support for small ethanol producers and the renewable fuels standard, which requires that suppliers annually blend 36 billion gallons of renewable fuels with gasoline by 2022.

Buttressed by the government's support, U.S. ethanol production has almost quadrupled since 2002. National production capacity has surpassed 8 billion gallons annually, and enough new plants are under construction to take that amount to 13 billion gallons, according to the Renewable Fuels Association. Yet even after such rapid expansion, biofuels still make up only a small portion of the 140 billion gallons of gasoline used in the U.S. each year.

Ethanol's rural revolution

Although the financial support for biofuels is coming from Washington, D.C., the real heart of the ethanol movement beats in the cornfields of rural America. And what is happening in those cornfields is changing the mix of the U.S. fuel supply.

Before the ethanol boom, demand for corn remained flat for most of the last half century. And the price a bushel of corn fetched on the market was often not enough for farmers to earn a living. By the late 1990s, corn actually cost more to produce per acre nationally than it was worth. Corn farmers hemorrhaged money and stayed in business only because the government subsidized them generously.

Ethanol has changed that situation. Corn prices languished at around \$2 per bushel in 2005, when the government first began pushing biofuels. Just three years later, a bushel of corn now fetches more than \$5 on the Chicago Board of Trade's futures market. Motivated by higher corn prices, farmers across the country are scrambling to grow more corn and cash in on the ethanol craze. For some, that means sharpening their business plans and trying innovative methods to extract more corn from the same amount of land.

Back in Colorado, harvesting time has arrived on Weathers' farm. It's a warm fall day, but winter blows in early to the farm, which sits on the Rocky Mountains' front-range plateau, more than 4,000 feet above sea level. As Weathers' continues harvesting, in the cab of his combine the dusty air smells of cornmeal with a hint of diesel fuel mixed in, and Weathers nonchalantly discusses how farmers have promoted ethanol production to vertically integrate their businesses and boost demand for corn. Now, he says, farmers have lots of different markets for corn beyond just selling it for human and animal consumption.

A flat-panel screen just above his head displays current and average data on speed, moisture level and yield per acre – data that elicit comments from him on why different patches of ground produce higher yields than others. “Land is pretty tough to find around here,” he says. “We’re always trying, though.” Because additional land is hard to come by, the only way to produce more corn is to increase the yield, Weathers says.

Several years ago he began using a different tilling process, called strip-tilling, which has helped boost yields significantly. “Our net dollars per acre has jumped more than any other change we’ve ever made,” he says. In addition to producing higher yields, strip-tilling is also more environmentally friendly than the old process. While Weathers says he’s skeptical about the effects of global warming, he’s prepared regardless. “If it does turn out to be real, we’ll be well positioned with our strip-tilling to receive carbon credits,” he says about the type of credits the government might issue if a carbon-emissions trading scheme were implemented.

The better times for corn farmers that Weathers sees on the horizon wouldn't be possible without places like the local ethanol plant, which is only a few miles from Weathers' farm. The plant, which produces around 50 million gallons of ethanol annually, is operated by Yuma Ethanol and was started in 2005 by a local group of corn farmers and cattle feeders, says Dave Kramer, company president and general manager. "It's a real good natural hedge for them," Kramer says, "so if the price of corn goes down they can make the return up in the ethanol plant."

In Colorado, ethanol isn't just helping out the corn farmers, Kramer says; it's also supporting the cattle industry. "Without the ethanol plants in eastern Colorado, the cattle industry here wouldn't be a viable business any more," he says. One coproduct from the plant's ethanol production is wet distiller's grains, which cost less than corn and can be used for cattle feed. Thanks to that profitable coproduct and the ready supply of local cattle farms, the Yuma Ethanol plant continues turning a profit even while other ethanol plants struggle because of higher corn prices, Kramer says.

Farming for higher profits

The practice of local farmers starting a local ethanol plant isn't new. Farmers have been behind many of the new ethanol plants springing up across the country. One such farmer is 55-year-old Dave Nelson of Belmond, Iowa. Nelson got involved with ethanol in 1999 when he invested in the construction of a local ethanol plant by his local farmers' cooperative.

Ethanol production in the United States that year was still small, but demand started growing a few years before when the gasoline additive methyl tertiary butyl ether,

MTBE, was discovered in drinking water supplies across the country. After the discovery, ethanol, which can be substituted for MTBE, received attention from refiners as an alternative additive. When the groundwater contamination from MTBE continued to spread, the Environmental Protection Agency responded in 2000 and introduced recommendations to phase out MTBE nationally. MTBE fell out of favor, and “that’s when ethanol really took off,” Nelson says.

Nelson’s plant began making ethanol in 2001, with an annual production capacity of 50 million gallons. Although he didn’t know it at the time, ethanol was on the cusp of a construction boom that has resulted in 78 new ethanol plants built in the U.S. since then. Farmer-owned cooperatives such as Nelson’s are responsible for the majority of the new ethanol plants, according to the Renewable Fuels Association.

Not wanting to miss out, Nelson’s cooperative recognized the trend and took action. “We were making pretty good money,” he says. “So we turned around and expanded the plant in 2003 to produce 100 million gallons a year.” Nelson describes the plant’s history in a barn on the 5,000-acre farm he runs with his younger brothers, Dennis and Neil. An old radio, perched on a shelf behind him, blares out an ad sponsored by Monsanto, a large agricultural technology company, about “ethanol man” and his exploits for a better fuel supply.

Nelson chuckles at the ad and explains how after the expansion, ethanol’s growing popularity motivated his cooperative to sell a 60 percent stake in the plant to Global Ethanol, based in Minneapolis, Minn. “Farmers are pretty good at running things,” he says. “But when it gets to be a multimillion-dollar business, it’s too much.” Nelson was satisfied with the sale and thinks Global Ethanol brought better management

and “all the bells and whistles” of a major corporation. Plus, he still gets a share of the profits from ethanol sales, and the plant serves as a local market for some of the corn grown on his farm.

Revisiting ethanol’s past

But even though the ongoing ethanol boom is getting plenty of hype, its addition to the U.S. fuel supply isn’t really a new development. During the 1970s and early 1980s, volatile events in the Middle East, such as the Arab oil embargo and the Iranian hostage crisis, drove gas prices to record highs. With oil supplies short, worried consumers formed lines at gas stations across the country.

In response to the crises, the U.S. government attempted to ration gasoline and ended up exacerbating the problem. Prices continued skyrocketing.

So corn farmers stepped in with a solution: distill corn into alcohol, blend it with gasoline and fill ‘er up. The resulting fuel, marketed as gasohol, typically consisted of 90 percent gasoline and 10 percent ethanol.

First introduced in 1974, gasohol five years later had migrated from a Midwestern novelty to an exciting new product at East Coast gas stations. New lines formed at gas stations as people wanted to try running their cars on all-natural, home-grown gasohol.

Yet despite farmers’ best efforts to market gasohol as the patriotic, all-American alternative to foreign oil, criticism of the fuel abounded. A 1978 New York Times article noted, “Gasohol currently costs more to make than gasoline and it depends on sizable tax advantages to be competitive. Moreover, manufacturing the alcohol actually consumes

more energy than the product saves.” These same arguments are also made against ethanol today.

Unfazed, the industry grew, helped along by strong political support. In 1980, the Carter administration announced a program intended to boost ethanol production from 175 million gallons to more than 500 million gallons per year. Just enough “to displace a little more than one day’s worth of oil imports,” an article in Time magazine dryly noted.

America never resolved the gasohol controversy because a year after Carter’s announcement oil prices started declining, and ethanol producers struggled to turn a profit. In an attempt to save the ethanol industry, the U.S. government offered a generous subsidy of 60 cents per gallon of ethanol in 1984. The program failed, and by the end of the next year less than half of the nation’s 163 commercial ethanol plants remained in business. Although the United States would continue producing small amounts of ethanol for the next 15 years, the gasohol dream was dead – and the hopes of corn farmers along with it.

Reliving ethanol’s past

A quarter century after the demise of gasohol, driving on N.C. 55 to visit Charles Alexander, a corn farmer from Stonewall, N.C., feels like traveling through a time warp. Shabby homes line the roadside – their tin-roofs rusted and paint peeling. Broken-down cars litter the lawns. A variety of old butcher shops, single-pump gas stations and small grocery stores flit by.

In front of almost every shop in this town of 200 people, an American flag waves. Patriotism runs deep in rural North Carolina. Alexander says patriotic pride is one reason

he, like many others, supports ethanol – an “American fuel” – with his wallet as well as his words. “I would rather pay farmers instead of Iraq,” he says.

Despite the dilapidated appearance of Stonewall and other rural towns across the country, many farmers are feeling optimistic again after decades of depressed corn prices forced them to live off government handouts.

“Ethanol, as a whole, has been darn good for farmers,” enthuses Alexander, a director of the National Corn Growers Association in 2000-2006. He has good reason to celebrate. Until a year ago, farmers across the country “were getting slaughtered on corn,” he recollects in his slow, Southern drawl. Without a pause from surfing the Internet for up-to-the-minute corn prices, Alexander optimistically chats about how ethanol will get corn farmers off government subsidies for good. Scattered on the wall behind his desk are half a dozen dusty plaques for awards such as “Pamlico County Corn Champion – 1997.”

Reinvigorated corn farmers like Alexander believe the extended profit drought is over, thanks to ethanol. And it’s about time, he says: “We have just been struggling. People just don’t realize what farmers do to try to survive.”

Before the ethanol boom, corn farmers received subsidies based on a safe price set by the government. If farmers couldn’t sell their corn for as much as the safe price, the federal government paid them the difference, a situation Alexander hopes to avoid in the future. “We’re tired of farming on welfare,” he says. But if support for ethanol dwindles, he admits, “the government is going to have to go back and subsidize us like they have all these years. It’s a vicious cycle.”

But subsidies are the last thing on Alexander's mind now because ethanol production has "created the best demand in the market that I can remember in 39 years of farming," he says. Since its newfound popularity, ethanol has claimed a greater share of the U.S. corn harvest each year. According to the U.S. Department of Agriculture, 14 percent of the 2006 corn crop went to ethanol, an amount expected to grow to 31 percent during the next decade.

Even though ethanol has helped boost corn prices during the last few years, corn farmers might be celebrating prematurely. Outside the cornfields, many Americans have reservations about ethanol's viability as a fuel supply. Environmentalists argue that ethanol yields little more energy than it consumes to produce. And they worry about farmers plowing corn on currently unused land. Skeptics wonder if ethanol can ever replace enough foreign oil to make the effort worthwhile. Still others blame ethanol for the jump in corn prices and claim it's driving up food costs and starving the poor.

In addition to these arguments, much of the current demand for ethanol is due to political intervention rather than grassroots support. If that support were to disappear, then so would the ethanol industry. And while thousands of farmers such as Dave Nelson continue investing their newfound corn profits in ethanol plants, the boom has stalled. The price of ethanol peaked in June 2006 at \$4.33 per gallon. Since then, ethanol has declined to below \$2 per gallon.

One reason for ethanol's decline lies in its distribution bottlenecks. At this time, ethanol is transported by trucks or railroads, which are more expensive than the pipelines used for oil. While there is some discussion about building ethanol pipelines, it won't

happen soon. In the meantime, all the new ethanol plants have driven production capacity past demand.

Many farmers blame these issues on the oil companies, but either way solutions must be found for ethanol to continue its momentum. Whether the ethanol boom will turn to bust, as it did in the 1980s, isn't clear yet. But many ethanol plants already find it more difficult to turn a profit now than just a few years ago.

Nelson remains optimistic about ethanol's long-term viability as a fuel, but he doesn't expect it to make him or other farmers rich. The prices of his farm's inputs, such as fertilizer, diesel fuel and land rent, have all gone up considerably in the last year. "Right now we're doing fine because we're working off of last year's inputs and getting this year's prices," he says. But what comes next is probably more of what corn farmers are all too familiar with – struggling to get by. "We feel like we had a little cash for a while," he says, "but it's going to all go away."

What comes after corn?

Despite the rapid expansion of corn-based ethanol production, the demands of the Renewable Fuels Standard cannot be met by corn alone, says Gary Schmitz, external affairs manager at the National Renewable Energy Laboratory. "We can maybe double the amount we get from corn," Schmitz says, "but beyond that we need something else. We don't want to get into an issue of food versus fuel."

Some believe that the next step for biofuels will be cellulosic ethanol. Unlike the corn-derived form of ethanol, cellulosic ethanol can come from a variety of different feedstocks and is made through different processes. Cellulosic ethanol can be made from

agricultural waste such as corn husks and stalks, wood chips and rice straw, or it can be made from crops grown specifically for the purpose, such as switch grass.

The diverse array of potential feedstocks could make cellulosic ethanol a superior product, Schmitz says. “We believe that cellulosic ethanol will have economic and environmental advantages over ethanol from corn.”

One of the greatest advantages of cellulosic ethanol will be its flexibility across geographical regions. “Every state in the nation will have an opportunity to start a biofuels industry,” Schmitz says. “The industry will look different everywhere based on each region, the climate and the resources.”

With this type of regionally based biofuels idea in mind, the Department of Energy in 2007 announced funding of up to \$385 million for six cellulosic biofuel plants. The plants will be located in a variety of areas across the United States.

Each plant will use different processes and feedstocks based on what is available regionally. So a plant being built by the Broin Companies in Emmetsburg, Iowa, will produce ethanol using corn fibers, cobs and stalks, while BlueFire Ethanol’s plant in Southern California will run on “green waste” from a nearby landfill.

But even with a few plants going into production, cellulosic ethanol is still a long way from being commercially viable. “It’s not going to be simple,” Schmitz says. “There are some technical hurdles that lay before us. Mostly that involves figuring out the manufacturing processes, but the biggest problem is cost. The plants going in now are getting federal support because these are higher-risk ventures than the industry would undertake on its own.”

And even if cellulosic ethanol does become commercially viable, some farmers, such as Charles Alexander, are skeptical that it will be able to compete with corn. “They will keep trying other products,” Alexander says, “but corn will continue to be the king.”

The next wave of biofuels

Although the promise of cellulosic ethanol appears to be the next big thing in biofuels, several companies are already working on what could be the next, next big thing: making biofuels chemically identical to petroleum-based products. One downfall of ethanol is that it will work only in limited quantities in most gasoline-powered cars. A mix of 10 percent ethanol is the maximum that most cars can handle without suffering mechanical issues. While flex-fuel vehicles are sold that can run on much higher quantities of ethanol, not many are on the road yet – only about 4.4 million in the U.S. out of more than 250 million total cars.

To solve this problem, OPX Biotechnologies and other companies are working on processes to make copies of petroleum-based products such as gasoline and jet fuel. The tool OPX Biotechnologies plans to use to do this was developed over the course of five years at the University of Colorado at Boulder by the company’s founders, Mike Lynch and Ryan Gill.

The key to the company’s success, says CEO Robert Chess, is developing organisms that can take a variety of different feedstocks and turn them into the desired product. While other companies have similar goals, OPX Biotechnologies is trying a different method. “Typical approaches haven’t been very cost-effective because the

organisms aren't very efficient," Chess says. "We have the technology to optimize the process of finding efficient organisms 1,000 to 5,000 times faster than our competitors."

Chess won't go into details about exactly how his company's proprietary process works, but he will give a basic overview. "We identify what each gene in the organism does," he says. "Then we determine which genes make a difference, and we say, 'Let's modify those.'" This approach, Chess says, is like being stuck in a forest and everyone else is trying to find the right paths to get out. "What we're doing is buying the GPS photo."

Having such tight control over the genes of their organisms will allow OPX Biotechnologies to make its products from many different feedstocks equally well. "We're going to be feedstock agnostics," Chess says. "It would be like we'd have common modules and we'd optimize feedstock to feedstock. That's the nice thing about this tool. You can do that very quickly."

So far OPX Biotechnologies, formed in June 2007, has gotten only to the point where its organisms can make the desired products. The next step will be to build a prototype manufacturing plant, although Chess isn't speculating about when this might happen. "The key to success," he says, "isn't just developing the next generation of biofuel processes but making them economic."

With that in mind, the people concerned about the long-term energy future of the country should be concerned about there being long-term support for biofuels, and not just high oil prices, says Schmitz of the National Renewable Energy Laboratory. "There are significant amounts of U.S. financial resources going to certain parts of the world that have not historically aligned with U.S. interests," he says. "The more we can turn to

domestic sources of energy, and have those sources of energy provide environmental benefits as well, the better for our country.”

If Schmitz and other supporters of biofuels are right, and the goals of the Renewable Fuels Standard are realized, then at some point in the future biofuels will make a major contribution to the national fuel supply. For now, though, with a national thirst for 140 billion gallons of gasoline annually, biofuels make up little more than a drop in the bucket.

Chapter 3

Getting Plugged in to Conservation

Driving into Charleston, S.C., with Jim Poch looks and feels just like an ordinary car ride. Gnarled oak trees hung with Spanish moss line the roadside, as Poch's car cruises through the downtown of this charming Southern city with its abundance of historic houses and buildings.

The difference between this trip and any other is the amount of gas being used – Poch's car averaged 94 miles per gallon during the 15-mile trip into Charleston. What's his secret to such great fuel economy? Poch drives a Toyota Prius, which has been converted into a plug-in hybrid vehicle. The conversion allows him to charge his car from a normal electrical socket and then drive it for short distances on pure electric energy.

On the dashboard of his Prius, Poch has a green button that he presses to switch between pure electric mode and the Prius's regular hybrid mode, which combines a gasoline-powered engine with the electric engine. Poch's car also has an energy monitor that provides real-time data on the car's fuel economy as he drives, a feature he greatly enjoys. "It really makes you think about your fuel usage," he says. "It's like a sport, trying to get the best mileage."

These days, cars that get good fuel economy are valuable commodities. Oil prices continue to hit new highs on a seemingly weekly basis, and, as a result, the amount the

average consumer pays at the gas pump has jumped to \$3.31 – more than double the price of just five years ago, according to the Energy Information Administration.

Higher gas prices have motivated U.S. drivers to do something that hasn't happened in decades – get serious about their gas mileage. The downward spiral in national fuel economy, which had been declining for almost two decades, finally ended in 2005, when Hurricane Katrina caused oil price spikes. Since then, fuel economy has risen as have sales of more efficient vehicles such as hybrids. But even with the gains, national fuel economy still remains below its peak in 1987, according to the Environmental Protection Agency.

With the nation struggling under high oil prices and a torpid economy, Poch believes that ultra-efficient vehicles such as plug-in hybrids can help the U.S. kick its expensive oil addiction. Driven by this belief, in 2006 Poch started a non-profit called the Plug-in Hybrid Coalition of the Carolinas. “The overall goal is to accelerate the adoption of plug-in hybrids for environmental, economic and national security purposes,” Poch says.

Poch launched his plug-in project when he was 36 because he wanted to do something he could be really passionate about. “I just surfed the Internet,” he says. “One of my interests was clean domestic energy, and I wondered why we are sending so much money overseas to buy oil.”

After stumbling across the Web sites of some plug-in hybrid enthusiasts, Poch, who formerly worked in sales for a healthcare company, did some networking, made a few cold calls and raised enough money to start his non-profit organization. His coalition includes state representatives, mayors, other non-profits and large energy companies such

as Duke Energy and Progress Energy, that want to be part of changes in energy usage in the country.

In addition to recruiting partners for his coalition, Poch also went through the process of converting his 2007 Toyota Prius into a plug-in hybrid. A company called Hybrids Plus in Boulder, Colo., did the conversion, which cost Poch \$24,000, although he says that cheaper kits are available for around \$10,000. But Poch isn't using his organization to convince other drivers to modify their regular hybrids into plug-ins. "We're not trying to get other folks to convert their cars," he says. "We want to create consumer demand so that automakers will realize that the public wants this."

Poch hopes that his efforts will spur automotive manufacturers to take plug-in hybrids from an environmental niche product and into mass production. "I'd like to see this as a mainstream option that's available in all cars someday," he says.

Driving out of the niche

Poch's dream might not be too far from becoming reality. Several automakers are currently developing plug-in hybrids, and at least one, General Motors Corp., said in 2007 that it will be the first to put a plug-in into commercial production.

The reason for the rush towards plug-in hybrids is all about oil, says Pete Savagian, engineering director for hybrid power trains at GM. "You might have different views on petroleum," he says, "about how much is there and how long it will last." But what's clear is that demand is going to rise, and "we want to displace petroleum by bringing on diverse sources of energy."

Savagian believes that the key to achieving diverse energy sources is the electrification of the automobile, because electricity can be produced in many different ways, including renewable energy technology. “As time goes, we’re going to need the ability to use more and more energy that doesn’t come from petroleum sources,” he says. “We think electricity is the obvious candidate for how to do that.”

For GM, the first part of accomplishing that goal is to make its existing Saturn Vue hybrid, which was just released in 2008, into a plug-in hybrid similar to Poch’s converted Prius. By doing this, Savagian estimates that the plug-in version of the Vue could achieve almost double the gas mileage as the regular hybrid model, which currently gets about 32 miles per gallon on the highway.

But even after developing the plug-in hybrid technology, achieving such significant gains in fuel economy isn’t a sure thing. Drivers’ habits must also be taken into account. In an upcoming research paper for SAE International, a professional society of mobility engineers, Savagian and several GM colleagues evaluated real-world data on the driving habits of a sample of drivers from Southern California.

Savagian’s team found that plug-in hybrids can be driven mostly on battery power at low speeds and low power levels. “But when driven like a lot of people drive, the engine is going to be coming on a lot,” Savagian says. And when the engine comes on, gasoline is needed to run it. “So in terms of completely displacing petroleum, they’re not going to do it,” he says.

So while plug-in hybrids might constitute a first step toward reducing national oil dependence, Savagian believes the next part of the progression will be the production of extended-range electric vehicles, or EREVs. Unlike plug-in hybrids, which have a

gasoline-powered engine that kicks in at higher speeds, EREVs run on pure electricity but also have a gasoline engine that acts a generator when the batteries become depleted below a certain level.

Having an onboard gasoline engine ready to recharge the EREV's batteries solves a major problem GM discovered when it tried to launch the first fully electric vehicle, the EV1, in the late 1990s, Savagian says. Many owners of the EV1 developed what Savagian describes as a "range anxiety," meaning they were worried about running out of battery power and getting stranded, since the EV1 had only about a 100-mile range. This anxiety made the EV1 inconvenient for many drivers, Savagian says, but now "we're taking an electric vehicle and making it practical. We learned what was impractical before."

GM has already developed a concept EREV, called the Chevy Volt, which it unveiled at the Detroit Auto Show in 2007. Based on the driver-habits study, Savagian expects that around 64 percent of Volt owners will be able to end a typical day of driving without ever having their gasoline engine come on at all.

But even though the Volt shows a lot of promise, GM hasn't officially committed to putting it into commercial-scale production yet, although it does have an internal goal of entering production by 2010. GM has committed to producing the Vue and hopes to have it on the market by 2010 as well, but that depends on a lot of factors, says Brian Corbett, manager of GM's hybrid communications. "It's assuming we get everything buttoned down and everything falls into place," he says. "And we don't know if it will."

Other carmakers are also in the race to put plug-in hybrids on the road. Toyota plans to begin production on a plug-in in 2010, and several smaller companies are

planning on producing high-end plug-in hybrids. But GM hopes to be the first to grab the market with the Vue and the Volt. For a company that some have accused of killing the electric car, receiving publicity for helping resurrect the electric vehicle and winning the plug-in race are tantalizing prizes.

How the government drives fuel economy

As carmakers and non-profits work to bring plug-in hybrids into commercial production, the U.S. government is also beginning to promote oil conservation. In January 2008, the Department of Energy announced \$30 million in funding for plug-in hybrid research and development projects. It's a relatively small amount of funding compared to the billions of dollars spent annually to support biofuels production.

The real policy vehicle of the U.S. government for oil conservation is the Corporate Average Fuel Economy standard, or CAFE. Congress passed CAFE in 1975, and the law mandates a minimum miles-per-gallon requirement for auto manufacturers' new lines of cars and light trucks. At the end of 2007, President Bush signed the first revision to the CAFE standard since it was passed. The revision raised mileage standards by 40 percent for cars and light trucks to 35 miles per gallon by 2020, which will be a significant increase from the current national fuel economy of 20.2 miles per gallon.

The changes to the CAFE standard will help curb the growth in national oil consumption, says David Greene, a senior researcher at Oak Ridge National Laboratory in Tennessee, home to a variety of energy research. "There will be savings in oil consumption over what it would otherwise have been," Greene says. "That will not mean an absolute reduction in oil consumption but rather very little or slow growth."

Greene predicts that the CAFE standards will help restrain U.S. oil consumption through about 2025. But in order to reduce the country's overall oil consumption, Greene believes that complimentary policies are needed in addition to CAFE.

One such complimentary strategy would be raising the motor fuel tax, which has a current nationwide average of \$.047 per gallon, although it varies by state. But raising the tax properly requires a solid grasp on consumers' buying habits, Greene says. A research paper presented by Greene and several colleagues at a transportation and climate policy conference in 2007 helps explain why understanding consumer response is important to implementing higher gasoline taxes. Rather than engage in a typical policy debate, Greene and his colleagues attempted to evaluate the situation from the consumer's perspective. If the public at-large isn't going to go along with an energy savings plan, they asked, then what's the point? Uncertainty about future fuel prices makes it difficult for loss-averse consumers to invest in fuel economy with their next car purchase.

To help reduce this uncertainty and maximize national fuel economy, Greene says, both policies should be implemented together. "I think there's value to harmonizing CAFE's requirements on manufacturers with raising the gasoline tax. It's definitely worth sending the market the right signals."

In addition to higher gas taxes, CAFE's focus on cars and light trucks isn't going to be enough, Greene says. "We need to address the other areas that we use oil in our economy. It may be that we need to have fuel economy standards for trucks, and aircrafts and everything."

Daniel Sperling, director of the Institute for Transportation Studies at the University of California at Davis, agrees with Greene that while CAFE was a good first

step, the government needs to go further. “There’s a huge opportunity to make our transportation system and vehicles more efficient,” he says. “We’ve never regulated or provided incentive for heavy-duty trucks, and that’s something that merits attention.”

Ultimately, Sperling envisions government policy and higher oil prices driving the nation toward much greater efficiency in the transportation system as a whole. And one of the keys, he says, will be producing automobiles that can plug in to the electric grid.

The smart-grid city

If plug-in hybrids and EREVs are the country’s best options for reducing oil consumption, then the national electricity supply must be ready to meet the additional demands. At this time, the U.S. has enough off-peak electricity production capacity to charge 84 percent of the country’s 220 million vehicles if everyone drove plug-in hybrids, according to a study by the Department of Energy. But the study assumes drivers will primarily charge their cars during off-peak times, such as at night while they sleep.

That assumption might be overly optimistic. So to prepare for new demand from plug-in hybrids and for the further deployment of renewable technologies, Xcel Energy is implementing a smart grid electricity system in Boulder, Colo. “The system is expected to allow customers more choices as to when, where and how they are going to use their electricity,” says Ethnie Groves, a media relations representative for Xcel.

Xcel’s concept behind the smart grid is to add networking abilities to the power supply that will allow the system to auto balance, self monitor and easily accept a diverse array of energy supplies. Those features should simplify connecting renewable energy

systems into the grid, Groves says, and will allow Xcel to better prepare for plug-in hybrids by being capable of handling the types of demand peaks that plug-ins might create. “We recognize that’s kind of the wave of the future and the way things are going right now,” she says.

Xcel expects to have the first phase of the system installed in several homes by August 2008 and will complete deployment to the entire city of 50,000 homes by the end of 2009.

Boulder is an ideal location for the smart grid because it has the right type of residents to support it, says Kara Mertz, Boulder’s assistant to the city manager. “We have a well-educated community and a number of environmentally conscious businesses and people,” she says. “I think people will be excited to play with the technology to see how they can maximize their benefits.”

Although the city is still considering what types of projects to do with the smart grid, Mertz says that Xcel can expect lots of residents to plug their hybrids into the system once the cars are commercially available. “We already have the highest per-capita purchases of Priuses of any county in the country,” she says. “So I’m sure we’ll have lots of people buying plug-ins when they are on the market.”

For Jim Poch – whose Prius was converted by Hybrids Plus, which is located in Boulder – the smart grid is yet another exciting new development to plug-in to. “Electrify the transportation sector and make the power grid capable of handling it and more efficient,” he says. “It’s the ultimate solution.”

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